Universidad de Málaga

Escuela de Doctorado

Programa de Doctorado en Ingeniería de Telecomunicación

TESIS DOCTORAL

AI-Based Medical Assistance via Mobile Devices and Enhanced CNN for Diagnostic Imaging

Autor:

Ali Yousuf Khan

Directores:

Miguel-Ángel Luque-Nieto

Pablo Otero Roth

Málaga, 2025

UNIVERSIDAD DE MÁLAGA

UNIVERSIDAD
DE MÁLAGA

AUTOR: Ali Yousuf Khan

https://orcid.org/0000-0001-9091-9069

EDITA: Publicaciones y Divulgación Científica. Universidad de Málaga

Esta obra está bajo una licencia de Creative Commons Reconocimiento-NoComercial-SinObraDerivada 4.0 Internacional:
Cualquier parte de esta obra se puede reproducir sin autorización
pero con el reconocimiento y atribución de los autores.
No se puede hacer uso comercial de la obra y no se puede alterar, transformar o hacer obras derivadas.
http://creativecommons.org/licenses/by-nc-nd/4.0/legalcode

Esta Tesis Doctoral está depositada en el Repositorio Institucional de la Universidad de Málaga (RIUMA): riuma.uma.es

UNIVERSIDAD DE MÁLAGA

Escuela de Doctorado
29071 Málaga
Tel.: 952 13 10 28 / 952 13 14 61 / 952 13 71 10
E-mail: doctorado@uma.es

DECLARACIÓN DE AUTORÍA Y ORIGINALIDAD DE LA TESIS PRESENTADA PARA OBTENER EL TÍTULO DE DOCTOR

Ali Yousuf KHAN

Estudiante del Programa de Doctorado INGENIERÍA DE TELECOMUNICACIÓN de la Universidad de Málaga, autor de la tesis, presentada para la obtención del título de doctor por la Universidad de Málaga, titulada "AI-Based Medical Assistance via Mobile Devices and Enhanced CNN for Diagnostic Imaging",

Realizada bajo la tutorización de Pablo Otero y dirección de Miguel Ángel Luque Nieto y Pablo Otero

DECLARO QUE

La tesis presentada es una obra original que no infringe los derechos de propiedad intelectual ni los derechos de propiedad industrial u otros, conforme al ordenamiento jurídico vigente (Real Decreto Legislativo 1/1996, de 12 de abril, por el que se aprueba el texto refundido de la Ley de Propiedad Intelectual, regularizando, aclarando y armonizando las disposiciones legales vigentes sobre la materia), modificado por la Ley 2/2019, de 1 de marzo.

Igualmente asumo, ante a la Universidad de Málaga y ante cualquier otra instancia, la responsabilidad que pudiera derivarse en caso de plagio de contenidos en la tesis presentada, conforme al ordenamiento jurídico vigente.

En Málaga, a 23 de junio de 2025

Fdo.: Ali Yousuf KHAN
Doctorando

Miguel Ángel Luque Nieto
Director de tesis

Pablo Otero
Tutor y codirector de tesis

UNIVERSIDAD DE MÁLAGA

EFQM AENOR ISO 14001 BUREAU VERITAS Certification bequal

This page intentionally left blank

UNIVERSIDAD
DE MÁLAGA

UNIVERSIDAD DE MÁLAGA

Instituto de Ingeniería Oceánica
Universidad de Málaga

AUTORIZACIÓN DEL TUTOR Y DE LOS DIRECTORES DE TESIS DOCTORAL

El alumno del Programa de Doctorado en Ingeniería de Telecomunicación Ali Yousuf KHAN, es primer autor de las siguientes publicaciones en revistas indexadas en los *Journal Citation Reports* (JCR) del *Web of Science* (WoS):

- A.Y. Khan, M.Á Luque-Nieto, S. Batool, H. Ahmed, A.H. Saeed, Z. Asif. 2023. “SOS Application Under Android: Help Pro”. *Wireless Personal Communications*, vol: 128, Issue 2, pp. 987-1002, Jan. 2023 (JCR-Q3). DOI: 10.1007/s11277-022-09985-4.
- A.Y. Khan, M.Á Luque-Nieto, M.I. Saleem, and E. Nava. 2024. "X-Ray Image-Based Real-Time COVID-19 Diagnosis Using Deep Neural Networks (CXR-DNNs)". *Journal of Imaging*, vol. 10, no. 12: 328, 2024 (JCR-Q2). DOI: 10.3390/jimaging10120328.

Estas publicaciones avalan su tesis doctoral y ninguna otra tesis.

Por todo ello, su director de tesis Miguel Ángel Luque Nieto y su tutor y codirector de tesis Pablo Otero autorizan al Sr. Ali Yousuf KHAN a depositar su tesis doctoral ante las Autoridades académicas de la Universidad de Málaga.

En Málaga, a 23 de junio de 2025

Fdo: Miguel Angel Luque Nieto

Fdo: Pablo Otero

UNIVERSIDAD DE MÁLAGA

This page intentionally left blank

UNIVERSIDAD
DE MÁLAGA

Abstract

The COVID-19 pandemic underscored critical flaws in global healthcare diagnostics and emergency response systems, revealing the urgent need for practical solutions. AI-driven technologies can function under real-world pressures, and this dissertation responds to those challenges through three applied contributions that incorporate artificial intelligence to enhance medical diagnosis of diseases (COVID-19 and brain tumors) by image classification, and crisis communication in both routine and emergency settings.

The first work of research, discussed in Chapter 3, involves the creation of an Android-based mobile application named Help Pro: SOS Application. Using a variety of programming applications such as Android Studio, Java, Firebase, Google Maps API and Laravel, this tool allows users to send essential information including their geographic location, identification, and the nature of the emergency (vehicle mechanical problem, ambulance, blood donation, police or firefighter) to preselected contacts or responders with a single touch. The app is further optimized to operate effectively in limited connectivity environments, with testing focused on usability, response time, and system stability. The major goal is to minimize delays during emergency situations and to support timely response and intervention on site.

Chapter 4 presents the second contribution, a deep learning model called CXR-DNN, which was built using the EfficientNetB7 architecture to detect COVID-19 in chest X-ray images. The model underwent training and validation on several datasets (e.g. COVID-19 Radiography Database from Kaggle, or Actualmed COVID-19 Chest X-ray Dataset Initiative), followed by performance evaluation using essential metrics such as accuracy, precision, recall, and F1-score. Also included are suggestions for enhancing the fairness and robustness of models, as well as issues like class imbalance, hardware restrictions, and the openness of AI decision-making.

The third and final contribution, presented in Chapter 5, introduces a CNN-based joint diagnostic framework for classifying brain tumors using CT and MR imaging. The system uses MobileNetV3 to assess a six-category dataset, four of them using MR images (tumors: Glioma, Meningioma, Pituitary, and No Tumor) and other two classes considering CT images (tumor, non-tumor). The experimental results suggest that this strategy could be valuable in neuro-oncology, where the combination of the two imaging modalities significantly enhances classification accuracy.

Chapter 6 concludes the dissertation by summarizing the results and proposing directions for further research, including expanding the diagnostic tools to detect additional illnesses and improving the functionality of the SOS application. This work combines artificial intelligence with healthcare and emergency management to deliver practical solutions capable of making a meaningful impact in real-world scenarios.

UNIVERSIDAD DE MÁLAGA

Resumen

1. Introducción

Como resultado de la pandemia de COVID-19, se revelaron en todo el mundo graves fallos en los diagnósticos médicos, así como en los sistemas de respuesta a emergencias. Se volvió vital diseñar soluciones tecnológicas que no solo fueran rápidas, sino también escalables y confiables para satisfacer la creciente necesidad de aplicaciones efectivas de comunicación de emergencias y diagnósticos médicos rápidos. Esto se hizo para satisfacer la creciente demanda. El objetivo de esta tesis doctoral es responder a dicha demanda mediante tres contribuciones prácticas de investigación que utilizan inteligencia artificial (IA) compatible con tecnologías móviles para mejorar la salud y la seguridad públicas. La primera contribución es la creación de "Help Pro: SOS Application", que es una solución de ayuda de emergencia basada en Android. El segundo trabajo presentado es el diseño y ajuste de "CXR-DNN": un modelo de aprendizaje profundo (*Deep Learning*, abreviado DL) para el diagnóstico preciso de COVID-19 mediante imágenes de radiografías de tórax (imágenes CXR). Finalmente, la última contribución es un nuevo modelo basado en redes neuronales convolucionales (CNN) para el diagnóstico conjunto de la clasificación de tumores cerebrales mediante imágenes de tomografía computarizada (TC) y mediante resonancia magnética (RM).

Esta investigación parte del reconocimiento de que las innovaciones digitales e impulsadas por IA pueden proporcionar herramientas poderosas para resolver problemas del mundo real cuando se guían por objetivos específicos, conjuntos de datos robustos y estrategias prácticas de implementación. Si bien la IA ya ha demostrado ser muy prometedora en numerosos sectores en cuanto a su papel en la detección por imagen médica y los sistemas de apoyo a emergencias, sigue siendo infrautilizada en muchos contextos de respuesta urgente o con limitados recursos. Esta tesis busca llenar ese vacío mediante el desarrollo de soluciones que no solo sean técnicamente robustas, sino también fáciles de usar, adaptables y listas para usarse como aplicaciones en tiempo real.

En este trabajo, se ha utilizado una estrategia multidisciplinar que integra diversas disciplinas de estudio, como la atención médica, los servicios de emergencia, el desarrollo de software y el aprendizaje automático. Uno de los paradigmas descritos en esta tesis es que, a largo plazo, mejora significativamente los resultados para pacientes y personas que atraviesan momentos difíciles. Este paradigma resulta en un diagnóstico mejorado, una reducción en los tiempos de respuesta y, en última instancia, resultados más favorables. El análisis de las tecnologías que se utilizan actualmente, la identificación de las deficiencias en los sistemas existentes y el desarrollo de aplicaciones basadas principalmente en inteligencia artificial son algunas de las estrategias que se están empleando en el marco de esta tesis. Las siguientes secciones, abordarán el análisis de cada una de estas contribuciones con mayor profundidad, además de abordar el estado del arte actual. Concretamente, se abordará su historia, las técnicas que se emplean, sus implicaciones y resultados, y las perspectivas que les aguardan en los próximos años.

2. Estado de la técnica

El objetivo de este capítulo es resumir los trabajos previos relevantes dentro del área de investigación, presentando una sinopsis de los numerosos trabajos que se revisarán en los próximos capítulos. En concreto, se investigan los usos prácticos de la IA en el campo de la

UNIVERSIDAD DE MÁLAGA

imagen médica, así como en aplicaciones móviles para la respuesta a emergencias. Pero no solo se presentarán las experiencias previas, sino que también se hará hincapié en aquellas áreas con oportunidades de desarrollo futuro.

2.1 Aplicaciones para emergencias

A lo largo del tiempo se han desarrollado diversas aplicaciones móviles para ayudar a personas que se encuentren en una situación difícil, como una emergencia. La gran mayoría de estas soluciones ofrecen a los usuarios la oportunidad de emitir alertas, informar sobre su condición física o contactar con sus familiares o servicios de emergencia, independientemente de su ubicación.

A pesar de estas características, aún existen muchos desafíos pendientes. Algunas aplicaciones son difíciles de administrar para los usuarios finales (técnicamente, la experiencia del usuario), presentan problemas de rendimiento o carecen de funciones de seguimiento en tiempo real. Todos estos factores pueden ser causa de problemas. En muchos casos, estas aplicaciones no son viables debido a la infraestructura limitada, por ejemplo, en zonas que carecen de infraestructura esencial, como en países con bajos niveles de riqueza, y algunos servicios no están destinados para el público en general. En ocasiones, la decisión de no implementar la infraestructura necesaria se debe a que la zona se considera menos apta para su uso. Esto se debe principalmente a una mala adaptación del entorno para el despliegue de estas tecnologías. Ante los problemas surgidos, existe una necesidad imperiosa de contar con equipos de emergencia mejorados que no solo sean rápidos y fáciles de usar, sino también fiables. Al completar con éxito el desarrollo de la aplicación móvil “Help Pro”, diseñada para cumplir con estos criterios, damos un paso en la dirección correcta para promover este tipo de servicios y demostrar que es posible implementarlos de forma eficaz.

2.2 Uso de Inteligencia Artificial en imágenes médicas para COVID-19

Desde el inicio de la pandemia, las imágenes CXR se han empleado con frecuencia para diagnosticar la COVID-19. Los modelos DL basados en CNN han demostrado resultados prometedores y beneficiosos. El modelo CXR-DNN de esta tesis se desarrolló para solucionar estos problemas mediante una estructura más robusta y mejores métodos de entrenamiento. Sin embargo, presenta algunos problemas típicos, como: (a) bajo rendimiento con datos nuevos, (b) falta de variación en las fotos y (c) la disponibilidad de conjuntos de datos extremadamente pequeños.

(a) Un desafío importante con los modelos de imágenes médicas es que no son tan precisos al probarlos con datos nuevos o inexplorados. Esto ocurre principalmente cuando el modelo experimenta demasiados patrones exactos en los datos de entrenamiento y no sabe cómo usarlos en nuevas aplicaciones.

(b) Si el conjunto de datos no incluye mucha variabilidad, podría ser bastante difícil que el modelo se adapte a las diferencias del mundo real. Por ejemplo, esto ocurre si los ángulos de las imágenes, la demografía de los pacientes o el equipo de escaneo son todos iguales. El modelo no funciona tan bien en circunstancias inesperadas o a corto plazo, ya que no coincide con la esperada uniformidad en las imágenes.

(c) La mayoría de las veces, los métodos DL requieren grandes conjuntos de datos para funcionar correctamente. Sin embargo, en medicina, no hay una gran cantidad de datos debido

UNIVERSIDAD DE MÁLAGA

a problemas de privacidad y al coste de adquisición/mantenimiento, lo que dificulta el entrenamiento de modelos que funcionen bien sin sobreajuste ni sesgo.

A pesar del creciente número de modelos de IA evaluados o utilizados en entornos clínicos, su uso sigue siendo relativamente bajo. Esto se relaciona con la aplicación práctica de los modelos en el ámbito sanitario. El modelo CXR-DNN que se presenta en esta tesis se desarrolló con la intención de abordar estas deficiencias y mejorar su rendimiento. Para lograr este objetivo, se hizo un diseño de red más robusto y un mayor entrenamiento del modelo. Ambas estrategias se analizarán más adelante.

2.3 Deficiencias y objetivos

Tras una investigación sobre los sistemas actualmente en uso, se ha determinado que poseen dos deficiencias importantes. En primer lugar, no hay garantía de que el procedimiento de solicitud de emergencia se complete rápidamente, sea sencillo de usar ni de que proporcione resultados fiables y eficientes (véase el capítulo 3). En segundo lugar, se quiere mejorar la capacidad de los sistemas expertos médicos (basados en IA) para identificar enfermedades en pacientes humanos (véase el capítulo 4 y 5).

Una importante deficiencia de los sistemas expertos de detección de COVID-19, se basa en que los modelos IA desarrollados presentan un rendimiento inferior al esperado cuando se implementan fuera de sus entornos de prueba originales. La investigación realizada en esta tesis trata de superar dos limitaciones clave identificadas en la literatura y el panorama tecnológico existentes. El uso de las capacidades de la inteligencia artificial debe proporcionar (i) herramientas útiles y eficientes, pero también (ii) pertinentes en situaciones reales. Para (i), elegimos Android y un teléfono inteligente como plataforma tecnológica para responder a emergencias, y para (ii) diseñamos y optimizamos dos CNN diferentes aplicadas al diagnóstico clínico de dos enfermedades: COVID-19 y tumores cerebrales.

3. Desarrollo de la aplicación SOS: “Help Pro”

La aplicación “Help Pro” es una utilidad móvil para Android diseñada para optimizar la respuesta ante emergencias, permitiendo una comunicación más rápida, sencilla y fiable. Este capítulo tercero de la tesis describe el proceso de desarrollo de la aplicación y su operación práctica. El concepto surgió de un problema común en la vida real durante las emergencias: las personas a menudo pierden tiempo crucial intentando navegar por sus teléfonos o aplicaciones complejas. El objetivo de este proyecto era ofrecer una solución clara y sencilla, a la vez que eficiente.

3.1 Campo de uso

Las emergencias requieren acción inmediata; no hay tiempo para dudas ni confusión. Muchas aplicaciones de emergencia existentes evaluadas resultaron ser demasiado complejas, poco intuitivas o lentas. Esta sección del capítulo explicará la motivación detrás del desarrollo de una aplicación para que cualquier persona, sin importar su edad o conocimientos técnicos, pudiera usarla con un solo toque en el terminal móvil. El objetivo era desarrollar una aplicación ligera capaz de enviar alertas rápidamente y compartir coordenadas GPS.

3.2 Especificaciones funcionales

UNIVERSIDAD DE MÁLAGA

Los principales ejes centrales en el desarrollo fueron la simplicidad y la usabilidad. La aplicación se construyó en torno a tres funciones/requisitos esenciales:

- Enviar una señal de socorro (SOS) rápida.
- Compartir la ubicación GPS en tiempo real.
- Alertar a una lista predefinida de contactos de emergencia.

Estas funciones se desarrollaron para garantizar una alta capacidad de respuesta y fiabilidad. Se optó por una interfaz minimalista para que la aplicación fuera accesible para usuarios de todas las edades o con alguna discapacidad visual. También se priorizó la compatibilidad de "Help Pro" con una amplia gama de dispositivos Android, incluidos los modelos más antiguos, especialmente para usuarios en regiones donde las actualizaciones de software son menos frecuentes. Esta amplia compatibilidad podría aumentar la capacidad de SOS para llegar a una amplia gama de perfiles de usuario.

3.3 Pruebas de usuario

La aplicación se sometió a pruebas de usuario mediante escenarios de emergencia simulados para evaluar su funcionalidad y usabilidad. Los comentarios de los usuarios en estas sesiones de prueba permitieron importantes mejoras en el diseño. Si bien muchos usuarios finales apreciaron la velocidad y la simplicidad de la función para compartir la ubicación, otros solicitaron que se destacara la opción de enviar alertas silenciosas durante la operación. Integrar estos comentarios en el ciclo de desarrollo mejoró significativamente tanto el rendimiento de la aplicación como la satisfacción del usuario.

3.4 Fortalezas y áreas de mejora

La aplicación SOS cumple su función correctamente, pero puede presentar ciertas limitaciones que requieren mejoras según sea necesario. La fiabilidad de la aplicación en redes celulares y acceso a internet puede sufrir problemas debido a una baja conectividad o a entornos sin conexión a la red eléctrica. Las futuras actualizaciones podrían solucionar este inconveniente incorporando funcionalidad sin conexión y compatibilidad con relojes inteligentes u otros dispositivos portátiles. Estas mejoras incrementarían su fiabilidad y usabilidad en zonas con conectividad inestable.

4. Modelo CXR-CNN para detección de COVID-19

Este capítulo aborda el diseño, puesta a punto y testeo del modelo CXR-DNN diseñado para la detección de COVID-19 mediante imágenes CXR. El objetivo era crear una herramienta fiable basada en DL que permitiera diagnosticar casos positivos y negativos de COVID-19. La arquitectura EfficientNetB7, reconocida por su excelente rendimiento en tareas de clasificación de imágenes con un reducido número de parámetros, sirvió de base para el modelo. A partir de ahí, el capítulo detalla el proceso de construcción y entrenamiento del modelo, así como los problemas encontrados con el hardware necesario y las posibles actualizaciones futuras.

4.1 Desarrollo del modelo

El punto de partida fue organizar un conjunto de imágenes CXR, que abarcaran un rango amplio de edades, con diferentes niveles de gravedad de la enfermedad, incluyendo ejemplos tanto positivos como negativos de COVID. El objetivo perseguido era recopilar suficientes

UNIVERSIDAD DE MÁLAGA

datos sobre las características de las imágenes para que el modelo pudiera distinguir entre pulmones sanos y afectados por COVID.

Para crear este conjunto de datos, se obtuvieron primero imágenes a partir de repositorios de acceso abierto que proporcionan exploraciones médicas fiables y etiquetadas. Tras esta recopilación, las imágenes se sometieron a varios pasos de preprocesamiento, como el redimensionamiento, la normalización y la amplificación. Estos pasos ayudaron al modelo a gestionar diferentes tamaños de imagen, condiciones de iluminación y otras variaciones. Se realizaron comprobaciones exhaustivas para garantizar que ambas clases (COVID-19 positivo y negativo) estuvieran equilibradas y no estuvieran mal etiquetadas, y se eliminaron las imágenes de baja calidad.

Debido a la alta precisión que ofrece la arquitectura EfficientNetB7 y requiriendo menos recursos en comparación con otras arquitecturas CNN para clasificación de imágenes, fue seleccionada para el modelo CXR-CNN. Posteriormente, se decidió utilizar aprendizaje por transferencia (*Transfer Learning*) para iniciar el modelo a partir de pesos ya entrenados, lo que ayudó a acelerar el proceso de aprendizaje, especialmente porque el conjunto de datos específico de COVID-19 disponible no era muy grande.

4.2 Entrenamiento del modelo

Una vez preparado el conjunto de datos y elegida la arquitectura, comienza la fase de entrenamiento. Los datos se dividieron en tres partes: entrenamiento, validación y prueba. El conjunto de entrenamiento ayudó al modelo a aprender patrones, el conjunto de validación monitoreó su progreso y por último, el conjunto de prueba proporcionó una evaluación final con nuevas imágenes para evaluar la fiabilidad de predicción del modelo.

El modelo se entrenó durante 40 iteraciones ("épocas" en aprendizaje automático) utilizando el optimizador Adam, con una tasa de aprendizaje de 0,0001 y un tamaño de lote de 32. Se seleccionó la entropía cruzada binaria como función de pérdida, dado que se trataba de un problema de clasificación binaria (COVID-19 positivo o negativo). Para fortalecer el modelo, se utilizaron técnicas de aumento de datos, como la inversión, la rotación y la modificación del brillo, durante todo el proceso de entrenamiento.

Durante el entrenamiento, se monitorizaron métricas clave de rendimiento como la exactitud (*accuracy*), la precisión (*precision*), la recuperación (*recall*) y la puntuación F1 (F1-*score*). También se emplearon técnicas como la parada temprana y la reducción de la tasa de aprendizaje para evitar el sobreajuste y mantener la eficiencia del entrenamiento. Los resultados finales mostraron que el modelo CXR-DNN fue capaz de clasificar con precisión los casos de COVID-19, lo que demuestra su potencial para su uso en el mundo real.

4.3 Retos pendientes

Durante el desarrollo del modelo surgieron varias dificultades. La más significativa fue la escasez de imágenes CXR etiquetadas de alta calidad específicas para COVID-19. Dado que el sobreajuste es más probable con conjuntos de datos más pequeños, el rendimiento del modelo con datos nuevos y desconocidos podría verse afectado.

La interpretabilidad (o comprensión del funcionamiento interno de un modelo IA) fue otro problema. Si bien los modelos DL como EfficientNetB7 pueden realizar predicciones

UNIVERSIDAD DE MÁLAGA

correctas, los mecanismos subyacentes mediante los cuales lo hacen suelen ser opacos. Si bien se investigaron métodos como Grad-CAM para facilitar la visualización de las áreas de énfasis del modelo, la explicabilidad (o razonamiento del porqué de un resultado predicho por IA) sigue siendo un obstáculo, especialmente en aplicaciones médicas.

La variabilidad en la forma en que se tomaron las imágenes (distintas máquinas de rayos X, configuraciones y posiciones del paciente, etc.) también añadió inconsistencia. Esto dificultó la generalización adecuada del modelo. Si bien el preprocesamiento ayudó a reducir este ruido, estas variaciones permanecen como un problema común en las tareas con imágenes médicas.

4.4 Requisitos de computación

El entrenamiento de un modelo DL como CXR-DNN requiere un hardware potente. La arquitectura EfficientNetB7, si bien es más eficiente que la mayoría de los demás diseños requiere considerables recursos computacionales, en particular unidades de procesamiento para gráficos (GPU), que gestionen las exhaustivas operaciones necesarias para el entrenamiento y la inferencia.

En el caso de esta tesis, el modelo presentado se entrenó en un entorno con GPU, lo que permitió utilizar lotes más grandes y redujo significativamente el tiempo de entrenamiento. Sin esta configuración, el entrenamiento habría tardado mucho más y podría no haber convergido correctamente. Posteriormente, también se consideró el rendimiento del modelo en escenarios de tiempo real, especialmente en términos de velocidad de inferencia y uso de memoria, que son aspectos cruciales en entornos clínicos.

Esta experiencia puso de relieve la importancia de contar con una infraestructura escalable al trabajar con estructuras DL en el ámbito sanitario, especialmente cuando se buscan sistemas fiables en tiempo real.

4.5 Líneas futuras

De cara al futuro, existen algunas líneas importantes de ampliación de este trabajo. En primer lugar, aumentar el tamaño y la variedad del conjunto de datos facilitaría la generalización del modelo. Incluir más datos demográficos de los pacientes, diferentes condiciones en las imágenes obtenidas, y niveles de gravedad de la enfermedad, podría mejorar el rendimiento del modelo en diferentes poblaciones y entornos sanitarios.

En segundo lugar, es fundamental mejorar la transparencia del modelo. Incorporar técnicas de explicabilidad como SHAP, LIME o Grad-CAM puede proporcionar información sobre el razonamiento del modelo que sustenta una predicción, fomentando la confianza de los médicos y profesionales sanitarios del sistema.

Finalmente, la integración del modelo en sistemas hospitalarios o departamentos de radiología reales facilitaría su uso práctico. Para ello, es necesario optimizar la velocidad y la fiabilidad del modelo en diversas plataformas de hardware. Probar el modelo en entornos reales y con datos clínicos en tiempo real sería un gran paso hacia su implementación definitiva.

En conclusión, el establecimiento del modelo CXR-DNN proporciona una base sólida para el uso del DL en el diagnóstico de COVID-19 mediante imágenes CXR. La tecnología IA tiene un gran potencial para mejorar la atención médica, especialmente en áreas con pocos

UNIVERSIDAD DE MÁLAGA

radiólogos profesionales, gracias a la disponibilidad de más datos, una mejor interpretabilidad y la posibilidad de realizar pruebas en condiciones reales.

5. Modelo CNN para diagnosis de tumores cerebrales usando conjuntamente imágenes RM/TC

5.1 Introducción

El diagnóstico de tumores cerebrales desempeña un papel fundamental para determinar las estrategias de tratamiento más eficaces y mejorar sus resultados en los pacientes. La detección temprana y precisa sigue siendo un reto médico clave. Este capítulo se centra en el desarrollo de un modelo basado en DL, cuyo objetivo es mejorar la precisión diagnóstica mediante la combinación de datos procedentes de imágenes de resonancia magnética (RM) y tomografía axial computarizada (TAC, o abreviadamente TC). El uso de estructuras DL junto con el procesamiento de imágenes es un concepto innovador en las ciencias médicas. Este enfoque conjunto e integrado facilita significativamente la toma de decisiones por parte de los profesionales médicos y mejora los métodos actuales de clasificación tumoral mediante CNNs.

5.2 Uso de detección combinada MR/TC

Las imágenes médicas son esenciales para el diagnóstico y el tratamiento de tumores cerebrales. Entre los procedimientos de imagen más utilizados, la RM y la TC ofrecen ventajas y funciones únicas pero complementarias. La RM es conocida por su mejor contraste de tejidos blandos, que ayuda a los médicos a visualizar la arquitectura cerebral y a mejorar la visión y los resultados. Este alto contraste ayuda a detectar los bordes del tumor y a examinar las características internas, como la necrosis y el edema. Estas cualidades hacen que la RM sea esencial para la caracterización, la identificación, la planificación y el desarrollo prequirúrgicos de tumores.

A diferencia de la resonancia magnética, la TC cuenta con capacidades específicas que la complementan. Las TC son más rápidas y accesibles en entornos clínicos, especialmente en emergencias, cuando el diagnóstico inmediato es esencial para procedimientos y tareas. La TC es muy eficaz para mostrar estructuras óseas e identificar calcificaciones tumorales, algo que la RM no puede. La TC es menos susceptible al movimiento del paciente y puede detectar hemorragias agudas, lo cual puede ser crucial en el caso de neoplasias (masa anormal de tejido) cerebrales malignas.

Si bien la RM y la TC tienen sus ventajas, cada una presenta limitaciones cuando se utilizan por separado. La RM destaca por su excelente contraste de tejidos blandos, pero puede pasar por alto calcificaciones menores o afectación ósea, cruciales para la identificación y gradación tumoral. La TC puede carecer del contraste de tejidos blandos necesario para diferenciar los tipos de tumores o detectar tumores diminutos. Por lo tanto, la integración de los datos de la RM y la TC en un marco de diagnóstico conjunto puede resolver estos problemas. Los especialistas médicos pueden comprender mejor las características tumorales al integrar información complementaria o accesible de ambos métodos. Esta estrategia de imagen dual aprovecha las capacidades de cada técnica para reducir los diagnósticos erróneos y mejorar la categorización y el diagnóstico de tumores.

Los modelos informáticos que gestionan datos de RM y de TC permiten una mayor extracción de características, reconocimiento de patrones, diagnóstico y clasificación. Una estrategia

UNIVERSIDAD DE MÁLAGA

conjunta de imágenes supera las deficiencias diagnósticas y se alinea con la tendencia de fusión de datos multimodales de la IA médica. La integración mejora la toma de decisiones clínicas y los resultados del paciente mediante opciones de tratamiento individualizadas.

5.3 Construcción y preparación del conjunto de datos

5.3.1 Colección de datos

Para construir un conjunto de datos completo, esta investigación recopiló un total de 10.330 imágenes de seis clases: cuatro clases para imágenes RM (glioma, meningioma, tumor hipofisario y ausencia de tumor) y dos clases en el caso de imágenes TC (con y sin tumor). Estas imágenes se obtuvieron cuidadosamente de fuentes de acceso público, garantizando así su calidad y diversidad. El conjunto de datos refleja una amplia gama de afecciones en pacientes, asó como diferentes parámetros de imagen, lo que permite el desarrollo de un modelo más robusto y generalizado.

5.3.2 Preprocesado y aumento de datos

Los pasos de preprocesado realizado a las imágenes incluyen el redimensionamiento, la normalización y el mapeo o conversión a un formato uniforme compatible con las entradas de CNN. Para mejorar y avanzar en la generalización del modelo y abordar el desequilibrio entre clases, se aplicaron diversas técnicas de aumento de datos, como el volteo, la rotación y los ajustes de contraste. Estos métodos fueron eficaces en la ampliación del conjunto de datos de entrenamiento y redujeron la probabilidad de sobreajuste, especialmente en aquellas clases con menor número de imágenes.

5.4 Modelos DL utilizados

5.4.1 Selección del modelo

Se han explorado cuatro arquitecturas CNN de vanguardia: ResNet50, DenseNet, EfficientNetB1 y MobileNetV3. El motivo de esta selección se basa en su rendimiento histórico y comprobado en tareas de imágenes médicas y su capacidad para equilibrar la precisión con la eficiencia computacional, la fiabilidad y las medidas de seguridad. Los modelos fueron entrenados desde cero como parte de una fase de evaluación inicial, y revelaron que MobileNetV3 superó consistentemente a las demás plataformas en cuanto a precisión de clasificación, velocidad de procesamiento, fiabilidad y seguridad.

5.4.2 Configuración final del modelo

Tras evaluar las 4 diferentes arquitecturas CNN mencionadas, se seleccionó MobileNetV3 para la aplicación debido a su excelente equilibrio entre rendimiento de clasificación y economía computacional. Su diseño ligero y su sólida trayectoria en aplicaciones de imágenes médicas lo convierten en una buena opción para una implementación con un uso eficiente de los recursos. Posteriormente, se construyó el modelo para gestionar la categorización conjunta de imágenes de RM y TC en seis clases, cuatro para RM y dos para TC: glioma (RM), meningioma (RM), tumor hipofisario (RM), y tumor (TC) / ausencia de tumor (RM, TC). La etapa de salida (*layers*) de la arquitectura DL fue diseñada para clasificar estas clases. Mediante repetidos intentos de experimentación y validación, se seleccionaron hiper-parámetros para un rendimiento óptimo. Un tamaño de 32 lotes equilibró la estabilidad del entrenamiento y el uso

UNIVERSIDAD DE MÁLAGA

de memoria del modelo. La tasa de aprendizaje del modelo fue 0,005 para evitar sobrepasar los parámetros ideales durante el método del gradiente descendiente. Las tendencias recíprocas entre los parámetros de pérdida de entrenamiento y validación indicaron que 40 épocas eran suficientes para la fase de entrenamiento. Por encima de este umbral, a más épocas, menores retornos y mayor riesgo de sobreajuste.

Se utilizó una función de activación *softmax* para interpretar los resultados como probabilidades, lo que mejoró el rendimiento de la clasificación y la interpretabilidad clínica. En las últimas capas de DL, que son más sensibles tanto a los datos aprendidos como a los resultados de la observación, se incorporó intencionalmente la eliminación de capas para evitar el sobreajuste. La modalidad dual del conjunto de datos (RM y TC) dificultó la dimensionalidad y la estandarización de la entrada. Por lo tanto, se estandarizaron los procesos de preprocesado de entrada para garantizar la homogeneidad del tamaño de los datos, la resolución y el escalado de valores de píxel.

La capa de entrada de la red DL se dimensionó para acomodar imágenes de dimensión fija de ambas modalidades de imagen RM/TC. Esta fase fue crucial para garantizar que el modelo pudiera procesar de forma consistente las entradas de TC y de RM, conservando al mismo tiempo la información diagnóstica específica de cada modalidad. Se utilizó el optimizador Adam para la optimización debido a su versatilidad y eficacia para modificar las tasas de aprendizaje durante el entrenamiento. Debido a que se realiza una clasificación multi-clase, se ha elegido como función de pérdida una función de tipo entropía cruzada categórica, como es habitual en este tipo de problemas. Se incluyó un mecanismo de detención temprana durante el entrenamiento para finalizar el proceso si la pérdida de validación dejaba de mejorar después de un número específico de épocas, evitando así el sobreajuste y el desperdicio de recursos computacionales.

El modelo se entrenó y evaluó utilizando una interfaz en línea de aprendizaje profundo para tareas de clasificación de imágenes, lo que facilitó la gestión de la canalización de datos y la creación de prototipos. El motor utiliza TensorFlow.js, lo que ofrece flexibilidad de implementación en sistemas web de apoyo a la toma de decisiones clínicas. Un criterio de diseño para el modelo fue conservar una estructura ligera durante su configuración para que fuera útil en instituciones médicas remotas o con financiación insuficiente y baja capacidad computacional.

El modelo final también se diseñó para adaptarse a cambios futuros, como la adición de tipos de tumores o modalidades de imagen. El modelo utiliza una técnica de desarrollo modular, lo que permite intercambiar o modificar componentes como la etapa de clasificación final sin tener que volver a entrenar la red.

Las métricas de rendimiento y la practicidad clínica, junto con las consideraciones de hardware y la capacidad de modificación a largo plazo, influyeron en el diseño final de MobileNetV3. El ajuste de hiper-parámetros, la regularización de algoritmos y la personalización de la arquitectura de red crearon un modelo de clasificación estable y preciso para aplicaciones de diagnóstico en el mundo real.

5.5 Evaluación del rendimiento

5.5.1 Exactitud, y métricas por clase

UNIVERSIDAD DE MÁLAGA

El rendimiento del modelo final se evaluó utilizando métricas estándar y óptimas, como exactitud, precisión, recuperación y puntuación F1. Los resultados esperados mostraron una precisión alta y fiable en las seis clases, lo que indica la gran capacidad del modelo para diferenciar entre tipos de tumores y entre imágenes RM y TC. El análisis de la matriz de confusión reveló un mínimo de falsos positivos y negativos, lo que confirma la fiabilidad del modelo y la garantía de las medidas de calidad.

5.5.2 Análisis comparativo

En comparación con otros modelos probados, MobileNetV3 logró resultados superiores con un menor costo computacional. Si bien ResNet50 y DenseNet también tuvieron un buen rendimiento, requirieron mayor memoria y potencia de procesamiento. EfficientNetB1 mostró resultados prometedores, pero no superó a MobileNetV3 en consistencia general para las seis clases. El rendimiento del modelo híbrido, que combina datos RM y TC, demuestra la mayor precisión diagnóstica de todos los modelos comprados en las pruebas realizadas.

5.5.3 Esfuerzo computacional

Una de las razones clave para elegir MobileNetV3 fue su ligereza. El modelo funcionó bien incluso en sistemas con hardware limitado, lo que lo hace ideal para su implementación en entornos clínicos con recursos limitados. Su menor tiempo de entrenamiento y latencia de inferencia también contribuyen a su uso práctico.

5.6 Resultados y estadísticas

Para complementar el análisis estadístico, se incluyen varios gráficos, como la precisión de entrenamiento/prueba y las curvas de pérdida. Estos gráficos proporcionan información sobre la convergencia del modelo y el comportamiento de aprendizaje. También se generaron una matriz de confusión y tablas de precisión por clase, lo que también ayuda a validar las fortalezas del modelo, las áreas de mejora y la fiabilidad para mejorar los resultados obtenidos.

5.7 Conclusión y líneas futuras

El desarrollo propuesto de un modelo de clasificación basado en CNN que integra y combina datos de imágenes de RM y TC no solo representa un avance significativo para mejorar el diagnóstico de tumores cerebrales, sino también para mejorar la eficiencia y la fiabilidad. Al aprovechar las ventajas de ambas técnicas de imagen y aplicar un modelo de aprendizaje profundo cuidadosamente seleccionado, este estudio e investigación ofrecen una herramienta novedosa y eficaz para el uso clínico en ciencias médicas y aplicaciones de técnicas de procesamiento de imágenes. La implementación exitosa y significativa de MobileNetV3, respaldada por sólidas métricas de rendimiento, también demostró el potencial de implementar este modelo en entornos de atención médica y diagnóstico reales.

De cara al trabajo futuro, se pueden explorar varias líneas de investigación. Estas incluirán la expansión y difusión del conjunto de datos para incluir tipos de tumores más raros, junto con la experimentación con técnicas de aprendizaje por conjuntos, y los módulos de explicabilidad integrados para que las decisiones del modelo sean más transparentes para los profesionales médicos. Además, el refinamiento de los hiper-parámetros y la exploración de estrategias avanzadas de regularización pueden mejorar la generalización de datos no analizados, lo que mejorará la fiabilidad de los resultados.

UNIVERSIDAD DE MÁLAGA

6. Conclusiones generales

6.1 Resumen de contribuciones aportadas

La aplicación “Help Pro” ayuda en emergencias, uno de los objetivos de esta tesis. Rastrear a una persona necesitada, enviar alertas SMS y recibir mensajes de audio simplifica el proceso. Se pueden enviar mensajes urgentes y recibir sonidos útiles, lo que aumenta la capacidad de la aplicación. La interfaz diseñada para la aplicación fue sencilla para un uso exigente a largo plazo. Se obtuvieron excelentes resultados en condiciones simuladas. Para garantizar su fiabilidad, se requieren pruebas en condiciones reales.

En el caso del modelo CXR-DNN, el objetivo final era diagnosticar COVID-19 mediante imágenes CXR. El modelo se entrenó utilizando la arquitectura EfficientNetB7 y presenta una alta precisión tras modificar los hiper-parámetros y evaluar los resultados y cálculos para su rendimiento. En general, es un buen modelo, pero tuvo problemas para responder a nuevos conjuntos de datos, posiblemente debido a la poca variedad de fotos de entrenamiento durante el procesamiento.

Finalmente, se diseñó y ajustó otro modelo basado en CNN para lograr el objetivo de diagnosticar tumores cerebrales mediante una técnica conjunta con imágenes de TC/RM, con excelentes resultados.

6.2 Retos pendientes

En la primera contribución de la aplicación SOS, la disponibilidad de internet limita su utilidad en lugares distantes. Habría que disponer de un modo de funcionamiento off-line que pudiera tener una funcionalidad suficiente para las emergencias más graves.

En el segundo trabajo (modelo CXR-DNN) y el tercero (basado en CNN con imágenes TC/RM) presentados, se requiere una gran potencia de procesamiento para funcionar correctamente. Esto puede presentar problemas para los institutos médicos con equipos inadecuados. Los sistemas demuestran que la IA puede utilizarse de forma estratégica y eficiente para apoyar a los profesionales médicos y al público en circunstancias cruciales, y en este caso se ha verificado que se cumple para ambos sistemas de diagnóstico de enfermedad considerados.

6.3 Mejoras potenciales

Relativo a los modelos CNN y de aprendizaje profundo presentados, una mejora será la incorporación de más imágenes para la fase de entrenamiento. Además, las consideraciones realizadas en los modelos CNN (como esfuerzo computacional, tiempo de respuesta, etc.) y de aprendizaje profundo pueden indicarnos los requisitos necesarios para una implementación operativa. Estos podrían satisfacerse pronto con nuevos avances, como la incipiente tecnología de computación cuántica.

Otro caso interesante radica en añadir monitorización de la actividad del usuario para que la aplicación “Help Pro” sea más inteligente. Podría implementarse integrando comunicación con dispositivos sensores de salud pequeños (llamados wearables) que se portan de forma cómoda

UNIVERSIDAD DE MÁLAGA

en el usuario. Otro caso alternativo, sería usar otros dispositivos portátiles para aumentar la flexibilidad de la aplicación para diferentes perfiles de cliente (sordos, mudos, invidentes, etc).

6.4 Reflexión final

Esta tesis muestra cómo la inteligencia artificial puede transformar el mundo. La aplicación de emergencia "Help Pro" y los modelos basados en IA propuestos para diagnosis de enfermedades, demuestran que la tecnología inteligente puede resolver problemas actuales y futuros. Ambos sistemas de diagnóstico pueden ayudar a los médicos a diagnosticar pacientes o salvar a personas en peligro.

6.5 Implicaciones éticas y sociales

En esta área de investigación, es fundamental examinar las cuestiones éticas y sociales de la IA en el ámbito sanitario. Una preocupación importante es la privacidad de los datos. La geolocalización y los datos médicos son sensibles en "Help Pro" y en los modelos de diagnóstico implementados (CXR-DNN, diagnosis conjunta RM/TC). La confianza y la ética requieren la seguridad de los datos con el consentimiento del usuario.

Otro problema es el sesgo del modelo de IA. Los datos de entrenamiento afectan considerablemente al aprendizaje automático. Si los conjuntos de datos de entrenamiento carecen de varianza o presentan sesgos ocultos, los modelos pueden funcionar de forma diferente en distintas poblaciones. Las disparidades en la atención sanitaria pueden fomentar la desigualdad. Los futuros procesos de desarrollo de modelos deben contener conjuntos de datos variados o representativos, así como pruebas de imparcialidad, para abordar este importante problema.

Por último, también es importante la influencia en los profesionales humanos. Estos modelos benefician a los médicos, pero la automatización de la atención sanitaria y los servicios de urgencias plantean inquietudes sociales. En cuestiones éticas o de juicio complejas, la dependencia excesiva de las tecnologías automatizadas puede perjudicar la supervisión humana.

La aplicación "Help Pro" muestra cómo la tecnología móvil ayuda a los servicios de emergencia. Los teléfonos inteligentes y las conexiones a internet no son accesibles en todas partes ni para todos los estratos socioeconómicos. La igualdad tecnológica y los sistemas inclusivos en los países de bajos recursos se ven amenazados. La IA puede mejorar la atención sanitaria y la seguridad pública si se planifica, desarrolla y utiliza adecuadamente. Las soluciones de IA deben enfatizar la apertura, la responsabilidad y la inclusión para lograr beneficios éticos y equitativos.

UNIVERSIDAD DE MÁLAGA

This page intentionally left blank

UNIVERSIDAD DE MÁLAGA

Acknowledgements

First, I would like to thank Allah Almighty for providing me the strength, patience, courage, and the right direction I needed to go through this lengthy PhD journey. Getting my PhD was one of the hardest things I have ever done.

I wish to express my sincere appreciation to my supervisors, Prof. Dr. Miguel Angel Luque-Nieto and Prof. Dr. Pablo Otero Roth, for their continuous support and encouragement. Their trust in my abilities gave me the confidence to keep going. I also want to respectfully remember the late Prof. Dr. Javier Poncela, whose early guidance and contributions are warmly acknowledged.

This dissertation is dedicated to the loving memory of my beloved late parents, Prof. Dr. Muhammad Yousuf Khan and Mrs. Shabnum Yousuf Khan, and my beloved elder late sister, Dr. Sadia Yousuf Khan. Their values, sacrifices, and unwavering belief in me have been a driving force throughout my life. I deeply miss them on the completion of my PhD.

I owe heartfelt thanks to my wife, Tarab Ali Khan, for her unwavering patience, love, and encouragement during the most demanding phases of this work. My two sons, Muhammad Usman Ali Khan and Muhammad Shaheer Ali Khan, have been my biggest inspiration, their smiles and innocence kept me grounded and motivated.

I express my gratitude to my elder brothers, Engr. Faisal Yousuf Khan and Engr. Hasan Yousuf Khan, for always being with me during my PhD studies, they supported me a lot and helped me tremendously to build my confidence and courage in my efforts to reach the goals.

Lastly, I would want to express my sincere gratitude to all of my friends, coworkers, and well-wishers who helped me in any way throughout my PhD journey.

UNIVERSIDAD DE MÁLAGA

Table of Contents

Abstract i
Resumen ii
Acknowledgements xv
Table of Contents xvi
List of Tables xxii
List of Figures xxiii
List of Abbreviations xxiv
Chapter 1: Introduction 1
1. Introduction 1
1.1 The Background 2
1.2 Artificial Intelligence 3
1.2.1 Machine Learning 6
1.2.2 Artificial Neural Network 7
1.2.3 Deep Learning 9
1.2.4 Convolutional Neural Network 11
1.3 Research Objectives 12
1.3.1 Scope of Research 13
1.3.2 Contributions to the Dissertation 14
1.3.3 Scheduling of the Work 15
1.4 Dissertation Organization 15
1.5 Related publications 16
Chapter 2: State-of-the-Art 19
2. Introduction 19
2.1 Overall Literature Review 20
2.2 System Level Review 24
2.3 Dataset Review 27
2.4 Machine Learning Algorithm Review 29
2.6 Discussion 30
2.7 Conclusion 30

UNIVERSIDAD DE MÁLAGA

Chapter 3: Comprehensive Overview of the SOS Application: Help Pro 33
3. Introduction 33
3.1 System Design and Architecture 34
3.1.2 Android Operating System 34
3.1.3 Development Environment - Android Studio 34
3.1.4 Programming Language - Java 34
3.1.5 Database and Backend Services - Firebase 34
3.1.6 Location Services - Google Map API 35
3.1.7 Web Framework - Laravel 35
3.1.8 Summary of the System's Technological Integration 36
3.2 Methodology for Development 36
3.2.1 Conceptualization and Requirement Analysis 36
3.2.2 System Design Framework 37
3.2.3 Technology Integration 37
3.2.4 User-Centric Enhancements 37
3.2.5 Implementation and Testing 37
3.3 User Interface Design 37
3.3.1 User Module Design 37
3.3.2 Driver Module Design 39
3.3.3 Admin Module Design 39
3.4 System Components and Technologies Used 40
3.4.1 Android Platform 40
3.4.2 Android Studio 40
3.4.3 Java as the Backend Programming Language 40
3.4.4 Firebase for Backend Services 40
3.4.4.1 Authentication: 41
3.4.4.2 Real-time Database: 41
3.4.4.3 Cloud Storage: 41
3.4.5 Google Maps API 41
3.4.6 Laravel for Web Based Administration 41
3.5 Functionality and Testing 41

UNIVERSIDAD DE MÁLAGA

3.5.1 System Functionality Overview 41
3.5.1.1 FCFS Queue Integration: 42
3.5.1.2 Dijkstra's Algorithm Application: 42
3.5.2 Implementation Mechanics 42
3.5.3 Testing and Evaluation 43
3.5.3.1 Unit Testing 43
3.5.3.2 Integration Testing 43
3.5.3.3 System Testing 44
3.5.3.4 User Acceptance Testing (UAT) 44
3.6 Results and Comparative Analysis 44
3.7 Conclusion 44
Chapter 4: Development and Evaluation of the CXR-DNN Model for COVID-19 Diagnosis 45
4. Introduction 45
4.1 Related Work 46
4.2 The CXR-DNN Method 46
4.2.1 EfficientNetB7 Architecture 47
4.2.1.1 MBConv Blocks 47
4.2.1.2 Squeeze and Excitation 47
4.2.1.3 Compound Scaling 47
4.2.1.4 Training Parameters 48
4.2.1.5 Optimizer 48
4.2.1.6 Loss Function 48
4.3 Model Training Process 48
4.3.1 Data Preparation 48
4.3.2 Data Augmentation 48
4.3.3 Transfer Learning 49
4.3.4 Training Procedure 49
4.3.5 Validation 49
4.3.6 Validation and Testing 49
4.3.7 Validation Dataset 49
4.3.8 Testing Dataset 49

UNIVERSIDAD DE MÁLAGA

4.3.9 Performance Evaluation 49
4.3.10 Accuracy 49
4.3.11 Precision 49
4.3.12 Recall 50
4.3.13 F1-score 50
4.4 Results 50
4.4.1 Performance Metrics 50
4.4.1.1 Performance Metrics Overview: 50
4.4.2 Results on Validation and Test Datasets 51
4.4.3 Comparative Analysis 51
4.4.4 Additional Visualizations 52
4.4.4.1 Confusion Matrices 52
4.4.4.2 Training Dataset 52
4.4.4.3 Validation Dataset 52
4.4.4.4 Testing Dataset 52
4.4.4.5 Performance Metric Convergence Graphs 53
4.4.4.6 Precision Convergence 53
4.4.4.7 Recall Convergence 53
4.4.4.8 F1-score Convergence 54
4.5 Discussion 54
4.5.1 Discussion of Results 54
4.5.2 Challenges and Limitations 54
4.6 System Implementation 55
4.6.1 Integration with Machine Learning Platforms 55
4.6.2 Data Preprocessing and Augmentation 55
4.6.3 Platform Selection 55
4.6.4 Model Deployment 55
4.6.5 Real-Time Workflow for Diagnosis 56
4.6.6 Image Upload 56
4.6.7 Preprocessing 56
4.6.8 Model Inference 56

UNIVERSIDAD DE MÁLAGA

4.6.9 Results Visualization 56
4.6.10 Data Storage and Accessibility 56
4.6.11 Challenges in System Implementation 56
4.7 Conclusion 56
Chapter 5: Development of a CNN-Based Joint Diagnosis Model for Brain Tumor Classification Using CT and MR Imaging 59
5. Introduction 59
5.1 Related Work and Technical Background 60
5.1.1 Image Processing in Medical Imaging 60
5.2 Suggested Framework 61
5.2.1 Gathering Datasets 62
5.2.2 Preparing Data for Analysis 62
5.2.3 Enhancing the Data 63
5.2.4 CNN Models 63
5.2.5 Performance Measures 63
5.3 Results 64
5.3.1 Class-wise Accuracy Evaluation 65
5.3.2 Epoch-wise Performance Analysis 66
5.3.5 Computational Cost Analysis 67
5.4 Conclusion 68
Chapter 6: Conclusions and Future Work 69
6. Conclusions 69
6.1 Development of the CXR-DNN Model 69
6.2 Model Evaluation and Performance Metrics 69
6.3 Comparison with Other Models 69
6.4 Contributions to Medical Imaging 70
6.5 Future Work 70
6.5.1 Model Optimization 70
6.5.2 Expanding the Dataset 70
6.5.3 Multi-Modal Diagnosis 70
6.5.4 Real Time Deployment 70

UNIVERSIDAD DE MÁLAGA

6.5.5 Expanding Beyond COVID-19 71
6.5.6 Future Research in the SOS Application 71
6.5.7 Advanced AI Techniques 71
Appendix A 72
Bibliography 73

UNIVERSIDAD DE MÁLAGA

List of Tables

Table 1.1 Changes in the number of patent applications in the field of AI technology…..... 5
Table 2.1 Summary of Overall Literature Review……..……. 20
Table 2.2 Summary of literature with a focus on the technology employed..…….. 25
Table 2.3 Summary of brain tumor, Chest X-ray datasets reviewed…… 28
Table 5.1 Qualification of Brain Tumors……..… 62
Table 5.2 Accuracy Comparison Across CNN Models…… 64
Table 5.3 Per-Class Accuracy Using MobileNetV3……..… 65
Table 5.4 Precision, Recall, and F1-Score for MobileNetV3……..... 66

UNIVERSIDAD DE MÁLAGA

List of Figures

Figure 1.1 Overview of Artificial Intelligence Hierarchy....…….. 4

Figure 1.2 The Impact of AI on different structural dimensions……..... 5

Figure 1.3 Types of Machine Learning…… 6

Figure 1.4 The general architecture of Artificial Neural Network……. 8

Figure 1.5 Basic Convolutional Neural Network Architecture…….. 12

Figure 1.6 The key areas of the research work…… 13

Figure 1.7 Scope of research within the Artificial Intelligence Domain…….. 14

Figure 3.1 The Dijkstra Algorithm Concept…… 35

Figure 3.2 Laravel Implementation…….. 36

Figure 3.3 User help screen with Driver's Details and Location……38

Figure 3.4 Near by Hospital Screen…….. 38

Figure 3.5 Blood Friends Screen…….. 39

Figure 3.6 States diagram of overall use case of Help Pro……... 42

Figure 3.7 Level 2 - Data Flow Diagram……43

Figure 4.1 MBConv Blocks in the EfficientNetB7 Architecture…….. 47

Figure 4.2 3x3 confusion matrices…… 52

Figure 4.3 Convergence graphs…… 53

Figure 5.1 Convergence Deep Learning process architecture..... 61

Figure 5.2 MRI brain tumor images..... 64

Figure 5.3 CT brain images..... 65

Figure 5.4 Combined performance of MobileNetV3 across epochs..... …….. 66

Figure 5.5 Confusion matrix combined MRI and CT classification..... 67

UNIVERSIDAD DE MÁLAGA

List of Abbreviations

AI	Artificial Intelligence
ANN	Artificial Neural Network
API	Application Programming Interface
App	Application
CNN	Convolutional Neural Network
COVID	Corona Virus Disease
CXR	Chest X-ray
DL	Deep Learning
DNN	Deep Neural Network
HER	Electronic Health Record
FCFS	First Come, First Serve
FN	False Negative
FP	False Positive
GB	Gigabyte
GPS	Global Positioning System
GPU	Graphics Processing Unit
ICE	In Case of Emergency
IDE	Integrated Development Environment
IoT	Internet of Things
JSON	JavaScript Object Notation
kNN	k Nearest Neighbor
LSTM	Long Short-Term Memory
LUS	Lung Ultrasound
MBConv	Mobile Inverted Bottleneck Convolution
ML	Machine Learning
MRI	Magnetic Resonance Imaging
MVC	Model View Controller
NAAT	Nucleic Acid Amplification Test
NoSQL	Not Only SQL
OOP	Object Oriented Programming
OS	Operating System
OTP	One Time Password
PHP	Hypertext Preprocessor
RAM	Random Access Memory
ReLU	Rectified Linear Unit
RT-PCR	Reverse Transcription Polymerase Chain Reaction
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SMS	Short Message Service
SOS	Save Our Souls
SVM	Support Vector Machines
TB	Tuberculosis
TN	True Negative
TP	True Positive
UAT	User Acceptance Testing
UI	User Interface

UNIVERSIDAD DE MÁLAGA

Chapter 1: Introduction

1. Introduction

Over the last several years, the healthcare industry has been subjected and targeted to significant transformations because of the introduction of modern technology, particularly artificial intelligence. The speed with which medical treatments are carried out in general, and the state of patients' health have both been significantly improved because of these modifications. Reliable and mature CNN models for detecting brain tumors by using CT and MRI data and COVID-19 detection is the subject of this thesis. Further, the SOS App for Android, Help Pro, is also carried out for research. These recent findings pursued a great deal to the research that has been conducted in this particular field in the past recent years of development and research in medical sciences domain for measurements and precautions.

Within the scope of mobile health software, the SOS program for Android: Help Pro stands out as an amazing challenge. This software has the potential to be of great assistance in a medical setting. This application makes it simple to provide first responders with necessary health information promptly by offering them with data in real time and keeping track of the locations of all those who are working together. Those who were liable for developing the program were aware of how critical it was to have frequent access to the medical supplies. By allowing population to have a greater say in the events that take place, the healthcare system can perform more successfully, beneficially and support humans for their care and cure measures. The CXR-DNN model in this research indicates a real time solution for the diagnosis of COVID-19 using chest X-ray (CXR) images. Taking the benefit of deep neural networks, exclusively the EfficientNetB7 architecture, the model distinguishes between COVID-19, pneumonia, and normal cases with best accuracies. The model was trained, validated and tested on a big dataset of CXR images, and its run time diagnostic abilities make it a valued tool in handling the COVID-19 pandemic which can offer healthcare professionals a mature and organized method to make a rapid, and a reliable possibility in tough and critical environments for health professionals, practitioners and the para staff on the other hand as well.

UNIVERSIDAD DE MÁLAGA

Through the use of these works and findings, the main objective of this thesis is to highlight the significance of artificial intelligence (AI) and mobile health care technology to the manner in which medical care is implemented. Both the SOS App and the CNN model may teach us a great deal about how artificial intelligence can be used to enhance the quality of care provided to patients and expedite the diagnostic process. This is made capable by combining the use of new technologies with applications. If these technological advancements are completely recognized by the healthcare industry, they will have significant implications not only on the clinical practice that is now being conducted but also on the research that will be conducted in the future. The data presented in this thesis suggests that medical technology is continuously advancing and that this might result in a shift in the way that individuals interact with the healthcare system and the advancements for better and more meaningful outputs.

1.1 The Background

In recent years, artificial intelligence has been used a lot in medicine. This has managed to formation of new ways to treat, diagnose, and keep record of diseases. These changes are happening because people want better and more accurate medical care. This is true perception in situations that are hard to recognize like medical images and emergency response systems. Artificial intelligence is being used in different ways in the healthcare domain. The range of these uses is huge, from making testing tools better to using predictive analytics to help with patient care. Building on two important points of research that have already been found in the thesis demonstrates how vital this happening is by deeming into more detail about the results, readings, analysis, and the outcomes of the measurements and precautionary counting manners.

First, there is an app for Android called SOS. People who are having a health emergency can use the Help Pro app to help them get in touch with help quickly. This app helps the user quickly by using their present position and health details. More and more people are using healthcare-related apps on their phones, which shows that patients are becoming more independent and taking charge of their health. In disaster, the Help Pro app is meant to make it easier for people to talk to each other right away. These steps are meant to make sure that people who are in danger can get help quickly, which could save their lives. People have been saying that they can't get help quickly enough in medical emergencies. The problem might be fixed with this method.

A core contribution is the manuscript titled X-Ray Image Based Real Time COVID-19 Diagnosis Using Deep Neural Networks (CXR-DNN) which poses the application of deep learning techniques for the quick diagnosis of COVID-19 through CXR images. This research prompts the emergency need for reliable diagnostic methods, specifically in the context of a global pandemic where on run time detection is essential for effective patient management. Executing EfficientNetB7 architecture, our study shows how advanced CNN can improve the accuracy of COVID-19 diagnosis. Implementing a considerable dataset of CXR images, the proposed model not only distinguishes between COVID-19, pneumonia, and normal cases but also purposes to reorganize the diagnostic process and make it accessible to healthcare experts. Additionally, the last work (Ch. 5) is related to the detection of brain tumors with a jointly CT/RM imaging diagnostic. Both works focus on the transformative potential of artificial intelligence in improving analytical capabilities even in disasters.

This research looks into several of the most important problems the healthcare business is facing at the moment. They also show how AI-powered solutions may change in how doctors

UNIVERSIDAD DE MÁLAGA

identify illnesses and how emergency services work. As technology keeps on getting better, artificial intelligence is likely to become more important in the healthcare field. This will lead to the discovery of new ways to improve the level of care given to patients and the processes used in medical treatment. The goal of this study is to put light on the possible and real uses of these technologies in healthcare situations by showing research that has already been done.

1.2 Artificial Intelligence

Artificial intelligence (AI) is a branch of computer science that demonstrates how to make computers can think and reason like humans. Involvement in these activities will give skills that can be used in many situations such as the ability to study, think critically, to solve problems, focus on the present, and to understand everyday words. Artificial intelligence is useful in many business areas because it can be changed to fit different needs. The main reason for this is that it can be used for a lot of different things. In this group of technologies are systems that use machine learning and natural language processing for the results processing and the outcomes of different analyses.

An overview of Artificial Intelligence Hierarchy has been presented in figure 1.1. How are things set up in the field of Artificial Intelligence (AI), the picture called i.e. Overview of Artificial Intelligence Frameworks shows this. AI, which is made up of many ways that try to be smart like humans is at the top. There are two sophisticated areas of research i.e. Machine Learning (ML) and Deep Learning (DL). Machine Learning, or ML is the study of how to instruct computers to learn from the information. Deep Learning or DL is a more specified area of ML that utilizes advanced neural networks to perform things like language processing and image processing. Artificial Neural Networks (ANNs) and Convolutional Neural Networks (CNNs) are also discussed. These are basic building blocks of Deep Learning and are used to do things with pictures or images. The fact that other Machine Learning methods are used shows how many kinds of AI there are. In later parts of the thesis these ideas will be looked at in more depth.

A lot of changes have happened in the healthcare field because of the widespread use of technology based on artificial intelligence. Because of this, there have been huge changes in how medical staff treat patients. One of the many perks of artificial intelligence is that it can quickly and correctly look at huge amounts of data. It is hard to say how important this is for the healthcare system. When it comes to artificial intelligence, one of the most important things is that robots can learn from data, spot trends, and put what they've learned together. The fact that it does this is one of its best features. On the other hand, machine learning is an important part of artificial intelligence. Utilizing artificial intelligence systems is very important in the field of medical imaging because these systems can help sort through huge amounts of visual data, find problems, and guess what the clinical effects will be after complete examination.
In the healthcare field, artificial intelligence is used in many important ways. One of these is to make tests easier and better. A very high level of accuracy can be reached when X-ray and magnetic resonance imaging (MRI) pictures are analyzed by computer tools that are combined with artificial intelligence. There is a chance that this technology could help people find diseases, cancers, and broken bones that aren't visible to the naked eye. This is why these methods help people make decisions and give healthcare workers less work to do. For this reason, they have more time to help their patients and make better, reliable, and trustworthy treatments for them.

UNIVERSIDAD DE MÁLAGA

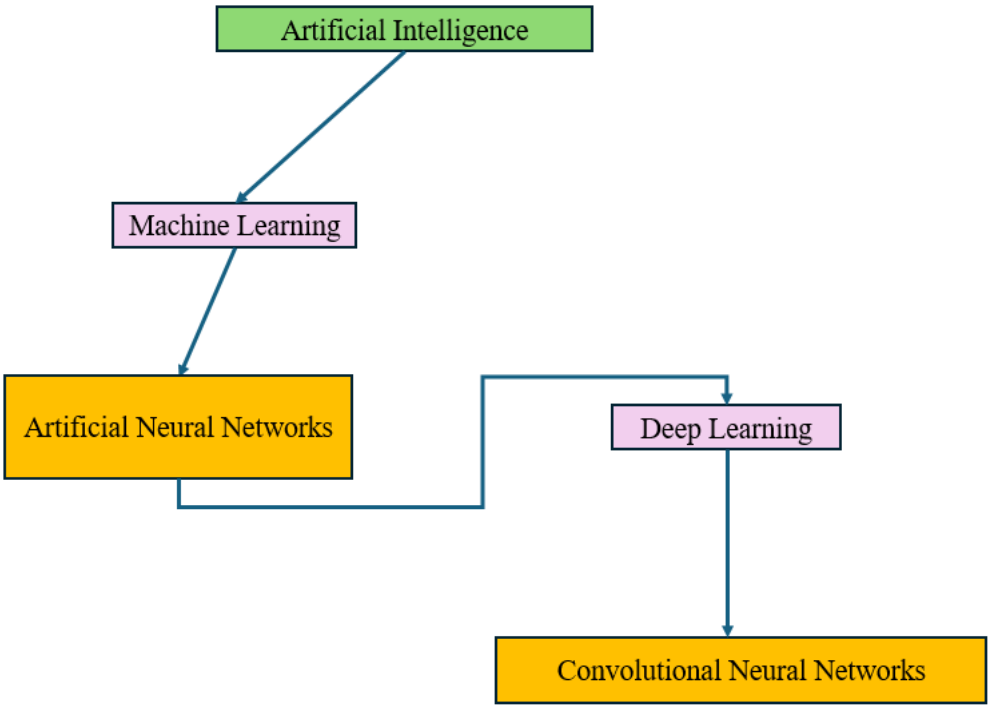


Figure 1.1 Overview of Artificial Intelligence Hierarchy**.**

Furthermore, prediction analytics is another area where AI is being used more and more. In this case, the focus is on using information from the past to guess what health problems might happen in the future. This approach makes it much easier to guess what patients will need, figure out which people are most likely to get sick and choose the best way to utilize the medical resources that are available. With the help of robots and virtual helpers that are driven by AI patients may be able to be more involved in their health care. People can get health information that is more relevant to their needs, get answers to their questions more quickly, and make meetings, manual readings, comprehensive studies, and rich predictions more easily with the help of these tools.

In figure 1.2, the impact of AI on different structural dimensions or domains can be observed. Moving from right to left, Artificial Intelligence Technology proceeds to the system architecture which shows different impacts and implementations in various aspects, further moving to the rightmost side is the performance measure of different outcomes of several utilities. There is strong evidence that artificial intelligence can be used in healthcare. However, there are still some problems that need to be fixed before they can be fully adapted. Several things need to be thought about, including how important data protection is, how likely it is that computers are biased, and the best ways to test and run artificial intelligence systems. Three very important traits that AI powered systems must have to win over both buyers and medical workers are transparency, fairness, and responsibility which play an important and magnificent role in future predictions too.

UNIVERSIDAD DE MÁLAGA

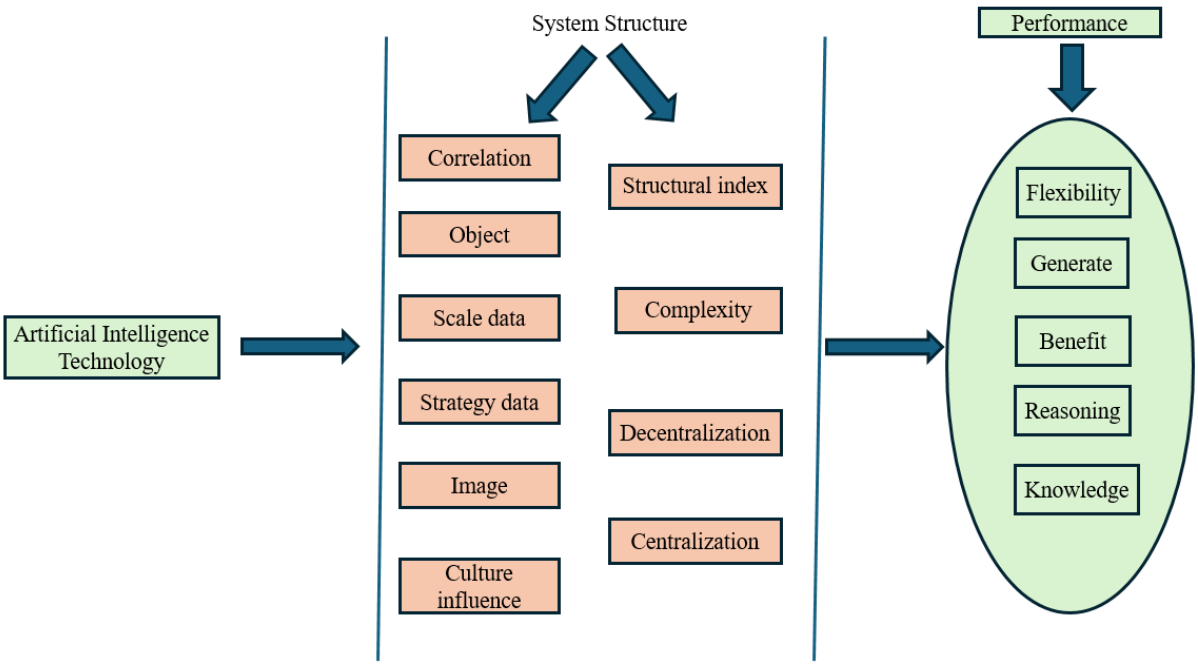


Figure 1.2 The Impact of AI on different structural dimensions**.**

For instance, only the number of patent applications in the field of AI technology in China in recent years has been mentioned in Table 1.1. Finally artificial intelligence has all the signs of a revolutionary technology that will change the way healthcare is provided by making seemingly unimportant tasks easier, improving the accuracy of diagnoses and making patients happier.

Year	Computer Identification	Instruction Recognition
2010	500	400
2011	600	500
2012	700	600
2013	1000	900
2014	1800	1400
2015	2200	2000
2016	5000	3600
2017	8300	4000
2018	3900	900
2019	8500	4300
2020	10000	5000

Table 1.1 Changes in the number of patent applications in the field of AI technology in China over the recent years [1].

Even though more research needs to be done in this area, using artificial intelligence in healthcare would be very helpful. Another interesting thing is that this is going to have a big effect on the upcoming generations which will make impact in different ways.

UNIVERSIDAD DE MÁLAGA

1.2.1 Machine Learning

Machine Learning (ML) is an important branch of artificial intelligence that investigates how statistical models and methods can be used to teach computers to do things on their own without help from a human. It is not true that machine learning systems follow a set of rules that don't change over time. On the contrary, they act in different ways based on what they have learned from trends in data and past events in history and different ages so far as concerned. Using data that has never been seen before is at the heart of machine learning, which is used to make guesses or choices. In general, a machine learning model can be expressed as:

$$y = f(x;\theta) \quad \textit{Equation (1)}$$

where y represents the output or prediction, x denotes the input data, and θ refers to the set of parameters or weights that are learned during the training and validation process. This compact formulation highlights the essence of ML, learning a mapping function from input to output based on data.

To do this, models need to be built that can generalize from the data that was used for training. There are three main types of learning that are often part of this process: supervised, unsupervised, semi-supervised and reinforcement learning. All these four can be observed in figure 1.3. Some of the implemented major sub domains or sub areas are also presented in the diagram of four learning types which shows the vital role and the measurements in the upcoming future are:

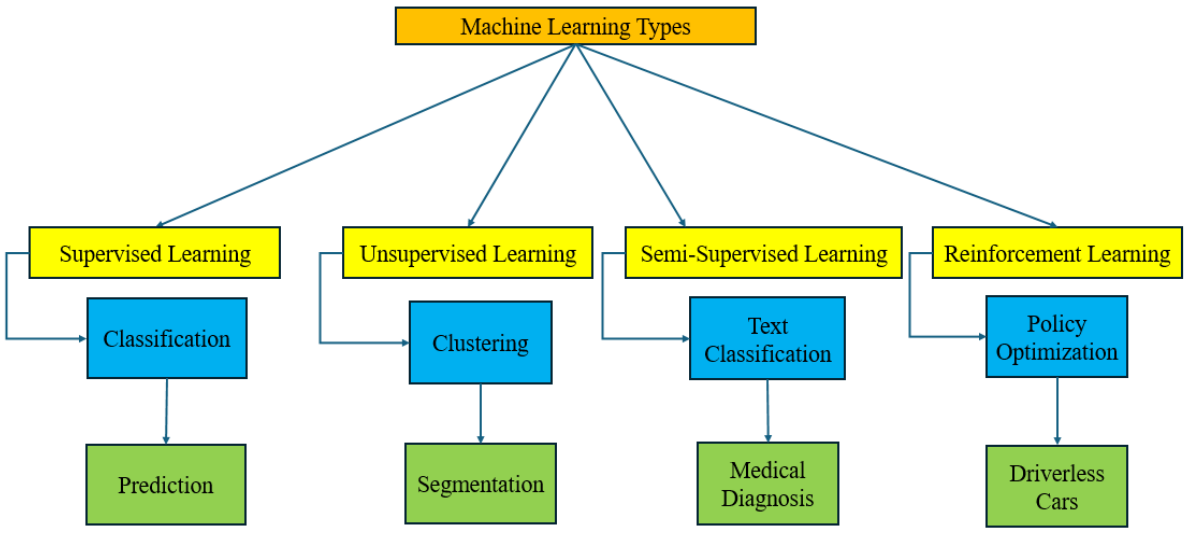


Figure 1.3 Types of Machine Learning**.**

- Using named data, the process of matching each training sample with the appropriate output is referred to as supervised learning. This is the method that is used to learn many algorithms. As the gap between what was expected and what occurred narrows, the model develops the ability to establish a connection between the characteristics of the inputs and the outcomes that were intended via the process. In the field of medical imaging, this technique is widespread since it gives models the ability to spot problems, concerns, and reservations in images via the use of labeled data.

UNIVERSIDAD DE MÁLAGA

- What makes unsupervised learning different from other types of learning is that the data does not have any names in it. There are times when it works without knowing what it is looking for to find patterns in the data. To make it easier to understand complicated data this method either reduces the number of variables or groups data points that are linked together.

- By allowing an agent to see and respond to everything around it the world can teach it how to make choices. This is possible with a technique called reinforcement learning in which computers learn by making mistakes. People often manage this method when they must choose what to do in a certain sequence like when they are playing a game or training robots.

Machine learning could be very helpful in the field of medicine. Machine learning systems that look at X-rays, CT scans, and MRIs can find a lot of issues. Because they can learn from huge sets of medical pictures, these systems get better at what they do over time and can handle more data, requests, and assigned targeted tasks. Another area where machine learning is useful is in making predictions. To try to guess how a patient will do in the future, these look at how they did in the past. Doctors can make much better treatment decisions when they have this knowledge. It lets them make care plans that are specific to the patient's needs, predictions, and recommendations to the reliable scale and recommendations.

One area where machine learning could be very useful is healthcare. However, it can be hard to use on a large scale. It's important to think about how to protect users' private information, stop fake bias, and make sure that models are 100% correct. For machine learning systems to be used in healthcare situations and work well they need to be dependent, and fair all the way through. Learning by machine is a useful tool in the field of AI in general. There are many ways it could be used, but the medical field stands out. Because it can learn from data and get better over time, it is possible to make evaluations more accurate, guess how patients will do, and provide better care overall.

1.2.2 Artificial Neural Network

The neural networks in animal brains are used as inspiration for computer models. These models are called Artificial Neural Networks or ANN's for short. In figure 1.4 the general architecture of artificial neural networks can be observed. The input layers take deep raw data such as text, images, or numerical values, and fix it for processing by the subsequent layers. After that the hidden layers are the intermediate layers between the input and the output layers that perform various deep transformations and computations on the input data to extract the features and patterns. The output layer at last produces the output based on the deeply processed information from the hidden layers and summarizes the results of the computations and presents them in a specific format.

In general, the operation of a single neuron in an ANN can be mathematically expressed as:

$$y = f(\sum(w_i x_i) + b) \quad \textit{Equation (2)}$$

where x denotes the input, w represents the weight, b is the bias, f is the activation function, i indicates index of each input weight pair and y is the output of the neuron. There are many situations where they are very useful because they learn from data. These changes have a major

UNIVERSIDAD DE MÁLAGA

impact on the fields of artificial intelligence, machine learning, and other related topics. In a connectionist way artificial neural network or ANN's process information. They are made up of groups of artificial neurons that are related to each other. In the area of artificial intelligence ANN's are used. A simulated nervous system is used to build these networks. Many kinds of networks can be told apart by how they are set up and how they gather data. The basic parts or building blocks of an artificial neural network (ANN) are the nodes, which are also called neurons.

This whole group of parts is what makes up the network. Depending on how they are put together, these nodes can be broken down into three main groups. This group includes the input layer, the secret layers, and the exit layer, among others. The raw data is changed when it comes back to the input layer after going through the hidden layers. The hidden layers are the part of the processing structure where the processing happens. While the person is being taught, changes are made to the weights of each brain link to make the forecast more accurate. A process called activation oversees going over all the information that our brain cells take in detail. Based on the data it has gotten so far, the activation function decides whether the cell should be turned on or off.

There is a new kind of activation function that may be considered and one example of this is the Rectified Linear Unit which is also frequently referred as the ReLU. We may take into consideration this activation function as one of the options. Even though the hyperbolic tangent function and the sigmoid function are somewhat different from one another, it is essential to take notice of the fact that both functions are included in this category of functions at the same time concurrently. However, because of the modifications that have been included in this network, the network is no longer constructed linearly. Because of this feature of its functioning, it can comprehend the intricate and, in some respects, difficult ways in which the data is associated via correlation. It can do calculations and operations that are necessary for a variety of situations, as well as the preventive measures and parameters that are essential for the output by the requirements and treatments for increased judgments and benefits. This is because it can accomplish all these things. As a result of the fact that it can do these essential operations and computations, this is the effect that you will experience.

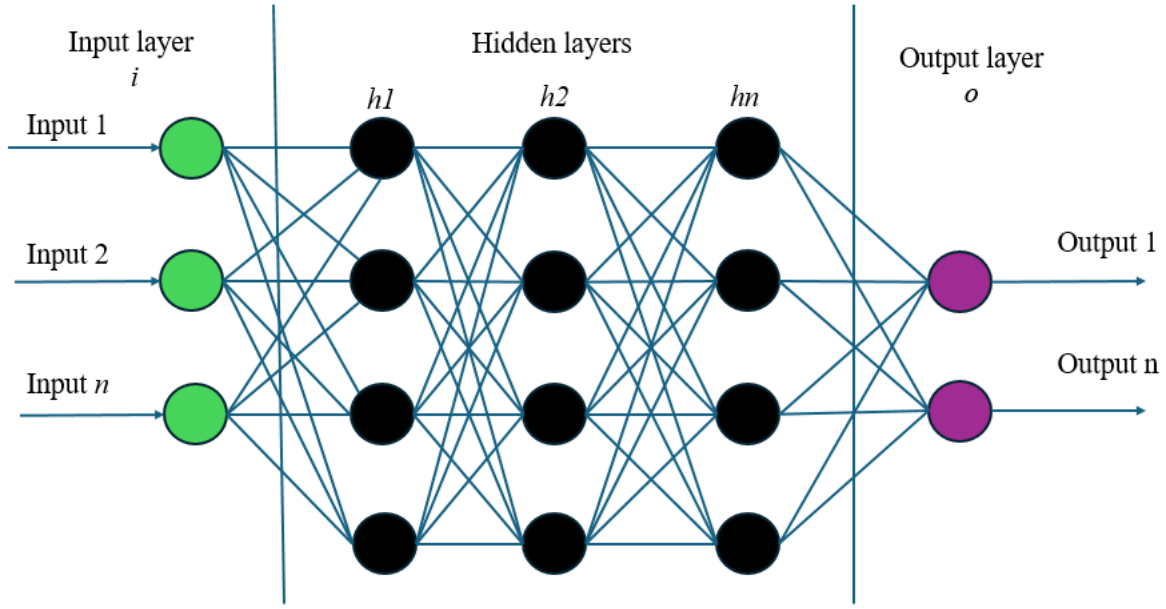


Figure 1.4 The general architecture of Artificial Neural Network**.**

UNIVERSIDAD DE MÁLAGA

Backpropagation is a method that is often used to teach artificial neural networks (ANN's) latest knowledge. Making use of the chain rule, this method can figure out the slope of the loss function for each weight. Having said that, this means that the weights can be changed quickly. The loss function is responsible for indicating the extent to which the estimates made by the network coincide with actual results. This review is done to help the learning process grow. One way to improve the accuracy of a neural network's performance is to use the training sample repeatedly. To make the ANN work better this could be implemented for better and more reliable calculations.

Artificial neural networks (ANN's) can generalize and conclude specific cases. One important thing about these networks is this. Many jobs, such as medical research, image recognition, and natural language processing, could pay more for people who are able to make good guesses from new information. People in many fields need this skill because it helps them figure out what is going on. Some of the things they can do are easy, like finding patterns, and some are hard, like moving themselves from far away. They are adaptable in, so they can do all these things meaningfully.

Artificial neural networks (ANN's) can do some good things and some bad things as well. For example, you need a lot of computer power and a lot of different kinds of information to teach kids. Another problem is that they might overfit. This is when the model starts to look too much like the data that was used to train it and does not do well with new data that it has not seen before. An artificial neural network is a powerful AI tool that lets us use a lot of different enhanced machine learning techniques. This very cool machine can figure out intricate patterns and change shapes to do a huge number of tasks by itself. It is one of the important parts of smart systems.

1.2.3 Deep Learning

Deep Learning is a branch of machine learning that focuses on making artificial neural networks that work like the brain. These networks are put together using techniques that are based on how the brain works. This way of doing things has been getting a lot of attention lately and working well in many areas such as healthcare, natural language processing, image and voice recognition, and other areas that need to look at large amounts of data and their inter connections and different dependencies in various aspects and different categories spreading widely.

Neural networks are the basic building blocks of deep learning. They are made up of layers of neurons which are nodes that are connected. The raw data is changed in a way that lets the model get more complex representations as it moves through the network. This takes place at every stage of the network. There are a few secret layers, an input layer, and an output layer that make up the structure of a deep learning method. Because these networks are so detailed they might be able to find complex data patterns and relationships that other machine learning methods would miss or may not be able to catch the exact data as it is needed or required as instructed. In general, the operation of a deep learning model can be mathematically expressed as:

$$y = f^{(L)}\left(f^{(L-1)}\left(\dots f^{(i)}(x)\dots\right)\right) \qquad \textit{Equation (3)}$$

Where x denotes the input data, $f^{(i)}$ represents the transformation and activation function at the i-th layer, L is the total number of layers, and y is the final output of the model. One of the best

UNIVERSIDAD DE MÁLAGA

things about deep learning is that it can learn straight from raw data, so people don't have to handle it. This is very helpful in medical imaging because it lets deep learning models be taught on a huge number of pictures. This makes it possible to instantly find diseases and other problems. The general architecture of deep learning typically consists of input layers that take raw data such as images, text, or numerical values, followed by hidden layers that transform and process the data to extract its features and patterns. Finally, the output layer produces the results based on the processed information from the hidden layers.

Among the different kinds of deep learning models convolutional neural networks (CNN's) are made to deal with data that looks like a grid, like photos. Because they are very good at recognizing spatial structures in visual data, they can do useful things like finding cancerous growths on X-rays and the prescribed images where the data can be managed and organized for the records.

Deep learning has been used in medicine so far and it has worked well. Convolutional neural networks (CNN's) can correctly identify a lot of different illnesses by looking at X-rays, MRIs, and computed tomography (CT) scans. These pictures show things like pneumonia, broken bones, cancer, and many more etc. Also, deep learning systems might be able to help doctors by giving them second opinions, pointing their attention to trouble spots, and generally improving the accuracy of diagnoses. There are many good things about deep learning, but there are also some bad things. Maybe it will be hard to train deep neural networks in the medical field because there aren't many computers available or a lot of datasets that have already been tagged. Interpretability is also a problem with deep learning models because they are black boxes which means that users can't easily figure out why the models make the choices they make. It depends on how open and responsible these tools are, what kind of use they get in healthcare settings, and measurements in different scenarios.

As the technology behind deep learning keeps getting better, then they might be able to get around some of these problems. It is not mandatory to have a lot of labelled data to show that transfer learning can be implemented to improve models that were learned on one dataset on a different dataset. Medical professionals may also have more faith in these technologies and be able to make better use of them. The goal is to make it easier, feasible, and manageable to understand models that are made for deep learning.

Not only is deep learning a big step forward in the field of machine learning but it also has a lot of potential to improve the accuracy of healthcare exams and the results for patients. A study that is still being worked on suggests that using deep learning in clinical procedures could help doctors get better at their jobs and let them make decisions based on data.

UNIVERSIDAD DE MÁLAGA

1.2.4 Convolutional Neural Network

This is what CNN's stand for i.e. convolutional neural networks. When pictures and other types of data are set up in a grid this type of deep learning model works well. They are common for computer vision for how well they can find things, sort parts of a picture, and group things together. Regular feedforward neural networks are built in a way that is different from how convolutional neural networks (CNN's) are built. CNN's have extra layers that help them find trends in the raw data that are related to space and the gaps for the perspective values.

The main part of a convolutional neural network (CNN) is called a convolutional layer. We use a group of trainable filters called kernels in this layer to process the picture that comes in because of this. As the filters move across the picture, they make each part bigger on its own, and then they add them all up until they reach the total. This takes a picture out of the features. After that, it can learn about patterns, lines, and things that look good, like colors, shades, and shapes. Many filters could be put on a single convolutional layer to make it pick up different parts of the data being sent to it. There is a way for the network to understand more complicated images. A lot of the time pooling layers are added to CNNs after the convolutional layers to reduce the size of the feature maps. It is almost always used to share with the maximum availability. For each feature map subregion, it is checked to see which one has the most. This method makes it easier to do math and reduces the number of factors in the model. When used in this way, this makes the facts easier to understand. Pooling adds translational invariance to a picture, which helps the network find things in different or distributed parts of it for calculations, and measurements.

CNN has a network with many convolutional and pooling layers. These layers help the network understand traits that get trickier as more data flows through it. With the help of this set of rules CNN's might be able to figure out how to get more and more information from raw data. CNN's, which stands for "convolutional neural networks," usually have layers that are all linked together. The basic convolutional neural network architecture can be seen in figure 1.6. A Convolutional Neural Network CNN's input layer takes in raw data or the images in the form of grid values of the prescribed image values. Then the convolutional layers use filters known as kernels to look for patterns like lines or textures and use those as features for making the calculations and measurements. After that the activation functions are implemented for those that are not linear such as ReLU known as Rectified Linear Unit which is an activation function commonly used in neural networks, especially in Convolutional Neural Networks (CNN's). Mathematically, defined as:

$$f(x) = max(0,x) \qquad \text{Equation (4)}$$

which means that for any input value x, ReLU outputs x if x is positive, and 0 if x is negative. In pool layers the feature maps become less complicated in terms of space and data that has been more important has been stored and does less processing. For feature extraction many stacked convolution and pooling layers are used. The patterns they pick up get more complicated as they go deeper. After that, the fully linked layers take the feature maps and turn them into a flat 1D vector. Then the classification has been performed. The last step is the output layer which shows the final classification results and calculations.

Artificial neural networks (CNNs) can learn useful traits from raw visual data without any help from a person. This means that feature extraction is no longer needed. Face recognition, medical image analysis, and the development of self-driving cars are just a few of the many

UNIVERSIDAD DE MÁLAGA

uses that have gained from their use. It is possible to pre-train CNN's using very large datasets like ImageNet when there is not a lot of labeled data. This makes transfer learning easier, more reliable, and safer.

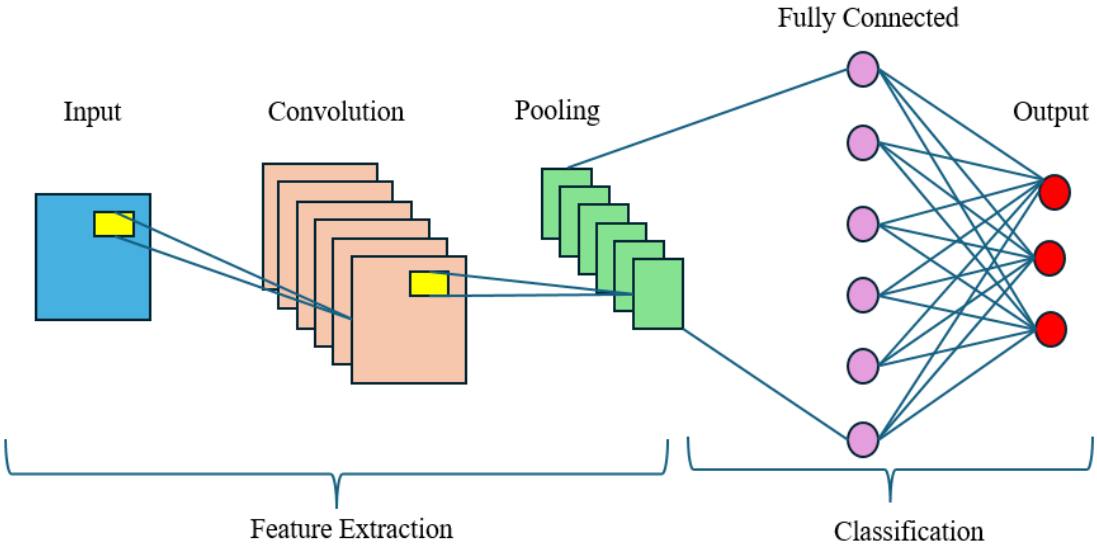


Figure 1.5 Basic Convolutional Neural Network architecture**.**

However, convolutional neural networks (CNNs) need a huge amount of data and a lot of computer power to work at their best while they are being taught. The issue of overfitting is much more important when working with datasets that are small or almost identical. Some common training methods that can be used to solve this problem are adding more data, taking data away, and making the data more reliable and mature for the projected training and calculations proceed to the output.

In conclusion, Convolutional Neural Networks are a big step forward in the field of deep learning because they make it possible to handle and understand visual information. Because of their unique shape and ability to gather information in a planned way they have been the best choice for many computer vision tasks and because of this, the field of artificial intelligence has been able to grow more quickly.

1.3 Research Objectives

The study has a lot of major goals that are meant to make the use of convolutional neural network (CNN) models in medical analysis better:

- **Data Augmentation and Preprocessing**: The research will circumvent the challenges that are associated with medical picture collections by using novel approaches, to add to the data that is already available. In this manner the CNN model is made more helpful by ensuring that it functions well with a variety of examples of data taken from the real world.

- **Improved Diagnostic Accuracy**: As one of the main goals is to create a CNN model that can make better guesses than the ones that are used now. The main goal of the study is to make the model work better in terms of sensitivity and specificity which are both very important in clinical tests.

UNIVERSIDAD DE MÁLAGA

- **Model Validation**: In order to guarantee that the CNN model is accurate, we will make use of a wide variety of success criteria that are typically used in scientific research on deep learning. With the help of this procedure, the model will be brought up to speed with the most recent best practices in the industry, and it will also be able to fulfill the predictable requirements of healthcare staff.

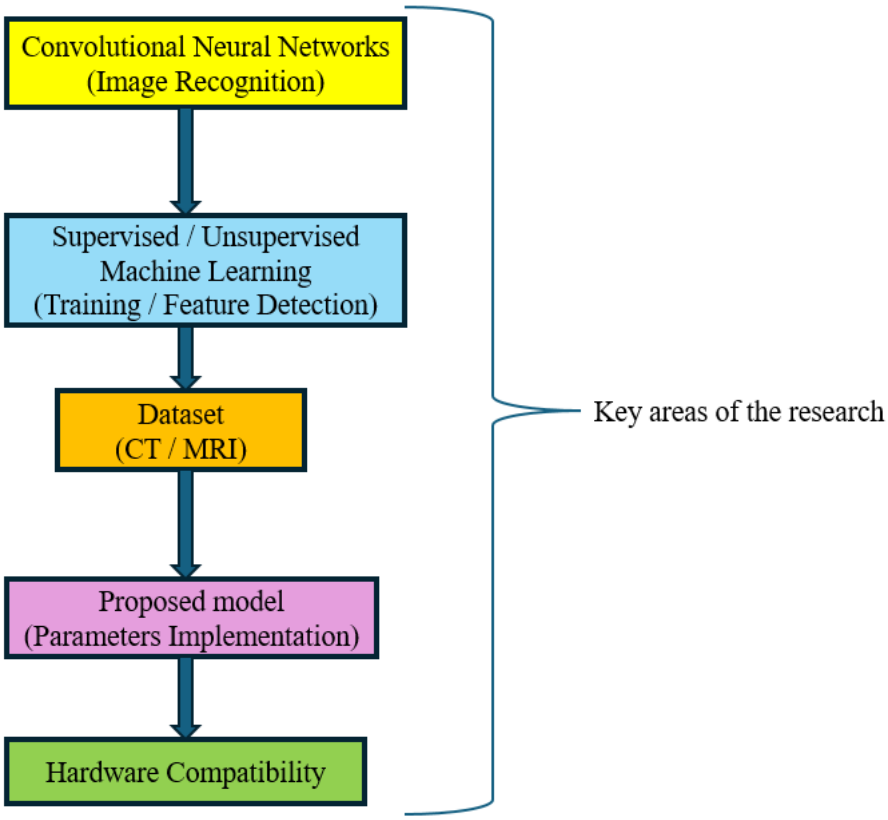


Figure 1.6 The key areas of the research work.

1.3.1 Scope of Research

The main point of this study is to find out if deep learning methods, more specifically Convolutional Neural Networks (CNN's), can help find brain cancers more accurately with MRI and CT scans. This section presents the scope of this research work. Figure 1.6 shows the key areas of this research work, which focuses on five main building blocks, which include CNN, supervised / unsupervised machine learning algorithms, selection of datasets, after proposed model parameters and finally the hardware availability or compatibility for the acquisition of the final execution step. Along the investigation into CNN for brain cancer recognition, this research also aims on using deep learning for diagnosing respiratory diseases. Figure 1.7 shows the scope of this research within the artificial intelligence domain. The solutions are implemented using the mechanism of machine learning and CNN. How CNNs can improve the accuracy of MRI and CT scans will be studied. Machine learning (ML) is quickly growing in importance in the field of medical research. It is getting clearer over time. This could make clinical tests much more useful and reliable. The goal of this study is to create

UNIVERSIDAD DE MÁLAGA

a convolutional neural network (CNN) model for brain cancer classification that is better than the ones that are already available. This new study will help the use of AI in health because of this. The second manuscript discovers the use of the EfficientNetB7 model to classify chest X-ray images into three categories: COVID-19, Pneumonia, and Normal cases. The target of this research is to explore the advanced capabilities of EfficientNetB7 to improve accuracy and provide healthcare professionals with a reliable tool for run time clinical decision making. By analyzing a large set of chest X-ray images, this research contributes to the suggestion of reliable diagnostic solutions and better health recoveries of the patients.

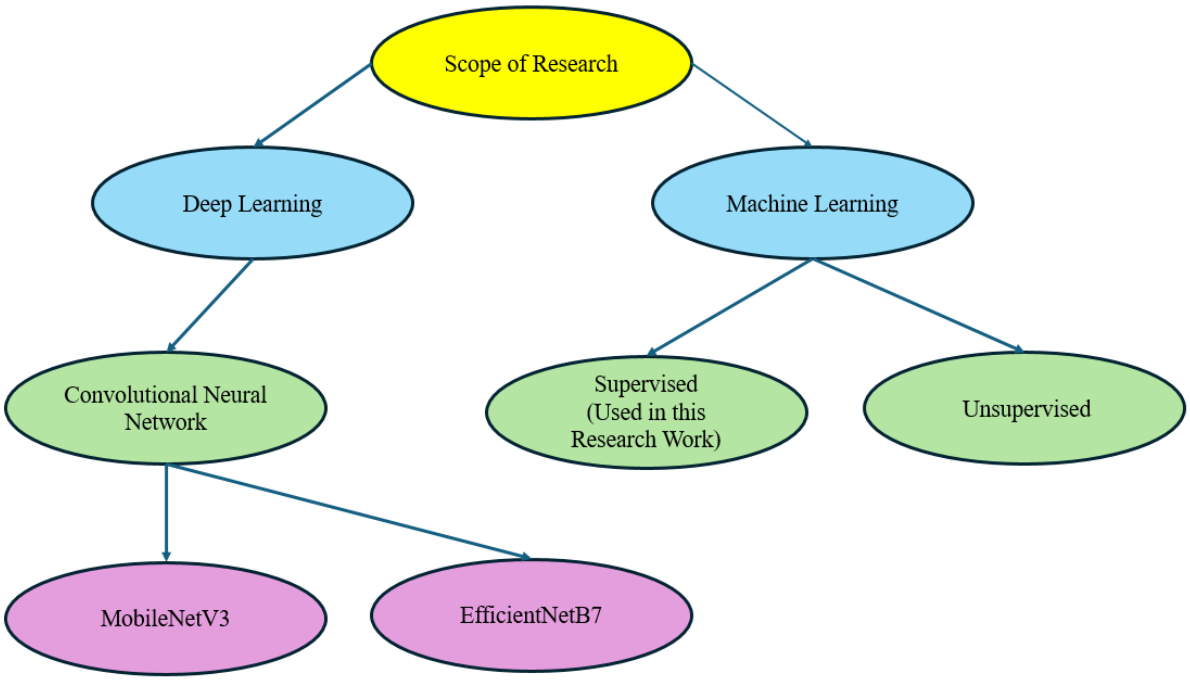


Figure 1.7 Scope of research within the Artificial Intelligence Domain using Supervised Learning**.**

1.3.2 Contributions to the Dissertation

This dissertation makes an important contribution to the field of artificial intelligence and medical science imaging. The major contributions are:

- **SOS Application for Emergency Response**: In the first published manuscript, I introduced the Help Pro application, which is designed to improve emergency response times by helping individuals quickly communicate during health crises. This app uses cellular phone technology to connect users and to help based on their desired location to save the lives during critical situations.

- **Deploying EfficientNetB7 for COVID-19, Pneumonia and Normal Diagnosis via Chest X-ray images**: The research work presented in the second manuscript provides a method for real time or on spot, and accurate COVID-19, Pneumonia and Normal detection. Furthermore, offering a practical tool that can assist and support healthcare professionals.

UNIVERSIDAD DE MÁLAGA

1.3.3 Scheduling of the Work

Year	2018			2019			2020		
Task	**Q1**	**Q2**	**Q3**	**Q1**	**Q2**	**Q3**	**Q1**	**Q2**	**Q3**
Task 1 (i.e.: Formal applications studies)		X	X		X	X			
Task 2 (i.e: Characterize challenges)								X	X

Year	2021			2022			2023		
Task	**Q1**	**Q2**	**Q3**	**Q1**	**Q2**	**Q3**	**Q1**	**Q2**	**Q3**
Task 3 (i.e. Implementation		X	X						
Task 4 (i.e.: Writing and submission of articles Paper I: **(completed)**					♦ accepted	♦ published			

Year	2024			2025		
Task	**Q1**	**Q2**	**Q3**	**Q1**	**Q2**	**Q3**
Task 3 (i.e. Implementation						
Task 4 (i.e.: Writing and submission of articles Paper II: **(completed)**			♦ accepted/ published			
Write dissertation, PhD exam					■	

From the scheduling of work, it can be examined that activities were carried out one by one as needed. The formal application studies related with different methodologies were conducted from 2018 till 2019 according to the PhD research work tasks as per instructions. The challenges were come to the point by 2020. After that the implementation work was started in terms of two presented conference papers and the first journal submission and publication from end of 2020 till 2022. Finally, the submission and the publication of second manuscript and the writing of thesis or dissertation work and the PhD exam hopefully will be carry before or by the end of 2024.

1.4 Dissertation Organization

Chapter 1 introduces the basis of the research worked out in this dissertation. It starts with a discussion on the role of artificial intelligence (AI) in healthcare domain then focusing on how AI techniques like machine learning (ML) and deep learning (DL) have transformed medical readings. The Convolutional Neural Networks (CNNs) are focused as a vital tool in our study and given their potential to enhance accuracy in tasks like brain tumor capturing and the detection of Covid-19, pneumonia and normal cases using images. The chapter also shows the research goals and scope thereby clarifying the emphasis on advanced CNN models like MobileNetV3 and EfficientNetB7 for medical image diagnosis. The models are then worked out for their maturity and capacity to enhance the scenarios involving diagnosis results by means of photographs. An overview of the dissertation's structure closes the chapter and offers a road map for the next ones.

UNIVERSIDAD DE MÁLAGA

Chapter 2 investigating the current state of the art has been carried out. This inquiry includes a comprehensive study of the most recent advancements in emergency response systems, brain tumor diagnostics, and the COVID-19 detection procedures. The contributions of my published and submitted publications are demonstrated in this chapter which not only compiles the related literature but also zoom out the contributions of those tasks and jobs. It does this by providing a background for the modern methods that are presented in the succeeding chapters.

Chapter 3 offers a close reading of the published paper SOS Application Under Android: Help Pro. Examining the design, development, and execution of the Help Pro system, this chapter explores its algorithmic framework, system components, and technology used. It describes Firebase integration of Android development tools' real-time emergency aid capability, Google Maps API for navigation and data processing using diagrams and technical drawings, the chapter also examines the architecture and operational flow of the system, therefore highlighting the capacity of the application to satisfy emergency response requirements. Along with how the application's functioning was verified to guarantee dependability and efficiency, key difficulties encountered during development and remedies chosen are covered.

Chapter 4 presents the fundamental evolution of the CXR-DNN model. The chapter goes over the model architecture which includes the usage of the EfficientNetB7 CNN, and gives thorough information on the training, validation and testing methods. The chapter assesses how well the model performs by utilizing a number of different measures including accuracy, precision, recall, F1-score, and confusion matrices. The model's merits in diagnosing COVID-19 are highlighted by analyzing and comparing the findings for the multiple datasets of training, validation, and testing.

Chapter 5 focuses on the development of a CNN-based joint diagnostic model for classifying brain tumors consisting of both CT and MR imaging. This chapter is based on an unpublished study and provides a comprehensive analysis of the use of several convolutional neural network (CNN) designs, including ResNet50, DenseNet, EfficientNetB1, and MobileNetV3, to categorize brain tumors into six separate categories. The chapter covers dataset collection, preparation, data augmentation, and performance evaluation. The MobileNetV3 model outperformed various classification metrics after rigorous testing and comparison. Tables showing class-specific accuracy, precision, recall, F1-score, confusion matrix, and training and testing visualizations support the conclusions. This chapter analyzes computer costs and clearly supports healthcare model use. This study enhances AI-driven healthcare research and may allow simultaneous CT/MR analysis in diagnostic procedures.

Chapter 6 encapsulates the dissertation's findings inside its conclusions. The proposed CXR-DNN model for COVID-19 diagnosis and its impact on medical imaging are emphasized. The major outcome of the research includes enhancements in classification accuracy and model efficiency of deep learning strategy. Citing the author's original paper, SOS (Save Our Souls) Application Under Android: Help Pro, in Wireless Personal Communications situates the work within a broader research context. Prior research established the foundation for the integration of AI and mobile technology into healthcare applications.

1.5 Related publications

[1] Ali Yousuf Khan, Miguel-Angel Luque-Nieto, Muhammad Imran Saleem, and Enrique Nava-Baro. 2024. "X-Ray Image-Based Real-Time COVID-19 Diagnosis Using Deep Neural

UNIVERSIDAD DE MÁLAGA

Networks (CXR-DNNs)" Journal of Imaging 10, no. 12: 328. https://doi.org/10.3390/jimaging10120328

[2] Ali Yousuf Khan, Miguel-Ángel Luque-Nieto, Samiya Batool, Hammad Ahmed, Abdul Hadi Saeed, Zaid Asif, “SOS Application Under Android: Help Pro,” Wireless Personal Communications, vol: 128, pp.: 987-1002, Jan 2023, Issue 2,doi: https://doi.org/10.1007/s11277-022-09985-4

[3] Ali Yousuf Khan, Miguel Angel Luque-Nieto, Hifsa Ansari, Ubaid-ur-Rahman, S. I. Waris and S. u. Z. Durrani, "Augmented Reality EleReactor Organic Chemistry," 2022 Global Conference on Wireless and Optical Technologies (GCWOT), Malaga, Spain, 2022, pp. 1-9, doi: 10.1109/GCWOT53057.2022.9772917.

[4] Ali Yousuf Khan; Pablo Otero Roth; Samiya Batool; Hammad Ahmed; Abdul Hadi Saeed; Zaid Asif, "Help Pro," 2020 Global Conference on Wireless and Optical Technologies (GCWOT), Malaga, Spain, 2020, pp. 1-5, doi: 10.1109/GCWOT49901.2020.9391618.

UNIVERSIDAD DE MÁLAGA

This page intentionally left blank

UNIVERSIDAD
DE MÁLAGA

Chapter 2: State-of-the-Art

2. Introduction

The most important purpose of this chapter is to study the most innovative techniques to artificial intelligence that are now accessible to the public. To be more specific, the chapter will focus only on deep learning and machine learning for the whole of its discussion. It is of the important factor that the many pieces of medical equipment, when used in combination with one another, become more accurate and dependable in terms of diagnosis. This is because the healthcare industry has been continuing to expand and thrive in recent years.

Over the course of the last several years, several convolutional neural networks (CNNs) have been offered as potential solutions to the difficult problems that are associated with picture identification. The study that is presented in this dissertation demonstrates that the use of sophisticated CNN design, such as EfficientNetB7 is effective in the categorization of Chest X-rays. This is especially true for the publications written on the subject. Because these models have shown that they have the potential to improve the accuracy of diagnosis, it is essential to pick the proper design based on the imaging modalities and clinical goals that are being pursued for better treatment and patient needs in medical space.

In this section, we will present a detailed overview of the previous findings, with a particular focus on the formations that are important for the use of artificial intelligence in medical imaging domain. Analyzing significant studies and different happenings may be of use in demonstrating the differences in the study that is now being implemented. The different circumstances that will be necessary for improvements in the thesis will be provided. The research provided with innovative ideas that will explain our conclusions later.

UNIVERSIDAD DE MÁLAGA

2.1 Overall Literature Review

Because of recent progress in artificial intelligence (AI) and machine learning (ML), day by day more and more people in the healthcare field are interested in the diverse ways that these technologies can be used. More people are interested in these tools now that they are better, which has made this wish grow. People are more interested in these kinds of changes, which have made them want more. All this attention is due to the big steps forward that have been made in these technologies, especially in the last few months. There would be no interest in this without these changes. Several studies have shown that artificial intelligence can make tests more accurate and help people get better care when they are used. This tech must be used for this change to take place. It is now possible to show that this promise might come true in the future thanks to AI. AI can be used to help people quickly in medical situations. The SOS app for Android, which is also called Help Pro, is a fitting example of this. Help Pro is an example because it works well. One great way is that AI can be implemented more efficiently in this tool. It's easy to see how artificial intelligence works in this program, which also does a great job of explaining how it works. You can really see how artificial intelligence (AI) works with this tool. This software always lets people know where they are and quickly share that information with people who can help them in an emergency. This way, they can get out of dangerous situations faster, which could save their lives. Table 2.1 is a summary of the overall literature review and details of the objective, methods, dataset information, accuracy, and limitations by the researchers.

Reference	Objective	Methods	Dataset Information	Accuracy	Limitations
[2] 2023	Brain tumor segmentation and classification	Neural Architecture Search (NAS), Transformer CNN	Public dataset (BraTS 2020)	87% for segmentation, 92% for classification	Limited testing, high computational cost
[3] 2023	Brain tumor segmentation and classification	Hybrid deep CNN, LuNet Classifier	BraTS 2018 dataset	Segmentation 91.2%, classification 93.5%	Demands high computational resources
[4] 2023	Brain tumor segmentation and classification	Deep hybrid representation learning	Public MRI dataset	Segmentation 92.8%, classification 94.1%	Demands optimization for real-time use
[5] 2021	Comparative analysis	Various CNN architectures	Private dataset (200 images)	95% accuracy	Restricted sample size
[6] 2022	Segmentation using DeepMRSeg for brain tumor classification	DeepMRSeg, Generative Adversarial Network (GAN)	Private dataset (150 images)	Segmentation 94%	Limited diversity in the dataset
[7] 2022	Unsupervised anomaly detection and segmentation in brain imaging	Transformers, Unsupervised Learning	Public dataset (ABIDE)	85% accuracy in anomaly detection	Requires extensive computational resources
[8] 2020	Automatic brain tumor classification	Transfer Learning, CNN-based framework	Private dataset (300 images)	Classification 96%	Limited dataset variety

UNIVERSIDAD DE MÁLAGA

Reference	Objective	Methods	Dataset Information	Accuracy	Limitations
[9] 2021	Brain tumor detection and multi-classification	Advanced deep learning methods	Public MRI dataset	93% in detection and classification	Restrained interpretability
[10] 2016	Automatic brain tumor segmentation and extraction in MR images	Image processing techniques	Private dataset (100 images)	Desired metrics not provided	Limited dataset size
[11] 2023	Brain tumor segmentation	Cascaded multiscale multitask learning	Private dataset (200 images)	Segmentation 95%	Needs further validation
[12] 2022	Differentiation of glioblastoma and brain metastases	Diagnostic differentiation	Clinical samples from patients	Differentiation 85%	Population diversity
[13] 2018	Glioma grading	Deep Learning, Transfer Learning	Conventional MR images	90% in glioma grading	May require further validation on larger datasets
[14] 2023	Malignant brain tumors classification	Classification pipeline	MRI dataset	Classification 94%	Institutional variability
[15] 2023	Brain tumor segmentation	Deep learning	MRI dataset (public)	Segmentation 93%	Different edge detection methods
[16] 2019	Multi-classification of brain tumor images	Deep Neural Network (DNN)	Public dataset	90.3% for multi-class classification	Model may not generalize well across all types
[17] 2020	Detection and classification of brain tumors	Deep learning techniques, image processing	Private dataset)	Classification 91.5%	Validation needed
[18] 2019	Localization and classification of brain tumors	Machine Learning, Deep Learning	Public dataset (150 images)	92% in tumor classification	May require validation on larger datasets
[19] 2018	Comparison of accuracy in brain tumor detection	Comparative study of diagnostic modalities	Clinical imaging data	Found MRI to be the most accurate	Inadequate sample size
[20] 2015	Brain tumor detection	Literature review of various image processing methods	N/A	Summarized various image processing techniques	Restricted focus on recent advancements
[21] 2017	Brain tumor detection and classification	Distinctive pattern recognition methods	Private dataset (150 images)	Classification 90.5%	Limited dataset size
[22] 2013	Detection and segmentation of brain tumors	Multifractal texture analysis	Public MRI dataset	Classification 92%	Requires extensive validation

UNIVERSIDAD DE MÁLAGA

Reference	Objective	Methods	Dataset Information	Accuracy	Limitations
[23] 2019	Brain Tumor detection and classification	Support Vector Machines (SVM)	Specific dataset not stated	Specific accuracy not provided	May require validation
[24] 2020	Brain tumor classification	Modified Local Binary Patterns	No Specific dataset	Classification 88%	Limited dataset diversity
[25] 2017	MRI brain tumor classification	Feature extraction	Specific dataset not stated	Classification 88%	Requires validation
[26] 2014	Performance analysis of brain tumor	K-Means, Fuzzy C-Means	MRI images (specifics not stated)	Fuzzy C-Means attained better accuracy	Limited dataset details
[27] 2019	Brain tumor detection and classification	Multilevel feature selection	MRI dataset (specific dataset not stated)	91% in tumor detection and classification	Limited to specific datasets
[28] 2022	Classification of Gliomas and Germinomas	Transfer Learning (TL)	Public dataset (specifics not stated)	92% classification in gliomas and germinomas	Limited generalizability to other tumor types
[29] 2015	To develop an Android app so that users find the nearest hospital	User testing	Data collected from GPS and hospital databases	Not provided	Limited regions
[30] 2011	To investigate Android operating system and its APIs.	Literature review and theoretical analysis	Not provided	Not assessable	Not provided
[31] 2017	Analyze the factors that affect teams in software development	Qualitative analysis	Different data surveyed	Subjective	Limited
[32] 2018	To create a smart system that provides real time location	Real-time tracking	User testing	High accuracy in pretend environments	Vary with different devices.
[33] 2020	An ambulance booking app	Application development and user feedback	Data from user interactions	Success differs by region	Requires internet reliable connectivity
[34] 2023	Overview of the COVID-19 pandemic	Review of pandemic response strategies	Data took from global COVID-19 case reports	Accuracy vary by region	Publicly available data
[35] 2020	To summarize the various modern technologies in reducing the pandemic	Review of existing literature	Includes studies and reports used in response to COVID-19	Findings may varied by regions	Limited to reviewed only
[36]	To develop a mechanism for				

UNIVERSIDAD DE MÁLAGA

Reference	Objective	Methods	Dataset Information	Accuracy	Limitations
2022	COVID-19 detection through chest X-ray images	Advanced feature extraction from chest X-ray images	Comprises of chest X-ray images	Varied on the dataset used and the model pattern	Limited by the size of the dataset
[37] 2020	To investigate the structure, and antigenicity of the SARS-CoV-2	Structural analysis using cryo-electron microscopy	Experimental data on the SARS-CoV-2 spike protein structure	Not diagnosed	Limited generalizability across SARS-CoV-2
[38] 2020	To utilize a deep learning approach for the detection of COVID-19	Uses deep learning techniques such as CNNs to extract features and classify COVID-19 from X-ray images	Public databases for COVID-19, pneumonia, and normal cases	Above 90% for COVID-19 detection	Limited to the quality and quantity of available data
[39] 2020	To investigate in screening for viral and COVID-19 pneumonia using chest X-ray images	Machine learning algorithms, including CNNs for pneumonia detection	The dataset includes a range of chest X-ray images from publicly available repositories	95% in distinguishing between different pneumonia types	May be influenced by the variability in image quality
[40] 2020	To identify COVID-19 samples from chest X-ray images using various	The study compares different transfer learning models	The dataset consists of chest X-ray images traced from publicly databases	Above 90%	Limited by the size and variety of the dataset
[41] 2020	To develop a deep learning model for identifying COVID-19 from chest CT-scan images	Analyze CT-scan images for COVID-19 diagnosis using transfer learning techniques	The dataset includes chest CT-scan COVID-19 images from public databases.	Around 95%	May vary based on the quality and size of the dataset
[42] 2020	To develop a classifier for recognizing COVID-19 from chest X-ray images	Used COVELM classifier	Dataset includes chest X-ray images from public sources	Around 91% for COVID-19 classification	Limited by dataset variability and size
[43] 2021	To develop an AI-based system for diagnosis of respiratory illnesses with COVID-19	Used an end-to-end AI-based classification system	Utilized respiratory illness datasets	Percentages not specified	Limited accessibility to varied patient datasets
[44] 2020	To classify COVID-19 cases using chest CT images	Employed an adaptive feature selection method	Used chest CT datasets for (details are not mentioned)	Achieved high accuracy, although exact accuracy not specified	May face limitations due to the need for extensive and labeled CT data

UNIVERSIDAD DE MÁLAGA

Reference	Objective	Methods	Dataset Information	Accuracy	Limitations
[45] 2021	To develop an automatic COVID-19 detection system using X-ray images	Implemented an ensemble learning approach	Utilized publicly available X-ray datasets	Approximately 96%	Limitations on dataset quality
[46] 2017	To develop a deep learning model for pneumonia detection in chest X-rays	Used a 121-layer DenseNet architecture	Utilized the ChestX-ray14 dataset	Approximately 92.8% for pneumonia detection	Limitations include potential biases in the dataset

Table 2.1 Summary of Overall Literature Review.

In these kinds of situations, people might be at risk of dying. This means that people can move faster when things happen that could put their lives in danger. The reason for this is that they can act more quickly. As an edge of benefit, this tool can react quickly to calls for emergency help while also helping people who need it. By including machine learning methods to the program, the software could look at data about its users and figure out what kinds of health problems those users are most likely to have. With the help of machine learning systems, this was possible. This capability was previously unavailable. Given these circumstances, the application is much more successful than it would have been under any other set of dependencies and requirements with the needs.

Radiologists may stand to receive from models that are powered by artificial intelligence and that evaluate picture data to assist in the diagnosis and classification of diseases, at least according to the results of research that has been undertaken around medical imaging. This study has been concluded to further do research in the field of medical imaging. The possibility that some aspects of the testing procedure may be automated with the assistance of these models would be advantageous to individuals who are now working in the healthcare industry. The prospect would be beneficial to these people. The individuals that fall into this category would be able to get advantages from this condition. It would be a direct consequence of this that assessments would be carried out in a way that is not only more accurate but also timelier than it would have been otherwise a delay may occur, and the desired operation cannot be carried out with the situation.

2.2 System Level Review

When it comes to the realm of healthcare, the single most important thing that can be done is to integrate apps that are driven by artificial intelligence into the system that regulates everything. This is because the utilization of medication in therapeutic settings is getting more perplexing to realize. To offer you a more complete explanation, this is because it is of the highest necessity to make the most of the opportunities that these programs provide and to ensure that they are used to the maximum extent of their potential. This is the reason why this is the case. The SOS app can offer first responders with the most accurate and up-to-date information possible with the help of its partnerships with hospitals in the surrounding region. This makes it feasible for the app to deliver this information. The fact that the two parties are working combinedly to achieve their goals is what makes all this feasible. Furthermore, this is

UNIVERSIDAD DE MÁLAGA

now conceivable because of the joint efforts that were made by the two parties in the past. This was impossible before. As a result of the collaboration between the two parties, this effort has been able to become a decision that is feasible.

It is a very important step that must be taken to ensure that resources are utilized in the most efficient way possible and to minimize the amount of time that is needed to respond to several different kinds of situations. Consolidating systems in this manner is a highly crucial step that needs to be undertaken. The accomplishment of both goals is of the highest importance and should be made a priority. It is of the utmost importance that these two goals be accomplished as rapidly as is practically possible as per the requirements and needs of them.

It is also not completely out of the question that technologies that are driven by artificial intelligence would be able to support medical practitioners in getting a more in-depth coping of how to assess medical imagery. Nevertheless, despite this, it is not completely out of the question for this to take place. One of the most important benefits of this idea is that it would considerably lessen the amount of time required for learning.

The total would drop by a substantial amount under these circumstances. It is anticipated that the amounts in concern will see a substantial decrease. Introducing artificial intelligence into the delivery of healthcare services has the potential to improve operational efficiency, which would be beneficial to patients. Taking this into consideration, there is a chance that it will occur. One of the most important steps is to consider the likelihood that this may occur. That every person has their unique idea is something that needs to be thought about.

It's important to do this. For example, if something like this happened, hospital staff would be able to spend their time helping patients more instead of doing pointless paperwork. In the same way, if they were able to reach this goal, it would make it easier for them to help other people. If they keep going in this direction, they will be able to meet people's goals by giving them the best medical care that is open to everyone. Table 2.2 is a summary of the undertaking review. The details include hardware and software requirements and a summary of the designed prototypes and products.

References	Hardware/Software	Summary
[29] 2015	Android Application	The research shows an Android application designed to assist patients in positioning the nearest specialized hospitals
[30] 2011	Android System	Discusses the development environment, tools, and frameworks available for Android app development
[31] 2017	Agile Software Development Tools	This study investigates the factors that inspire and demoralize teams in agile software development
[32] 2018	Android Smartphone, GPS, and Mobile Application	Presents a smart rescue system that utilizes Android smartphones for accident detection and real time location tracking.
[33] 2020	Mobile Application, Database Management System	Application facilitates quick ambulance bookings and includes a blood inventory management
[34] 2023	Not available / resource only	Provides comprehensive information on the COVID-19 pandemic including symptoms, transmission, prevention and impact on global health

UNIVERSIDAD DE MÁLAGA

References	Hardware/Software	Summary
[35] 2020	AI, IoT	Highlights the role of artificial intelligence, Internet of Things, and telemedicine in diagnosing, and managing COVID-19 cases
[36] 2022	Deep learning model application	Presents a novel approach for detecting COVID-19 from chest X-ray images using a deep learning model
[37] 2020	Structural analysis software	The findings provide potential therapeutic targets and vaccine development strategies against COVID-19.
[38] 2020	Deep learning frameworks, Convolutional neural networks	Research shows a method for detecting COVID-19 using deep learning methods
[39] 2020	AI frameworks, Machine learning algorithms, CNN models	Authors discussed various machine learning models and their effectiveness in evaluating chest X-ray and CT images
[40] 2020	GPUs for model training, Deep learning frameworks	The authors evaluate the performance of different architectures and highlight the transfer learning for COVID-19 detection
[41] 2020	GPUs for training models, Deep learning libraries	The authors utilize convolutional neural networks (CNNs) to classify CT images in detecting COVID-19
[47] 2017	Dataset available on Figshare	A dataset encompassing images of brain tumors for research purposes
[48] 2010	Fuzzy segmentation methods, MATLAB	Aims a novel fuzzy method for segmenting brain tumors
[49] 2018	K-Means and Fuzzy C-Means algorithms, MATLAB	Presents a segmentation technique combining K-Means and Fuzzy C-Means for MRI brain images
[50] 2017	Automatic segmentation techniques, MATLAB	Examines an automatic segmentation method employing local square features for brain tumors.
[51] 2018	Superpixel generation methods, FCM clustering algorithms, MATLAB	Explores glioma identification through superpixel techniques on brain MRI.
[52] 2018	Multiscale two-pathway-group CNNs, MATLAB	Presents a method for brain tumor segmentation for improved efficiency
[53] 2020	3D MRI segmentation	Proposes robust semantic segmentation of brain tumor
[54] 2021	Deep learning networks, semantic segmentation, 3D imaging tools	Focuses on brain tumor prediction
[55] 2022	Cascade multiscale residual attention CNNs, adaptive ROI methods, Python	Introduces a CNN-based approach
[56]	Fuzzy Otsu Threshold, MATLAB	Presents a segmentation technique
[57] 2011	Expert Systems software	Proposes a hybrid method for MRI brain image classification
[58] 2015	Wavelet-energy and biogeography-based optimization, MATLAB	Presents an automated classification technique for brain images
[59] 2017	MATLAB	The research proposes a decision support system (DSS) based on computer-aided diagnosis (CAD) for brain tumor classification
[60] 2013	MATLAB, SVM (Support Vector Machine), and k-NN (k-Nearest Neighbor)	Segmentation and classification from MRI images, using feature extraction and classification with SVM and k-NN algorithms
[61] 2014	MATLAB, Kernel-SVM	The paper focuses on brain tumor severity analysis using MRI images

UNIVERSIDAD DE MÁLAGA

References	Hardware/Software	Summary
[62] 2010	MATLAB, PCA (Principal Component Analysis), k-NN, ANN (Artificial Neural Network)	The research presents a hybrid classification model combining for MRI brain image classification.
[63] 2020	Hybrid image enhancement, CNN (Convolutional Neural Network)	The study develops a hybrid image enhancement approach to improve MRI brain image classification using CNN-based methods
[64] 2021	CNN (Convolutional Neural Network), Ensemble Learning, SVM, RF (Random Forest)	This study proposes an ensemble method that combines deep features from CNN models for MRI-based brain tumor classification.
[65] 2021	Multiscale Convolutional Neural Network (CNN)	The study explores brain tumor classification and segmentation using deep learning methods
[66] 2020	MATLAB, Python, Keras	The paper presents a convolutional neural network (CNN) for classifying brain tumors
[67] 2020	Python, TensorFlow, Keras	This research utilizes a convolutional neural network (CNN) to classify brain tumors
[68] 2021	TensorFlow, Python, Keras	Conducts a comparative analysis of deep CNN architectures for glioma classification
[69] 2021	TensorFlow, Keras	The paper presents a transfer learning and active learning framework for classifying brain tumors from MRI images
[70] 2021	TensorFlow, Keras, Python	This study proposes a high-precision brain tumor classification model using deep transfer learning
[71] 2022	Python, TensorFlow, Keras	This study develops an AI model for tumor grading and classification from MRI sequences of human brain gliomas
[72] 2022	CNN (Convolutional Neural Network), Bayesian Optimization	Proposes a novel classification method using CNNs enhanced by Bayesian optimization
[73] 2022	TensorFlow, Python	Introduces a deep learning framework for brain tumor classification using MRI
[74] 2022	MATLAB, Python, TensorFlow	Proposes a Gaussian CNN for brain tumor and glioma grade classification
[75] 2021	Separable CNN (Convolutional Neural Network), Python	Implements a separable CNN for three-class brain tumor classification from MRI images
[76] 2020	Python, TensorFlow, Keras	Employs deep convolutional networks with transfer learning to automate brain image classification

Table 2.2 Summary of literature with a focus on the technology employed.

2.3 Dataset Review

How positively artificial intelligence models work is strongly connected to the type of data set implemented and utilized. It's a big question, so this link is very important. The way the lesson was taught had to be followed for this result to happen. In addition, there is a link between this factor and how well the models do their work. Very big datasets, like pictures from MRI and CT scans, are used how to identify brain cancers. These datasets help make very smart

UNIVERSIDAD DE MÁLAGA

convolutional neural networks (CNN's). This is done to help with the way the information is handled.

Brain tumors are grouped by several different sources. This piece makes a case for different ways to group brain cancers. These steps are being taken to make it easy to make CNN's in the long run for the correct diagnosis, research, and the desired specifications and calculations and readings to take the prescribed treatment and the measuring parameters for the fruitful and meaningful outcomes which could be a beneficial step for upcoming future requirements and needs of different sort of kind of patients and the perspective operations to be carried out under different supervisions. Table 2.3 is a summary of the different brain tumors and Chest X-ray datasets reviewed.

References	Dataset	Dataset Size
[47]	Figshare Brain Tumor Dataset	3,066 images
[59]	Private MRI dataset	256
[60]	Public MRI dataset	300
[61]	Local MRI dataset	120
[62]	BRATS Dataset	210
[51]	Glioma MRI dataset	180
[52]	Multi-modal MRI dataset	400
[53]	Brain lesion BRATS	285
[54]	Multi-source MRI dataset	350
[55]	BRATS Dataset	390
[56]	Synthetic MRI dataset	450
[57]	Clinical MRI dataset	230
[58]	Local MRI dataset	320
[16]	MRI brain tumor dataset	3064 images
[18]	Brain tumor dataset	3000 images
[26]	Brain Tumor Dataset from public sources	100 images (each type)
[27]	Brain MRI Images	75 images
[28]	Glioma Dataset	100 images
[49]	MRI Brain Images	150 images
[50]	Brain MRI Dataset	80 images
[3]	BraTS 2020	369 scans
[8]	Brain MRI Dataset	2,540 images
[9]	Brain MRI Dataset	3060 images
[39]	Chest X-ray images	Not available
[40]	Chest X-ray images	Not available
[43]	Chest X-ray and other respiratory images	Not available
[45]	X-ray images for COVID-19 detection	Not available
[46]	Chest X-ray images	112,120 images

Table 2.3 Summary of brain tumor, Chest X-ray datasets reviewed.

New research finds out that implementing many datasets may facilitate the model technique to work better and find more types of cancer. This was one of the things that the research carried out. When images from computed tomography (CT) and magnetic resonance imaging (MRI) are looked at together, the model can more accurately tell the difference between the different features of tumors, which leads to more accurate demonstrations and distinguishes.

Even more specifically, the model's ability to tell the difference between different traits is shown to make this point stand out for the specifications and readings as per requirements and needs. There are a lot of big problems that need to be solved before it's possible to build artificial intelligence models that work. Every single one of these problems needs to be solved.

UNIVERSIDAD DE MÁLAGA

Two of the biggest problems that are being faced right now are the lack of data and the need for datasets that have been properly labeled. These two problems have something to do with what's going on now. If companies in healthcare work combinedly make bigger datasets with better annotations that can be used to teach AI systems, and these datasets may help doctors to make more accurate predictions, measurements and procedures for further proceedings.

This is possible if the data in these files is made up. People who work in the medical field might find these statistics useful, so people who work in the medical field might be interested in them. If something similar were to happen, it would be a lucky turn of events given the conditions according to the needs and the environment of the situation for the desired person.

2.4 Machine Learning Algorithm Review

In the medical diagnosis domain, it is now much capable to sort pictures into groups thanks to convolutional neural networks (CNN's) and other machine learning techniques. The reason for this is that it is now much easier to put pictures into groups. This result was directly caused by using these methods. Your study aims to demonstrate the creation of a unique convolutional neural network (CNN) model for the classification of brain tumors.

To do this, the building of the CNN model will be shown. By finding up new ways to boost speed, the model was processed successfully. Previous studies that have been done in this area are what this model is based on [25,26,27]. There has been a lot of talk lately about how adding attention processes and transfer learning to CNN systems might make recognition much more accurate [28]. This subject has been brought up because of a study that was done as recently as possible.

The idea in question has gotten a lot of attention over the last few years because it is so important for future needs and requirements. More research suggests that the integration method might be feasible to produce better manageable results than more common methods. This is because CT and MRI scans are used in technology as part of CNN. This is the case because the combination method uses both numeric and verbal data. This is because the combination method uses information from both CT and MRI scans. Here's the reason why this is possible. This is what happened because the process uses both types of information. Staff in the medical field might benefit from having access to a lot of different image data [29] because it would make it easier for them to see how complicated the pictures are. This is because it would be easier for them to get the information. They would be able to give more accurate findings because of this than they would have been able to give in any other situation for the specific environment and needs of an operation to be carried out for desired calculations.

2.5 Related Work Conclusions and Research Gap

AI and machine learning are still being widely used in healthcare, especially in emergency response and medical imaging. This is a very active area of study that has big effects on how patients are cared for. A lot of progress has been made, but there are still problems with getting data, figuring out how to use algorithms, and putting AI solutions into professional processes. Our manuscript addresses these problems by applying standard CNN models to improve the accuracy of diagnoses and to illustrate how decisions are derived from the results and calculations.

To ensure that artificial intelligence models are useful for therapeutic purposes in situations

UNIVERSIDAD DE MÁLAGA

that occur in the real world, it is recommended that future research concentrate on expanding the datasets that are used for training and validation, studying multi-modal approaches, and making sure that these techniques are utilized. This will confirm that the models are beneficial for therapeutic purposes. To achieve progress in the use of artificial intelligence in healthcare, which will ultimately result in better results for patients and more efficient healthcare systems, it will be vital to discover answers to these gaps. This will allow for the advancement of artificial intelligence in the healthcare industry. Additionally, because of this, it will be feasible to make progress.

2.6 Discussion

An Android-based solution to aid users in emergencies via location-based monitoring and communication is presented in the first publication, "SOS Application Under Android: Help Pro," which focuses on a major obligation within emergency response applications. There is a deep talk about health solutions in this literature, but many apps do not have user centered design or run time support capacities so they're not very helpful in crisis or in emergencies. This study improves the usability and efficacy of health solutions by creating and evaluating a solution that carries easy access and quick response. This is especially useful in situations when conventional communication could not be possible. This contribution fills a critical need by using mobile technology to implement the treatments that could save lives.

The need for effective, and real-time diagnostic tools in transferable disease management, with a focus on COVID-19, is addressed in the third publication X-Ray Image-Based Real-Time COVID-19 Diagnosis Using Deep Neural Networks (CXR-DNN). Previous research has shown that deep learning may be valuable for X-ray image-based diagnostics in a pandemic happening, but major obstacles include scalability and real time application. This research proposed the CXR-DNN model, which not only combines the practical deployment concerns with high accuracy diagnostic capabilities but also tackles the issues of speed, precision and recall which is very crucial in high demand medical situations.

To summarize, the technology in the following crucial areas is being advanced by these manuscripts: medical diagnostics for brain tumors, quick screening of infectious illnesses, and emergency response. Focusing on real time applications, model accuracy, and practical deployment, each of the study meets important gaps in literature and places the base for future progress by addressing boundaries in current research. They work in cycle to further the main objective of refining healthcare and emergency response times by using mobile technology and artificial intelligence to make services more accessible, and to increase analytical accuracy with decrease the waiting times.

2.7 Conclusion

This section focuses the COVID-19 tracking and emergency response system developments. The research study also shows how artificial intelligence, smart technology, and deep learning techniques are utilized for resolving healthcare concerns by highlighting their advantages and disadvantages.

The first study, SOS Application Under Android: Help Pro, covers a novel Android emergency response tool. This study fills a research gap by studying rapid, reliable, and easy-to-use emergency options essential for urgent communication. Real-time location-based support improves mobile health and emergency contact.

UNIVERSIDAD DE MÁLAGA

The second research study i.e. X-Ray Image-Based Real-Time COVID-19 Diagnosis consuming Deep Neural Networks (CXR-DNN), implements the pandemic with fast and accurate acquiring procedures. Real-time detection is essential to stopping dangerous diseases; thus, we prioritize distribution speed and accuracy. CXR-DNN works well on chest X-rays, making it a good choice for rapid, scalable healthcare testing. This enhances infectious disease control research.

These volumes fill gaps in neurological diagnosis, emergency medicine, and infectious disease screening using novel methodologies. This chapter showed how smartphones and AI are solving major healthcare challenges. It also laid the groundwork for the chapters' methodologies and research topics. These papers cover innovative ideas and practical implementations that simplify, improve, and speed up healthcare solutions.

UNIVERSIDAD DE MÁLAGA

This page intentionally left blank

UNIVERSIDAD
DE MÁLAGA

Chapter 3: Comprehensive Overview of the SOS Application: Help Pro

3. Introduction

Chapter 3 covers the analysis and detailed breakdown of the system design and architecture of the SOS (Save Our Souls) Help Pro application. This chapter begins by laying out the fundamental framework of the system describing how the application's various modules are interconnected to deliver essential emergency services to the customers. The architecture is designed on the core components including user, driver, and admin modules that how they collaborate to ensure quick response and seamless user experience. The design approach focuses on the integration of run time tracking and emergency features highlighting the use of Google Maps API and the Dijkstra algorithm for route specification for further proceedings.

After reading the chapter one may be able to have a general understanding of the development process. This strategy considers the decisions that are essential to the functioning of these underlying technologies, which include Android Studio, Java, and Firebase, among others. In this chapter, we will explore the functional components of the application; the incorporation of these technologies will contribute to an enhanced experience for the user. The design of the user interface is intended to study the method in which the user features and the architecture of the system work together to provide the functionality that is explicitly needed for the project. The design aims to reach this ideal and so the maximum degree of application expertise is the objective. The design is done with the intention of reaching that goal with efficiency.

The final part covers the subjects of testing and assessing system performance. Completing this portion guarantees that every feature fits the basic operational criteria and offers a pleasing response to the expectations of the users and the aim of this part is thus ensured. Because of the implementation of this approach the Help Pro application is now positioned as an essential

UNIVERSIDAD DE MÁLAGA

instrument that has the capacity to cut down on the amount of time it takes to react to an emergency and to save lives in the event of a catastrophe.

3.1 System Design and Architecture

This section outlines the essential components and the technologies involved in the design, focusing on the layers and frameworks that enable the application to provide its critical emergency response services efficiently.

3.1.1 Overview of the Technological Framework

Client side and server side technologies are combined in architecture. This hybrid paradigm guarantees that front end interactions and back-end procedures interact efficiently to provide quick answers and fast updates. Technology choices facilitate Android based deployment and make use of cloud computing for data storage and administration.

3.1.2 Android Operating System

The Android operating system forms the foundation of the Help Pro program. Built on the Linux kernel, Android is an open-source platform very flexible for mobile and other smart devices. Its open-source character allows developers to access its source code, thereby encouraging great customization while also ensuring confirmation to use guidelines that avoid financial concern.

3.1.3 Development Environment - Android Studio

The main Integrated Development Environment (IDE) for Android apps, the Android Studio supports the application development. Designed for creating, debugging, and effectively assessing the application, Android Studio offers a range of development tools rapid prototyping and flawless execution are made possible in great part by key elements such code auto-completion, built-in emulators, and real-time code analysis. The great support for Java and its capacity to replicate real or virtual devices throughout the development process drove the choice of this environment.

3.1.4 Programming Language - Java

Developing the application mostly used Java as the backend programming language. Development of modular, manageable, and scalable code finds perfect fit in Java's object-oriented programming (OOP) framework. The large libraries and platform independence of the language help to facilitate strong application development, therefore enabling the Help Pro app to keep excellent speed and simplicity of use.

3.1.5 Database and Backend Services - Firebase

Data management made use of Google's complete Firebase platform. This cloud-based service offers a NoSQL real-time database in JavaScript Object Notation (JSON) format assuring data retrieval, changes, and synchronization occur in real-time without complicated query needs. Firebase is also a necessary component of the design of the application as it provides image

UNIVERSIDAD DE MÁLAGA

storage, user authentication, and cloud messaging, therefore improving user experience and dependability of data processing.

3.1.6 Location Services - Google Map API

The Google Map API was integrated into the system to facilitate the run time location tracking and navigation.

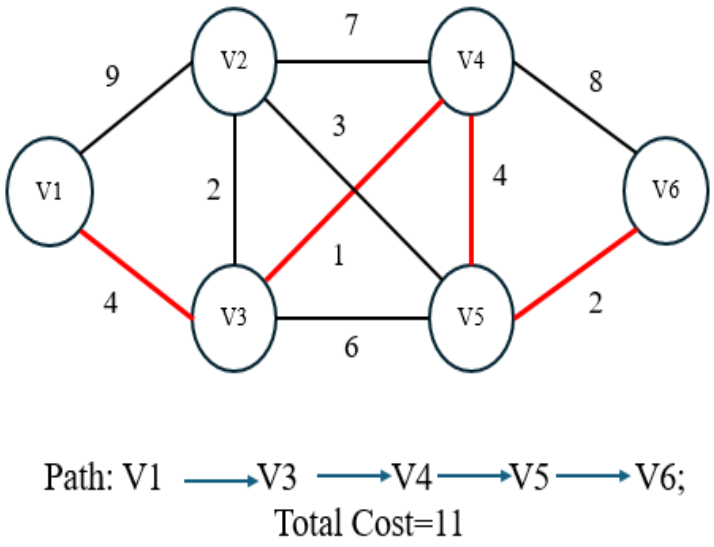


Figure 3.1 The Dijkstra Algorithm Concept

The API provides necessary mapping services enabling the Help Pro application to determine the user's real-time point to identify nearby ambulances and calculate optimal routes using algorithms like Dijkstra's for shortest path computation. The basic concept of Dijkstra algorithm has been presented in figure 3.1. The method of algorithm is basically that it repeatedly chooses the node with the lowest known distance and updates the route costs to its neighbors and continues until all nodes have been visited or the shortest path to the destination node is discovered. Commonly used in GPS navigation systems, network routing, and many optimization challenges. The integration of this API ensures that emergency services can rapidly locate and respond to the users.

3.1.7 Web Framework - Laravel

Laravel was used as the PHP-based web application framework. Clear code structure and improved development process are made possible by Laravel's MVC (Model View Controller; presented in figure 3.2) design, which also offers assembled capabilities for routing, database migrations, and security.

UNIVERSIDAD DE MÁLAGA

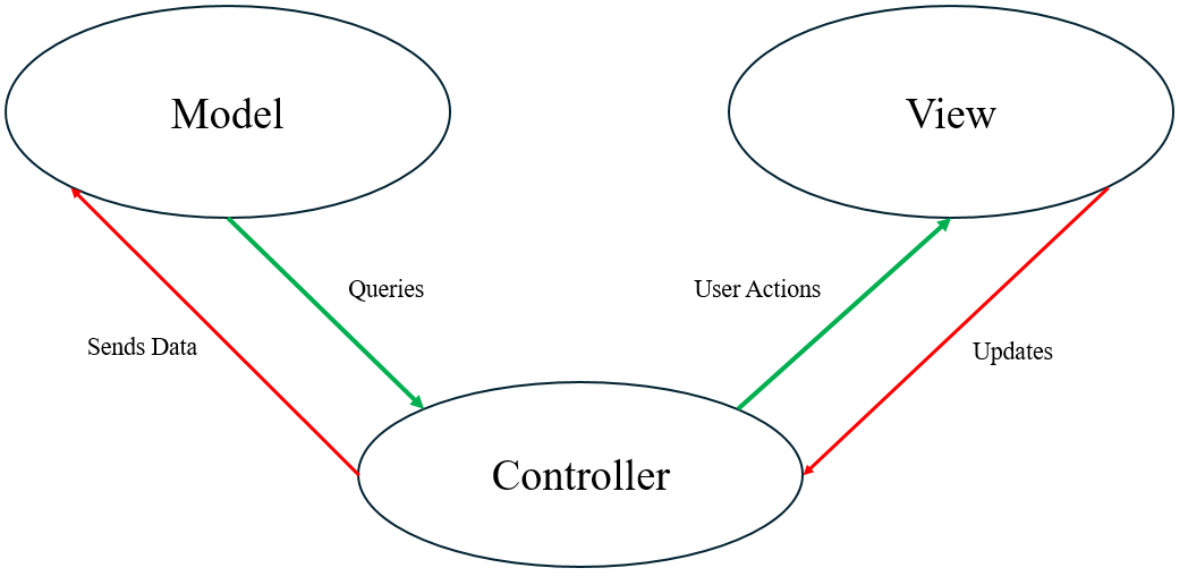


Figure 3.2 Laravel Implementation

Its dependability and stability for underlying components which rely on the Symfony framework help to make the application a perfect fit for managing challenging web-based capabilities.

3.1.8 Summary of the System's Technological Integration

Android OS, Android Studio, Java, Firebase, Google Map API, and Laravel taken together provide a full technological stack. This stack is designed to fulfill the need to provide quick assistance in case of an emergency. Every component offers a unique contribution so that the program may offer accurate, and user-friendly emergency response services supplied in real time. The orderly integration of the many components of the system finally helps to increase the general capacity of the application for efficiency and dependability by guaranteeing fluid communication among them.

3.2 Methodology for Development

The primary objective was to design and implement a mobile solution using smartphone capabilities to provide fast assistance during critical incidents. Emphasizing user safety and rapid responsiveness, this featured a rigorous approach to assure real-time data flow and safe interaction between users and drivers for smooth safe running of the desired application.

3.2.1 Conceptualization and Requirement Analysis

The first steps included realizing the difficulties experienced during crises, especially in cases when access to fast medical and emergency assistance is very vital. The initiative sought to provide a simplified approach for asking and getting aid to overcome delays that can lead to life-threatening circumstances and the situations for necessary actions to be taken immediately.

UNIVERSIDAD DE MÁLAGA

3.2.2 System Design Framework

Development of a user-oriented design guarantees that Help Pro will provide easy navigation and an understandable interface. Three separate modules like User, Driver, and Admin were planned into the design of the program. Every module was designed to serve certain purposes, therefore improving the general system efficiency and functioning. Using safe protocols to preserve data privacy and enable suitable access, the design included location tracking and real time data processing.

3.2.3 Technology Integration

The development reached its goals by using many innovative technologies. With its real-time database management, user authentication, and cloud services along with strong backend support of Firebase platform Integration of Google Maps APIs for location services and navigation let drivers track the fastest path to the user and guarantee timely arrival. The background communication among the modules was strengthened to stop illegal access, therefore guaranteeing that only confirmed staff may interact with the system for proceedings.

3.2.4 User-Centric Enhancements

Beyond its basic use, Help Pro was meant to be flexible and helpful for different crises such security events or fire breakouts. Beyond medical crises, the technology enabled one-tap calls to pertinent emergency services, therefore supporting its value. This adaptability makes the program a consistent instrument for all-encompassing emergency help.

3.2.5 Implementation and Testing

The program was developed and polished using an iterative process. There were integrated regular testing stages to guarantee functioning, solve any problems and improve speed. Features were changed in response to user comments to guarantee the software sufficiently matched the demands of its target market and increased usability.

3.3 User Interface Design

First developed with the user experience first, the Help Pro application ensures a perfect and simple interface throughout its three main modules: User, Driver, and Admin. The design approach focuses reliability, simplicity, and accessibility to assist customers in emergency conditions that require quick and efficient access to services and desired operational facilities.

3.3.1 User Module Design

Help Pro's user module consists of four main features: one-click emergency services, local hospital locating tools, blood requesting possibilities, mechanical aid access. Users provide their contact details at first registration, confirmed using Firebase Phone Authentication, therefore guaranteeing security via a one-time password (OTP) method. Users provide personal information like name, date of birth, blood type, city, gender, and a profile picture after verification. Users must also register two emergency contacts (ICE numbers or Case of Emergency numbers) therefore providing a consistent point of contact in case of an emergency.

UNIVERSIDAD DE MÁLAGA

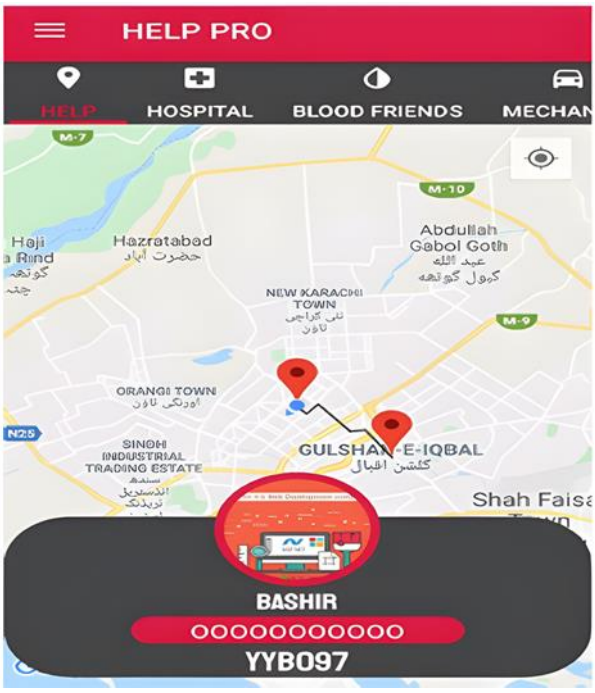


Figure 3.3 User help screen with driver's details and location [77]

The UI is set up for simple navigation mostly. With a simple touch, users may create an emergency request that sets off a five second countdown to verify intention and prevents inadvertent usage. Once confirmed, notifications including user location that are sent to the closest drivers and ICE contacts. A glance has been shown in figure 3.3. Real time position monitoring for the user and the ambulance made possible by the integration of Google Maps and navigation APIs helps to guarantee accurate and quick reactions.

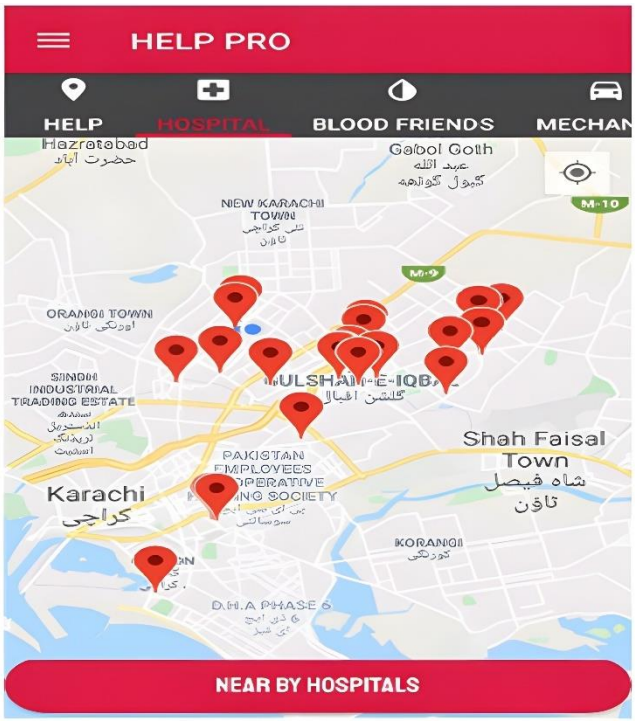


Figure 3.4 Nearby Hospital Screen [77]

UNIVERSIDAD DE MÁLAGA

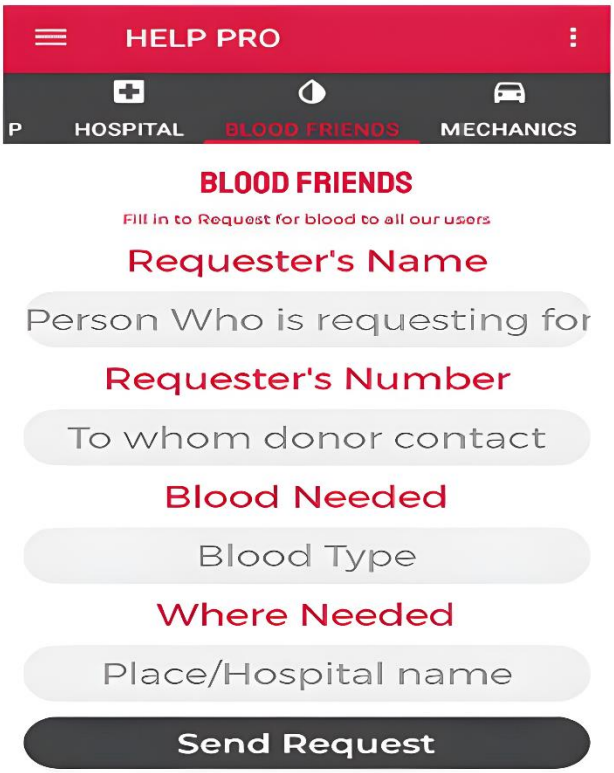


Figure 3.5 Blood Friends Screen [77]

The interface also provides dedicated buttons for directly contacting firefighters and police, eliminating the need for memorizing emergency numbers. The Help Pro app's user-friendly interface extends to the Blood Friend [77] feature as presented in figure 3.5, allowing users to request blood donations. Registered users receive notifications and can respond via push notifications or SMS, contributing to a connected community prepared for critical needs. Nearby hospitals [77] as presented in figure 3.4 and mechanics are easily accessible through the app's map functionality, which displays relevant information updated by the admin.

3.3.2 Driver Module Design

The driver interface is meant to be operational efficient and quick reaction. Drivers associate themselves with user requests using their credentials and car details. Once a request is started, the UI shows user information and should the driver agree, real-time navigation shows the path to the user's location. Should a driver fail to react, the system instantly transmits the request to another car within a 100-meter radius or the next closest available driver, therefore guaranteeing continuous coverage and minimum response times.

3.3.3 Admin Module Design

Designed on Laravel, the administrative module assures ease of use and reliability of administrative tools. Available from any desktop or mobile browser is this web-based utility connected to the Firebase database. The responsive administration interface adjusts to suit various screen sizes, therefore allowing flexible handling of program data. Originally determined by managers, login credentials might be altered for security concerns. The interface monitors and controls user and driver profiles by allowing the administrator access, changes,

UNIVERSIDAD DE MÁLAGA

and deletion of data as required. It also addresses handling mechanical communications and changing SOS numbers as needed or demanded as per the situation and the desired condition. Emphasizing simplicity and safety across all interactions, the user interfaces of the assistance Pro app are meant to deliver whole, user-centric solutions guaranteeing assistance can be sought and supplied properly.

3.4 System Components and Technologies Used

Many technologies and components were carefully chosen to guarantee dependable and strong performance in the evolution of the Help Pro program. Every one of these technologies was selected to improve system scalability, efficiency, and usability. The platform and backend services used for the application development help one to classify the system components.

3.4.1 Android Platform

Because of its open-source character and general usage the Android became the primary operating system used in the Help Pro application. Designed on the Linux kernel, Google's Android OS drives a range of devices including tablets, wearables, smartphones, and even cars. Its open-source quality lets one have complete access to the source code, thereby enabling development in line with project needs and customization. Using Android guarantees the program connects seamlessly with other Google services and reaches a wide user base, therefore improving the general usability of the application.

3.4.2 Android Studio

Development environment for the Help Pro application was contained in Android Studio, the official IDE for Android app development. Android Studio provides a suite of powerful tools for writing, debugging, and code testing developers need. Regarding application testing, it provides virtual emulator integration, real-time error detection, and codes autocompletion. Using Android Studio really improved the development process by enabling efficient coding approaches and quick testing, which speeds up the prototype and deployment phases.

3.4.3 Java as the Backend Programming Language

Backend development of the Help Pro application used Java as the main programming language. Scalability and with strong security features, and object-oriented programming (OOP) language platform independence define this language well. Java's class based approach helped to produce a readily maintained, reasonably controlled modular code. Since Java is the standard language used in Android app development and offers a consistent and familiar environment for writing, Java also permitted flawless connection with Android.

3.4.4 Firebase for Backend Services

Firebase provides Help Pro's cloud-based backend system, used for real-time data management and safe authentication. Firebase was selected for its simplicity of interface with Android applications and for handling JSON-formatted data without complicated query structures for data modification. The main services used in this project are: authentication, real-time database, cloud storage, Google Maps API (location), and Laravel (web administration).

UNIVERSIDAD DE MÁLAGA

3.4.4.1 Authentication:

Firebase Authentication simplified user sign-in processes by means of phone number verification, therefore ensuring secure and smooth user experiences of running application.

3.4.4.2 Real-time Database:

Real-time dynamic data synchronization of the database, allowing instant modification of user and driver information for the application to run and process smoothly.

3.4.4.3 Cloud Storage:

Firebase guaranteed that multimedia and other materials were stored securely by offering a scalable way for storing user and application data.

3.4.5 Google Maps API

Accurate position tracking, navigation and mapping capability depend on the Google Maps API being integrated. Google's built set of application programming interfaces let the software use real-time location data, map paths, and identify locations of interest including surrounding hospitals. By using these APIs users might effectively seek and monitor ambulance services, thereby improving user convenience and safety during an emergency. The Help Pro app's dependency on Google Maps API helped it to provide essential services by automatically connecting users and drivers across exact geolocation capability.

3.4.6 Laravel for Web Based Administration

Laravel was used for the admin module's development. The simple, clean syntax, and devotion to the Model View Controller (MVC) architecture define Laravel. It helped create a responsive and easily navigable online application available on many devices. Authorized users of the administrative module may handle user and driver data, then update SOS contacts and supervise notifications and feedback. Laravel's effective management of database transactions and support of strong security features which are very vital for safeguarding private data that led the choice to utilize it.

3.5 Functionality and Testing

In this part, we will talk about the operations of the system, the core algorithms and technologies that are used with utilization, as well as the techniques that allow for the verification of the dependability and efficiency of the system. Moreover, we will also discuss.

3.5.1 System Functionality Overview

Designed with a strong mix of technologies and algorithms, the Help Pro system is meant to handle different emergency scenarios especially those requiring the distribution of ambulances during important events when demand is high, but resources are limited. Help Pro is designed with a strong mix of technologies and algorithms, to handle different emergency scenarios, especially those requiring the distribution of ambulances during important events when demand

UNIVERSIDAD DE MÁLAGA

is high, but resources are limited. Two-pronged strategy drives the functionality: FCFS Queue Integration, and Dijkstra's Algorithm.

3.5.1.1 FCFS Queue Integration:

The First Come, First Served (FCFS) scheduling system answers patient inquiries in the sequence they are received. Following a simple sequential approach guarantees equity in providing consumers. But this approach does not naturally take into account factors like patient proximity or degree of illness.

3.5.1.2 Dijkstra's Algorithm Application:

Embedded to maximize routing by discovering the shortest route between the source i.e. ambulance location and the destination i.e. patient's location is the Dijkstra algorithm. When dynamic routing or traffic congestion is needed this is crucial so the system may suggest other pathways with modified journey times. Under high demand or otherwise, this mix guarantees that the allocated ambulances are used as effectively as they may be.

3.5.2 Implementation Mechanics

The Dijkstra algorithm is combined with the Google Maps API to provide exact position monitoring and route direction thus improving ambulances' capacity to move effectively approaching patients. Additionally helping drivers to minimize reaction times is traffic condition analysis supported by the API.

Acting as a centralized real-time database, Firebase securely stores and manages data. User information including GPS coordinates, medical records, and authentication tokens is stored there. While Firebase Cloud Messaging guarantees real-time alerts therefore assuring quick communication during crises. Firebase Authentication guarantees that only registered users may access system functionalities.

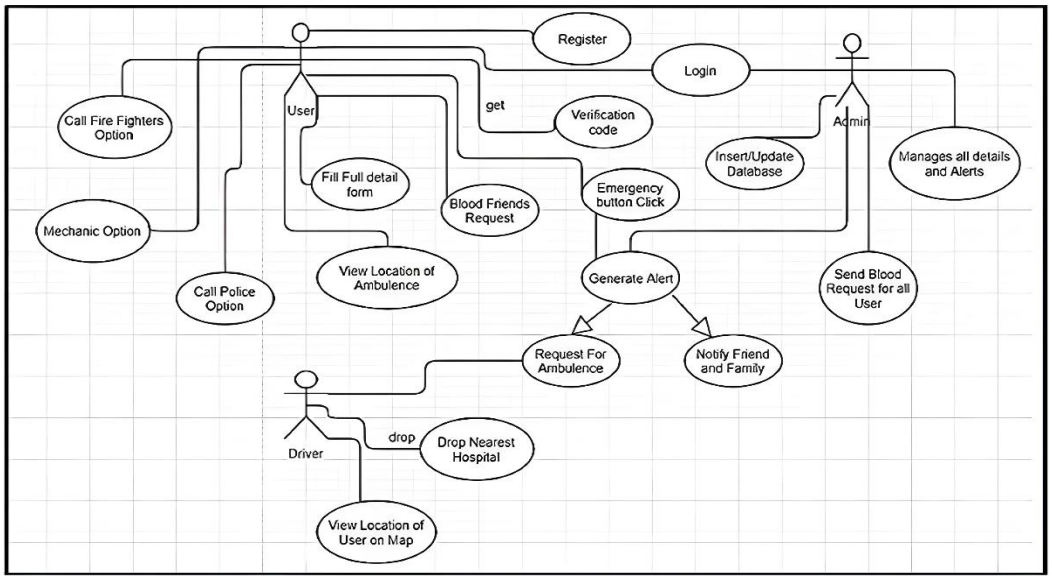


Figure 3.6 States diagram of overall use case of Help Pro [77]

UNIVERSIDAD DE MÁLAGA

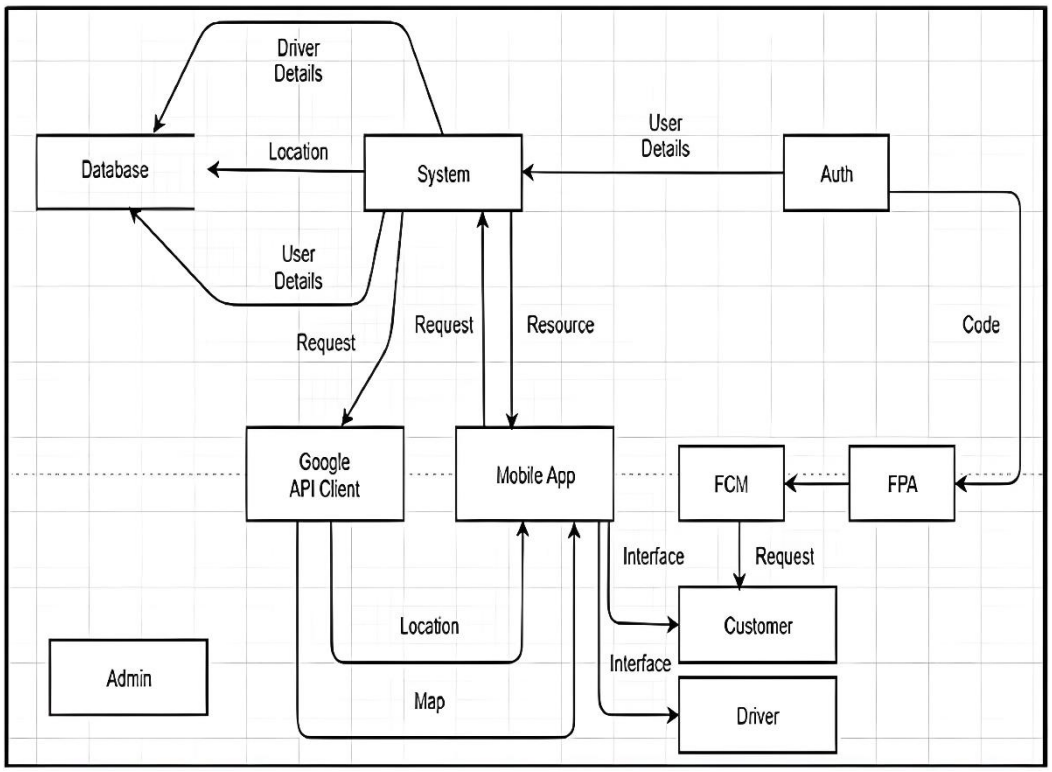


Figure 3.7 Level 2 - Data flow diagram [77]

The main actors, i.e. patients, drivers, and the system administrator as shown in the figure 3.6 System States Diagram [77] interact within the platform. Showcasing how user input is handled, saved, and used in real-time activities, figure 3.7, the level 2 data flow diagram [77] shows how data travels throughout the system architecture.

3.5.3 Testing and Evaluation

To validate the functionality of Help Pro rigorous testing procedures were conducted, covering unit, integration, and system testing phases:

3.5.3.1 Unit Testing

Each individual component was examined to ensure correct operations. For example, tests were performed to verify that the FCFS scheduling mechanism accurately queued and managed requests. Dijkstra based routing was also assessed for path optimization under various traffic situations.

3.5.3.2 Integration Testing

To guarantee flawless data interchange and location updates component interoperability between Firebase and Google Maps API was evaluated. Managing asynchronous data retrieval and guaranteeing real-time communication free of notable delay, presented difficulties at this stage.

UNIVERSIDAD DE MÁLAGA

3.5.3.3 System Testing

Real-world testing of the whole system was conducted to replicate high demand circumstances, therefore guaranteeing that it could assign ambulances properly and effectively alert consumers. To assess system responsiveness under stress, certain performance benchmarks were established; when reaction times followed preset criteria, the system produced good outcomes.

3.5.3.4 User Acceptance Testing (UAT)

A quality of user experience measurement, called “User Acceptance Testing” is included in Help Pro aimed at probable end users like medical professionals and patients to ensure that the interface was clear and that the general performance meet user expectations.

3.6 Results and Comparative Analysis

The testing phase emphasized the reliability and efficiency of the system as well as how quick route planning and decision-making emerged from the FCFS queue coupled with Dijkstra's technique. When the system was evaluated against traditional models employing simply FCFS without route optimization response times and resource allocation were much improved.

Managing server-side data synchronizing and handling heavy traffic volumes during peak hours proved difficult during testing. These were lessened by database structural and cache technique's optimizations.

Providing a user-friendly interface and matching industry standards for emergency response applications, the Help Pro system not only fulfilled but beyond the first expectations for capability overall. Effective use of real-time data integration and algorithmic scheduling guaranteed that the system could operate consistently under different circumstances thus providing necessary assistance during major emergency reactions.

3.7 Conclusion

This chapter covered the technical and algorithmic framework of the Help Pro system highlighting how its parts taken together effectively handle problems related to emergency response. To guarantee the best pathfinding and resource allocation, we investigated the integration of fundamental technologies like Android, Firebase, and Google Maps API as well as Dijkstra's algorithm. The manuscript analysis highlighted the significance of these tools and their contributions to a robust, user-friendly application that prioritizes rapid response and accurate routing. Testing results affirmed that the system meets its intended objectives of quick service provision and real-time data management, overcoming challenges like traffic congestion and resource scarcity. Combining first come, first served scheduling with Dijkstra's pathfinding improves operational efficiency and decision making. The thorough review and evaluation in this chapter support the dependability of Help Pro as a means of providing emergency aid, therefore laying the groundwork for debates in future chapters.

UNIVERSIDAD DE MÁLAGA

Chapter 4: Development and Evaluation of the CXR-DNN Model for COVID-19 Diagnosis

4. Introduction

In Chapter 4, we learn how the CXR-DNN model was created and tested to correctly identify COVID-19 using chest X-rays. In this chapter, we talk about new ways to identify COVID-19 and other lung illnesses that use advanced deep learning methods. Since it uses EfficientNetB7 and transfer learning the CXR-DNN model is a big step forward in the study of medical pictures. It works very well and could be quickly expanded to be used in healthcare.

It became clear that reliable testing methods were needed when strange cases of pneumonia were reported in Wuhan, China, in late December 2019. By the beginning of 2020 scientists had found that SARS-CoV-2 was the virus that caused the COVID-19 pandemic. Antigen screenings and nucleic acid amplification tests (NAATs) are the main ways to diagnose COVID-19. Imaging tests like chest X-rays (CXR) and CT scans on the other hand, can also help find lung problems caused by the virus. These methods of screening help doctors to keep an eye on the condition and treat it as needed.

The three-way classification problem that the CXR-DNN model is meant to solve is described in this chapter. Using the pre-trained convolutional neural networks and improvements that allow accurate sorting and measures that show how well the model works are all part of it. The research shows that the CXR-DNN model could make COVID-19 testing a lot better by making it faster and more favorable.

UNIVERSIDAD DE MÁLAGA

4.1 Related Work

Image-based detection methods, such as those that use chest X-rays (CXR), computed tomography (CT) scans, and lung ultrasounds (LUS), have become especially important for finding COVID-19 in recent years. Researchers are more and more using machine learning (ML) and deep learning (DL) methods to help medical pictures automatically spot COVID-19. Two steps make up a standard method. In the first step Convolutional Neural Networks (CNNs) are used to pull out data from the pictures. Long Short-Term Memory (LSTM) networks are used in the second step to sort the pictures into groups. However, this method has some issues, such as the fact that it can be hard to tell the difference between different views of CXR images and the fact that it can be hard to diagnose certain symptoms that aren't known.

Another well-known option is COVIDetectioNet, which uses an AlexNet design that has already been taught to automatically pull-out features from CXR images. At first, the Relief method was used to pick out the most important traits that described the picture. It is very important to spot COVID-19 right away and correctly, especially in places with few resources. In these cases, standard diagnosis tests like RT-PCR take longer and are harder to get. Deep learning models are a good choice in these cases because they speed up screening and increase the chance of early discovery.

However the traditional RT-PCR testing is still the most accurate way to diagnose COVID-19, but it is not always available and there are long waiting times. Antigen swabbing, on the other hand, gives results faster but is not as accurate. Antibodies can be found in serological tests, which are useful for finding out if someone has been exposed to an illness in the past but not so good at finding infections that are happening right now. Many picture-based medical systems have been offered as a way to fill in these holes. These systems use both CXR and CT scans, which are easier to get than some other types of imaging.

Deep learning has helped make models that can tell the difference between healthy people, people with COVID-19, and people with viral pneumonia. Some models, like CNN-based COVID-Net and others like it, have shown that they can correctly put CXR images into groups. Even though progress has been made, there is still a lot of work to be done to increase the information, make the model better, and lower the bias. Several studies are looking into how to solve these issues. Also, CT scans have been shown to be more sensitive than CXR pictures, but CXR pictures are still the main focus because they are easier to get.

Researchers are also looking into the use of other models, like Vision Transformers (ViT), which have been shown to work better than traditional CNNs in some situations. ViTs have been very good at telling the difference between CXR photos of COVID-19 and images of other things. These improvements show that image-based AI systems are always changing. This means that more study and development is needed to make diagnoses more accurate and deal with new problems.

4.2 The CXR-DNN Method

Deep learning is used in the CXR-DNN (Chest X-ray Deep Neural Network) method to automatically identify COVID-19, viral pneumonia and normal cases from chest X-ray (CXR) pictures. This model is based on the EfficientNetB7 design, which provides a quick and correct way to pull features and group them into categories. The next parts describe the method, including the design, training settings, model training process, and validation and testing steps.

UNIVERSIDAD DE MÁLAGA

4.2.1 EfficientNetB7 Architecture

EfficientNetB7 is a Convolutional Neural Network (CNN) that works very well and was designed to do so across a range of depth, width, and precision. To get the best of both speed and efficiency, it uses MBConv (Mobile Inverted Bottleneck Convolution) blocks that have depth-wise separable convolutions, squeeze-and-excitation, and compound scaling. Thanks to these strong parts, EfficientNetB7 is great for fast picture classification especially when working with large datasets like chest X-rays.

4.2.1.1 MBConv Blocks

The MBConv blocks are very important. They make it possible for the network to do light convolutions while still having a lot of power for modeling. The work that needs to be done is lessened because MBConv blocks use depth-wise separable convolutions. This is very helpful for jobs that require sorting images that have a lot of info.

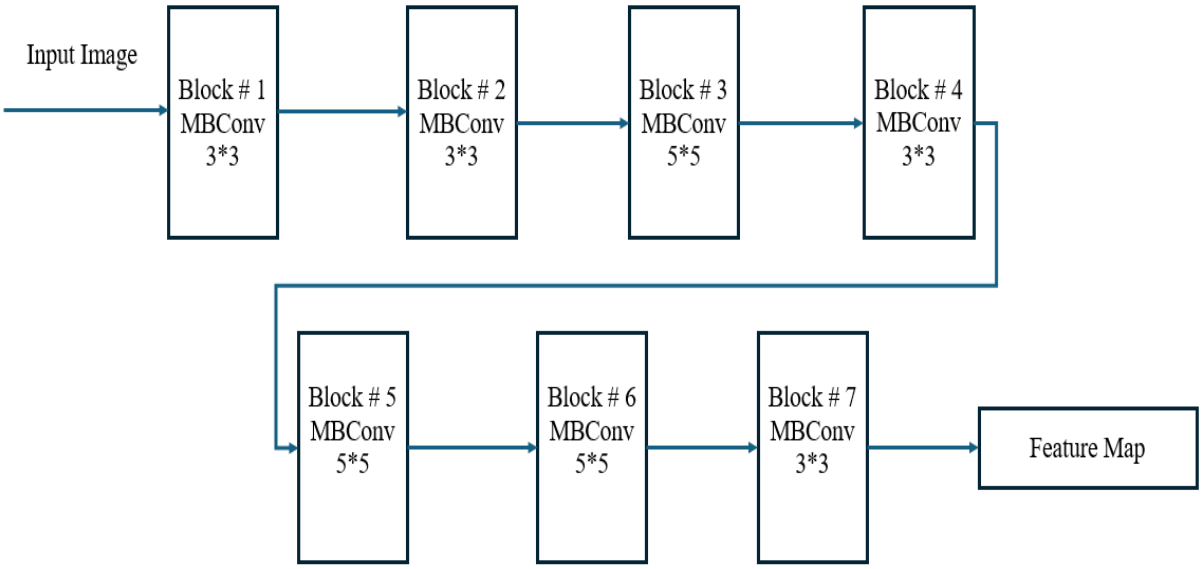


Figure 4.1. MBConv Blocks in the EfficientNetB7 Architecture [78]

4.2.1.2 Squeeze and Excitation

In the squeeze and excitation approach, channel-wise feature responses are adaptively recalibrated to make the network better at extracting features. This helps the model focus on key features in the input picture.

4.2.1.3 Compound Scaling

EfficientNetB7 uses compound scaling to change the model's depth, width and resolution all at once to get the best results without using too much computer power. Because of this, EfficientNetB7 is a good choice for sorting medical pictures because it makes generalization and model robustness better.

UNIVERSIDAD DE MÁLAGA

An important part of the CXR-DNN method is the EfficientNetB7 design, especially when the model is being built and features are being extracted. It helps the model get the right information from chest X-rays and put it into the right categories like telling the difference between COVID-19, normal, and pneumonia cases.

4.2.1.4 Training Parameters

The following settings were used to train the CXR-DNN model:

- **Epochs:** 100
- **Learning Rate:** 0.0001
- **Batch Size:** 32

4.2.1.5 Optimizer

The Adam optimizer is set to its usual settings.

4.2.1.6 Loss Function

Categorical Cross-Entropy which works well for problems where to need to sort data into many groups.

These training values were chosen to make sure that the model converges in the best way possible without becoming too perfect. The learning rate of 0.0001 makes sure that changes happen gradually during training and the batch size of 32 strikes a good balance between safety and speed of training.

4.3 Model Training Process

The first step in the model training method is to gather and prepare CXR images from three groups: COVID-19, normal, and pneumonia. These pictures were preprocessed using common methods like scaling, normalization, and data addition to making them more varied and useful for generalization.

4.3.1 Data Preparation

The training sample had 1,345 pictures divided into three groups: COVID-19, Normal, and Pneumonia. Before they were used, the pictures were managed by making them smaller to a certain size and setting the pixel values to a standard range of 0 to 1.

4.3.2 Data Augmentation

To make the model more general in techniques like rotations, zooms and horizontal flips were used to add to data. This step keeps the model from fitting well and makes sure it can manage a variety of picture angles and conditions.

UNIVERSIDAD DE MÁLAGA

4.3.3 Transfer Learning

As part of transfer learning, EfficientNetB7 weights that had already been learned were used. Since the CXR pictures were used to finetune the final classification layer and the model was able to learn certain traits that are important for identifying COVID-19.

4.3.4 Training Procedure

The model was trained on the training dataset 100 times. During the training process the Adam algorithm was used to lower the category cross-entropy loss. To keep an eye on the model's performance then its accuracy and loss were measured.

4.3.5 Validation

To see how well the model did during training a different validation sample was used. This keeps an eye on overfitting and making sure the model works well with the concerned data.

4.3.6 Validation and Testing

The model was trained and then the validation and testing steps were taken to see how well it did on the data.

4.3.7 Validation Dataset

For the validation of dataset the hyperparameters of the model were changed and it was checked to make sure that the model wasn't fitting too well. It was decided what the accuracy, precision, memory and F1-score were for each class (COVID-19, Normal and Pneumonia).

4.3.8 Testing Dataset

To examine how the efficient end model works in the real world was tested on a different dataset after it had been trained and validated. The confusion matrix with accuracy, precision, recall, and F1-score were used to test the model's ability to correctly put pictures into the desired placements.

4.3.9 Performance Evaluation

The following measures of success have been found.

4.3.10 Accuracy

Indicates how well the model places each image in its correct category.

4.3.11 Precision

Precision is the ratio of the number of expected positive outcomes to the actual number of positive outcomes for each class.

UNIVERSIDAD DE MÁLAGA

4.3.12 Recall

This parameter is the share of real good outcomes for each class out of all real good outcomes.

4.3.13 F1-score

The F1-score is the harmonic mean of accuracy and memory which is the middle number between the two. All tests showed that the CXR-DNN model worked well, proving that it can correctly and quickly find COVID-19 from chest X-ray data.

4.4 Results

4.4.1 Performance Metrics

In this section we will summarize the evaluation metrics used to assess the CXR-DNN model's performance, including precision, recall, F1-score and accuracy for each class (COVID-19, Normal, and Pneumonia). These metrics help evaluate the model's diagnostic capability on the training, validation, and testing datasets, ensuring a balanced evaluation of the multi-class predictions.

4.4.1.1 Performance Metrics Overview:

The model's performance was assessed using standard classification metrics, including:

Precision (P), defined as: $P = \frac{TP}{TP+FP}$ *Equation (5)*

Recall (R), defined as: $R = \frac{TP}{TP+FN}$ *Equation (6)*

F1-Score (F1), averages precision and recall**,** defined as: $F1 = 2\frac{P.R}{P+R}$ *Equation (7)*

Accuracy (A), which represents the fraction of correct predictions across all classes, defined as: $A = \frac{TP+TN}{TP+TN+FP+FN}$ *Equation (8)*

where:

- TP: True Positives
- TN: True Negatives
- FP: False Positives
- FN: False Negatives

These measures were generated independently for each class COVID-19, Normal and Pneumonia. Macro averaging was used to evaluate the overall performance of the model. This method included calculating the average of the metrics for each class in order to produce a performance rating that was equally weighted across all classes regardless of the distribution of the dataset.

UNIVERSIDAD DE MÁLAGA

4.4.2 Results on Validation and Test Datasets

In this section, we will provide the results of the model on both the validation and test datasets. The results from the three classes (COVID-19, Normal, and Pneumonia) will be provided in terms of precision, recall, F1-score, and accuracy. This will give us an understanding of how well the model can apply what it has learned to new data.

Validation Dataset		**Test Dataset**	
COVID-19 Class:		**COVID-19 Class:**	
Precision:	85%	Precision:	85%
Recall:	90%	Recall:	93%
F1-Score:	87%	F1-Score:	89%
Accuracy:	90%	Accuracy:	94%
Normal Class:		**Normal Class:**	
Precision:	81%	Precision:	78%
Recall:	81%	Recall:	81%
F1-Score:	81%	F1-Score:	79%
Accuracy:	81%	Accuracy:	81%
Pneumonia Class:		**Pneumonia Class:**	
Precision:	83%	Precision:	78%
Recall:	77%	Recall:	68%
F1-Score:	80%	F1-Score:	72%
Accuracy:	77%	Accuracy:	68%

4.4.3 Comparative Analysis

We will compare the performance of the CXR-DNN models to that of other models that are currently in use.

Models Comparison

Inception v3 :	79%
Xception:	84%
ResNet50:	86%
EfficientNetB7:	95%

The comparison shows that EfficientNetB7 is better when it comes to overall accuracy. This means that EfficientNetB7 is better at classifying chest X-ray pictures into the categories of COVID-19, Normal and Pneumonia with better accuracies.

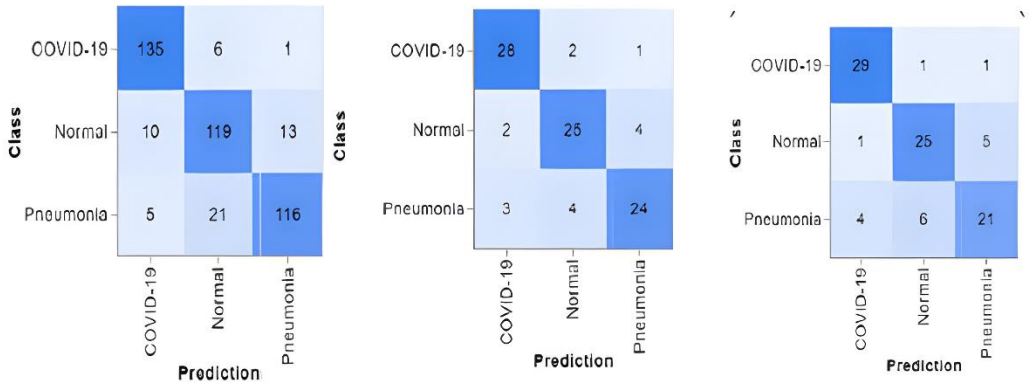
This comparative investigation demonstrates that sophisticated CNN architectures such as EfficientNetB7 are successful for medical image classification tasks especially when it comes to diagnosing COVID-19 utilizing chest X-ray pictures.

UNIVERSIDAD DE MÁLAGA

4.4.4 Additional Visualizations

4.4.4.1 Confusion Matrices

These matrices will show the number of correct and incorrect predictions for each class (COVID-19, Normal, Pneumonia) across the test dataset.



(a) (b) (c)

Figure 4.2. 3x3 confusion matrices for the (a) Training, (b) Validation, and (c) Testing datasets representing the model's performance for each class (COVID-19, Normal, and Pneumonia) [78]

The confusion matrices presented in Figures 4.2 (a), (b) and (c) represent the model's performance across three datasets: (a) Training, (b) Validation, and (c) Testing. Each matrix provides a breakdown of the model's classification results showing the number of True Positives (TP), False Positives (FP), True Negatives (TN) and False Negatives (FN) for each class: COVID-19, Normal, and Pneumonia.

4.4.4.2 Training Dataset

This matrix reflects the model's performance on the training data highlighting how well the model has learned to classify the various categories based on the training samples.

4.4.4.3 Validation Dataset

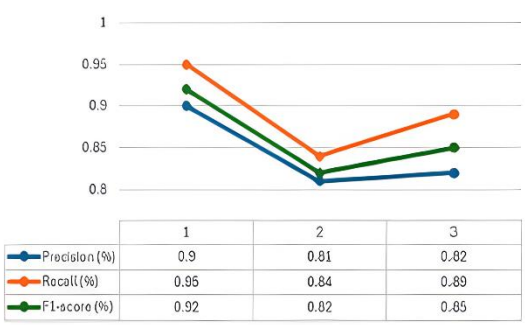
This matrix represents the model's performance on the validation dataset providing insight into how well the model generalizes to unseen data during the training process.

4.4.4.4 Testing Dataset

The confusion matrix for the test dataset illustrates the model's final performance on completely unseen data which is crucial for evaluating its real-world accuracy. The diagonal members of each matrix show the True Positives (TP) for each class, while the off-diagonal elements show the False Positives (FP) and False Negatives (FN). This indicates any misclassifications that may have occurred. The values in the matrices provide a detailed understanding of the model's strengths and shortcomings in reliably identifying instances of COVID-19, normal cases and pneumonia.

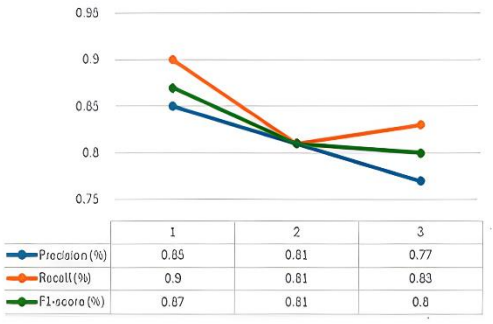
UNIVERSIDAD DE MÁLAGA

4.4.4.5 Performance Metric Convergence Graphs



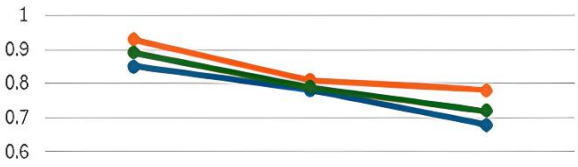
	1	2	3
Precision (%)	0.9	0.81	0.82
Recall (%)	0.96	0.84	0.89
F1-score (%)	0.92	0.82	0.85

(a)



	1	2	3
Precision (%)	0.85	0.81	0.77
Recall (%)	0.9	0.81	0.83
F1-score (%)	0.87	0.81	0.8

(b)



	1	2	3
Precision (%)	0.85	0.78	0.68
Recall (%)	0.93	0.81	0.78
F1-score (%)	0.89	0.79	0.72

(c)

Figure 4.3. Convergence for precision, Recall and F1-score in every dataset used: (a) training, (b) validation, (c) testing of classes: COVID-19, normal, and pneumonia [78]

The convergence graphs in Figures 4.3 (a),(b), and (c) illustrate the development of Precision, Recall, and F1-score for each class (COVID-19, Normal and Pneumonia) during the training process. These metrics are displayed for three datasets: (a) Training, (b) Validation, and (c) Testing. This provides insight into how the model performs at various phases.

4.4.4.6 Precision Convergence

This graph shows the Precision (the percentage of real positive predictions compared to all positive predictions) for each class throughout the Training, Validation and Testing stages. It demonstrates how accurately the model is able to retain its performance across the various datasets while training continues.

4.4.4.7 Recall Convergence

This graph shows the Recall for each class across the three datasets. Recall is the percentage of true positive predictions out of all real positive cases. It helps to understand how well the model can accurately identify all relevant instances of each class throughout the training, validation and testing phases.

UNIVERSIDAD DE MÁLAGA

4.4.4.8 F1-score Convergence

This graph shows the F1-score for each class in the Training, Validation and Testing datasets. The F1-score is a measure that balances Precision and Recall. This statistic shows how well the model is able to balance false positives and false negatives. This is especially relevant when assessing the model's performance on datasets that are not balanced.

4.5 Discussion

4.5.1 Discussion of Results

The EfficientNetB7 architecture that was introduced showed a lot of promise in identifying COVID-19 by utilizing chest X-ray pictures. The results obtained by this model demonstrate that it has the capacity to perform better than other network topologies that have been customized for this particular application. This research is important because it emphasizes the need for a quick, precise, and trustworthy diagnosis of lung infections during the pandemic. The EfficientNetB7 design has been shown to be successful in distinguishing COVID-19 patients from other respiratory illnesses, making it an essential tool for automated evaluations in healthcare situations with high demand.

One of the main advantages of this method is that it is precise and may be used for other jobs in medical imaging. This design is not only promising for identifying COVID-19, but it also has the potential to be adapted for diagnosing other thoracic disorders. This would make it more useful in clinical decision-making situations. In comparison to previous methods, the automated COVID-19 identification approach demonstrated greater accuracy across all three chest X-ray picture classes, highlighting its strength and efficiency.

4.5.2 Challenges and Limitations

Even while the findings are encouraging, it is important to recognize that the EfficientNetB7 design has a number of constraints. To begin with, the model's performance is greatly influenced by the quality and variety of the dataset that is utilized for training. The model's ability to generalize may be affected by deficiency in the dataset. This matter highlights the need for datasets that are varied and accurately reflect the real-world circumstances and parameters.

EfficientNetB7 demands a lot of processing resources which might be a problem in clinical settings that do not have access to the latest technological advancements and developments. Because of this reliance on computing infrastructure the design may not be widely adopted in healthcare settings that have limited resources.

Third, the architecture operates as a "black box," which makes it difficult to understand how it comes to its decisions. This lack of transparency may make it difficult to grasp how the model reaches its results, which is important for establishing confidence in diagnostic tools that use artificial intelligence. The model has produced outstanding results with the data that was utilized but it may need a lot more tweaking and validation in order to be used in other clinical situations or with other imaging modalities.

UNIVERSIDAD DE MÁLAGA

Finally, architecture's main emphasis on COVID-19 diagnosis restricts its immediate use for other thoracic disorders. Future research should focus on improving the generalizability of this method so that it may be used to successfully manage a wider variety of medical imaging problems. In addition, finding ways to facilitate understanding of the decision-making process of deep learning models could help therapists become more comfortable with and confident in these models.

In order to improve the clinical value of EfficientNetB7 and other deep learning models used in medical imaging, it is important to address these obstacles and constraints. Future work should concentrate on building datasets that are more varied, maximizing computing efficiency and developing explainable AI strategies to improve model interpretability and usability in healthcare contexts.

4.6 System Implementation

The system implementation for the proposed EfficientNetB7 based COVID-19 diagnostic model was built to guarantee that it could be integrated seamlessly with machine learning platforms and support a real time workflow for clinical applications. This section gives a summary of the processes required to make the model operational from preprocessing the data to making the final diagnosis, in order to guarantee that it is accurate and usable in healthcare settings with high demand.

4.6.1 Integration with Machine Learning Platforms

The proposed system was implemented using a robust machine learning framework that enabled efficient model training and deployment. The key steps included are detailed in sections 4.6.1-4.6.10.

4.6.2 Data Preprocessing and Augmentation

The chest X-ray (CXR) pictures were preprocessed by normalizing and shrinking them such that they would meet the input criteria of the EfficientNetB7 architecture. To improve the model's capacity to generalize, data augmentation methods including rotation, flipping, and brightness modifications were used.

4.6.3 Platform Selection

The model was trained and verified using a high-performance machine learning platform that supported sophisticated deep learning frameworks, such as TensorFlow and Keras. These systems provide optimized libraries and GPU acceleration to meet the computational requirements of EfficientNetB7.

4.6.4 Model Deployment

The model was exported and incorporated into a cloud-based diagnostic system once it was trained. This design allowed for remote access, which made the system suitable in a variety of healthcare settings.

UNIVERSIDAD DE MÁLAGA

4.6.5 Real-Time Workflow for Diagnosis

The real-time approach was created to make it easier to diagnose chest infections, including COVID-19, by utilizing CXR pictures. The following steps are included in the workflow:

4.6.6 Image Upload

Chest X-ray pictures are uploaded directly to the system by clinicians or radiologists via a secure portal.

4.6.7 Preprocessing

The photos that have been uploaded are automatically preprocessed in order to guarantee that they are consistent and compatible with the input criteria of the model.

4.6.8 Model Inference

The EfficientNetB7 model takes preprocessed pictures and makes predictions for three categories: COVID-19, pneumonia, and normal.

4.6.9 Results Visualization

The results of the diagnosis, including the probability for each class, are shown on a dashboard that is easy to use. This graphic helps physicians make educated choices fast.

4.6.10 Data Storage and Accessibility

All diagnostic data are retained securely for future reference, allowing for retrospective analysis and the possibility of integration into electronic health records (EHRs).

4.6.11 Challenges in System Implementation

The system has a high level of accuracy and efficiency, but its implementation has encountered a number of obstacles. These include the need for a large amount of computing resources and the need for comprehensive validation to guarantee that it performs reliably over a wide range of datasets. Further the real time processes need stronger security measures to safeguard patient data and comply with privacy rules.

This system's implementation not only demonstrates that deep learning models can be used in clinical applications in the real world, but it also emphasizes how important it is to include these technologies into healthcare processes in order to enhance diagnostic accuracy and efficiency. Future development must concentrate on improving the system's resource needs and the scalability so that more people can use it.

4.7 Conclusion

This chapter presents the results and conclusions that highlight the usefulness and promise of the proposed EfficientNetB7 based architecture for diagnosing COVID-19 and other thoracic disorders via the use of chest X-ray images. The model showed a high level of accuracy,

UNIVERSIDAD DE MÁLAGA

precision and recall when tested on training, validation and test datasets confirming that it is appropriate for use in real world clinical applications.

The system's performance was greatly improved by the combination of modern data preparation methods after careful parameter optimization and strong model architecture. EfficientNetB7's capacity to extract important characteristics from X-ray pictures made it possible to exactly tell the difference between COVID-19, pneumonia and normal patients.

The research also highlighted significant difficulties and restrictions, although the results were quite good. These include the reliance on the quality of the dataset, the need for substantial computing resources and the intrinsic black box character of deep learning models which may restrict their interpretability. In order to expand the therapeutic application of the system it will be definitely necessary to address these issues with future research and improvements. To sum up the approach that has been suggested is a dependable, quick and precise instrument that may assist medical professionals in diagnosing COVID-19 and other disorders. Its capacity can be scaled and adapted for detecting different medical issues further highlights its importance and usefulness in today's healthcare settings.

UNIVERSIDAD DE MÁLAGA

This page intentionally left blank

UNIVERSIDAD DE MÁLAGA

Chapter 5: Development of a CNN-Based Joint Diagnosis Model for Brain Tumor Classification Using CT and MR Imaging

5. Introduction

Tumors within the brain are generally classified as either primary originating in the brain itself or secondary, which are metastatic, meaning they spread from cancers elsewhere in the body, such as the lungs or breast. Although benign tumors are non-cancerous and often simpler to exercise surgically owing to their distinct margins, they may still impose detrimental strain on the brain. In contrast the malignant tumors are aggressive, rapidly proliferating, and often disseminate via cerebrospinal fluid making early discovery and management crucially essential.

Recent advancements in medical imaging, particularly MRI and CT scans have dramatically improved how clinicians detect and monitor brain tumors. MRI, with its strong soft-tissue contrast, is especially useful for evaluating neurological and musculoskeletal conditions, while CT excels in visualizing bone structures and acute trauma. Although MRI avoids ionizing radiation and is generally safer for use in children and pregnant women, it may not be suitable for patients with metal implants. CT while faster and more widely accessible, carries a small risk due to radiation exposure though modern systems now use low dose techniques.

Given that early diagnosis enhances survival rates, Artificial Intelligence (AI), particularly deep learning methods such as Convolutional Neural Networks (CNNs), has emerged as a crucial asset in medical diagnostics. Particularly good in tumor recognition and classification, these algorithms can identify complex patterns from large imaging data. Still the creation of

UNIVERSIDAD DE MÁLAGA

reliable deep learning models is still greatly hampered by the variation in size, shape and location of brain tumors.

Many studies have shown how well CNN-based methods classify various kinds of brain cancers. While others have employed hybrid models including Support Vector Machines (SVMs) or k Nearest Neighbors (kNN) classifiers to improve prediction accuracy while others have trained CNNs on T1 weighted MRI images to differentiate among gliomas, meningiomas and pituitary tumors.
By combining CT and MRI data this work presents a combined classification method employing a single CNN model to solve these problems. This innovative approach makes the most of both imaging modalities' advantages while maximizing diagnostic processes. Real-time clinical settings could benefit from the model developed utilizing the MobileNetV3 architecture.

Here are the main points of this work:

- Using a combined CNN architecture with data from CT and MRI scans.
- The use of a unified paradigm for tumor categorization that can manage six distinct types of tumors.
- The proof of concept of accurate categorization with very little computing resources.
- An efficient and scalable pipeline that gives therapeutic benefit while reducing human effort is proposed.

Through this integrated approach the goal is to enhance diagnostic precision, accelerate detection timelines and support healthcare professionals in making better-informed treatment decisions.

5.1 Related Work and Technical Background

5.1.1 Image Processing in Medical Imaging

Preprocessing is essential in medical imaging for transforming raw data into relevant analysis. A sequence of picture improvement and standardization actions has to be completed before any deep learning or machine learning model can be trained successfully. Typically, these first jobs include picture extraction, geometric modification and alignment to guarantee uniform formatting and spatial consistency of the data throughout the dataset. Figure 5.1 shows the pipeline followed in this work.

UNIVERSIDAD DE MÁLAGA

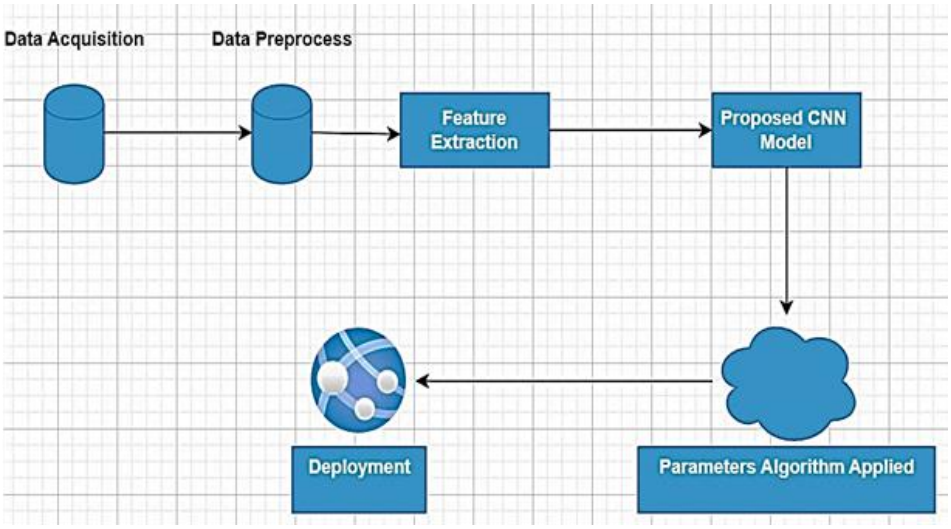


Figure 5.1 Convergence Deep Learning process architecture.

Preprocessing is mostly about getting rid of prototyping factors and noise in the pictures. Improper handling of artifacts unwanted distortions or anomalies might cloud model training. The noise that might originate from imaging sensors or environmental interference during scanning and capturing of the data is also minimized to provide clean and high-resolution images. Once these anomalies are corrected, the images are normalized. By altering the pixel intensity values across all images to a consistent range, normalization improves consistency and qualifies the dataset better for training neural models.

Besides cleaning and normalization, image processing also involves looking at visual components essential for downstream tasks such classification and segmentation.

Feature exploration enables the identification of patterns, edges, textures, and intensities that are indicative of tumor presence and type. To achieve this, computer vision and digital image processing techniques are employed. These methods interpret visual content in a structured way, enabling models to detect relevant anomalies or structures based on pixel-level characteristics.

The importance of good preprocessing in medical imaging work cannot be overstated. Without these processes the model may interpret noise as valuable information or overlook tiny differences among cancer types. The preprocessing not only prepares the data but also increases the potential of the model to generalize and run consistently across many contexts.

5.2 Suggested Framework

This part outlines the suggested approach for constructing the classification model for brain tumor detection depending on CT and MR data. It includes the CNN models utilized with the performance measures used for assessment, data augmentation methods, preprocessing procedures and the dataset gathering.

UNIVERSIDAD DE MÁLAGA

5.2.1 Gathering Datasets

Comprising more than 10,000 brain scan pictures spanning both CT and MRI modalities the experimental dataset utilized in this work was obtained from Kaggle. Ranging in size and quality the pictures provide a wide depiction of real-world medical imaging situations. The photos were preprocessed to eliminate unneeded margins hence guaranteeing consistency and relevancy so allowing later size and format changes fit for the needs of the CNN models. For this classification task, six distinct categories were considered:

1. MRI Glioma
2. MRI Meningioma
3. MRI No Tumor
4. MRI Pituitary
5. CT Tumor
6. CT No Tumor

Classification Type	Type	Description
Nature	Benign, Malignant	Grows slowly, could be life-threatening
Origin	Primary / Secondary Tumor	Originates in the brain or develops from other areas (lungs, breasts, etc.)
Grading	Grade I / II / III / IV	Basic, strange, grows quickly, reproduces
Progression	Stage 0 / 1 / 2 / 3 / 4	Grows fast (all stages)

Table 5.1 Qualification of Brain Tumors

This diverse set allows the model to learn tumor characteristics across different imaging modalities and conditions. Table 5.1 provides a brief classification of these brain tumor types based on their evolution and severity.

5.2.2 Preparing Data for Analysis

A systematic proper picture preprocessing workflow was used to the raw data to standardize inputs and improve pertinent characteristics after the dataset has been gathered. The following actions were systematically done especially for MRI scans:

- Image Resizing to standardize dimensions across the dataset.
- Grayscale Conversion to reduce computational complexity.
- Gaussian Blurring to minimize noise and irrelevant high-frequency content.
- Erosion and Dilation to refine boundaries and shapes.
- Contour Detection to isolate regions of interest.
- Cropping based on identified contours to focus on tumor-specific areas.
- This preprocessing ensured that the CNNs received clean and consistent input helping them focus on meaningful features relevant for classification.

UNIVERSIDAD DE MÁLAGA

5.2.3 Enhancing the Data

Methods of data augmentation that supported generalization and helped to combat with any overfitting. Applying with modifications to the preprocessed images increased the diversity of the training data artificially over this process. The following are the ways or techniques for producing observations and computations:

- Rotations
- Flips (horizontal and vertical)
- Shifts and scaling
- Zoom and angular adjustments

These augmentations help simulate the variability found in real-world clinical imaging, enabling the model to become more robust and accurate. The reliability of CNN predictions is tightly coupled with the quality and diversity of training data, making augmentation a crucial step in the pipeline.

5.2.4 CNN Models

ResNet50, DenseNet, EfficientNetB1 and MobileNetV3 were four well-known convolutional neural network (CNN) architectures used in this work. Every model has different advantages in terms of performance, efficiency, and appropriateness for many deployment situations.

ResNet50 is widely known for its depth and use of residual (skip) connections, which help maintain gradient flow during training. By adding bottleneck blocks and batch normalization the design increases accuracy and efficiency of deep model training.

DenseNet allows feature reutilization by means of connections between every layer and all subsequent levels in a feed forward configuration. This increases gradient flow with increased feature propagation and a major drop in the parameter count without compromising accuracy.

EfficientNetB1 offers a balanced trade-off between depth, width, and resolution through compound scaling. It serves as a middle ground between lightweight and performance-heavy models which offer flexibility and high accuracy on medical imaging tasks.

Optimized for mobile and embedded vision applications, MobileNetV3 maintains accuracy by use of depth-wise separable convolutions and squeeze and excitation blocks hence greatly lowering computing cost. It is particularly appropriate for low-resource edge devices.

MobileNetV3 also incorporates the hard-swish activation function, which combines the efficiency of ReLU with the smoothness of Swish, and allows for dynamic control over network width and depth. Its performance is measured using Multiply Accumulate Operations (MACs) which provide a proxy for both processing speed and energy efficiency.

5.2.5 Performance Measures

To assess the quality and effectiveness of the proposed models, three key evaluation metrics were used:

UNIVERSIDAD DE MÁLAGA

- **Confusion Matrix:** The Actual labels are compared with anticipated labels using this N×N matrix. The N is denoting the number of classes. It guarantees no class is excessively favored by measuring the performance of the model across all categories.

- **Epochs:** An epoch represents one complete forward and backward pass of all training data. The model's weights and biases are updated during each epoch to minimize errors. The number of epochs was selected to ensure adequate training while avoiding overfitting.

- **Accuracy:** A simple indicator of model performance, accuracy is the proportion of correct predicted observations to total data. Though often employed it is read with other measures like accuracy, recall, and F1-score. All are covered in the results section to provide a thorough picture of classification performance.

5.3 Results

This section presents the evaluation outcomes of the four previously introduced convolutional neural networks: ResNet50, DenseNet, EfficientNetB1, and MobileNetV3. Among them, MobileNetV3 demonstrated the highest classification performance based on the comparative accuracy metrics obtained during experimentation, as illustrated in Table 5.2.

CNN Model	Accuracy
ResNet50	74.9% [49]
DenseNet	78.44% [50]
EfficientNetB1	84.44% [52]
MobileNetV3	86.42% [51]

Table 5.2 Accuracy Comparison Across CNN Models

Its better performance made the MobileNetV3 model the choice for thorough investigation. It was trained on a dataset including CT scan brain pictures and MRI. Representative cases of MRI and CT brain tumor images used for categorization are shown in Figures 5.2 and 5.3.

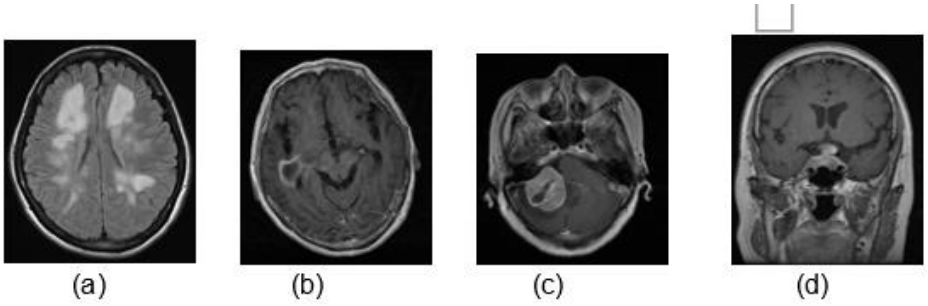


Figure 5.2 MRI brain tumor images: (a) No Tumor, (b) Glioma, (c) Meningioma, (d) Pituitary

UNIVERSIDAD DE MÁLAGA

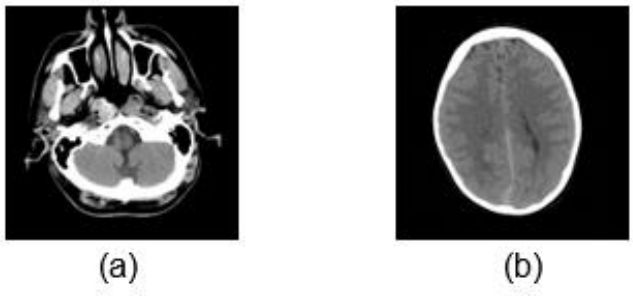


Figure 5.3 CT brain images: (a) No Tumor, (b) Tumor

While the other 35% was kept aside for assessment, then the MobileNetV3 model was trained using 65% of the dataset. With a learning rate of 0.005 and a batch size of 32, the training was done across 40 epochs. Best practices for MobileNetV3 guided the selection of these hyperparameters. The learning rate regulates the step size at each iteration while updating model weights, whereas batch size refers to the number of samples processed before updating the model. An epoch signifies one complete forward and backward pass of all training samples.

5.3.1 Class-wise Accuracy Evaluation

The classification performance of MobileNetV3 on each class with respect to the combined MRI and CT scan dataset has been presented in Table 5.3. The dataset comprised a total of 10,330 images, categorized into six distinct classes: four from MRI (Glioma, Meningioma, No Tumor, Pituitary) and two from CT (Tumor, No Tumor).

Class	Accuracy / #Samples
MRI Glioma	98% / 199
MRI Meningioma	90% / 201
MRI No Tumor	99% / 240
MRI Pituitary	96% / 219
CT Tumor	97% / 348
CT No Tumor	97% / 345

Table 5.3 Per-Class Accuracy Using MobileNetV3

Particularly for MRI No Tumor (99%), MRI Glioma (98%) and both CT Tumor and CT No Tumor (97%), it could be observed that the data reveal outstanding class wise accuracies. Considering the difficulty of medical image categorization, the somewhat lower accuracy for MRI Meningioma (90%) is still acceptable. These results show MobileNetV3's ability to distinguish between many categories of brain cancer and non-tumor cases across both MRI and CT imaging systems.

UNIVERSIDAD DE MÁLAGA

5.3.2 Epoch-wise Performance Analysis

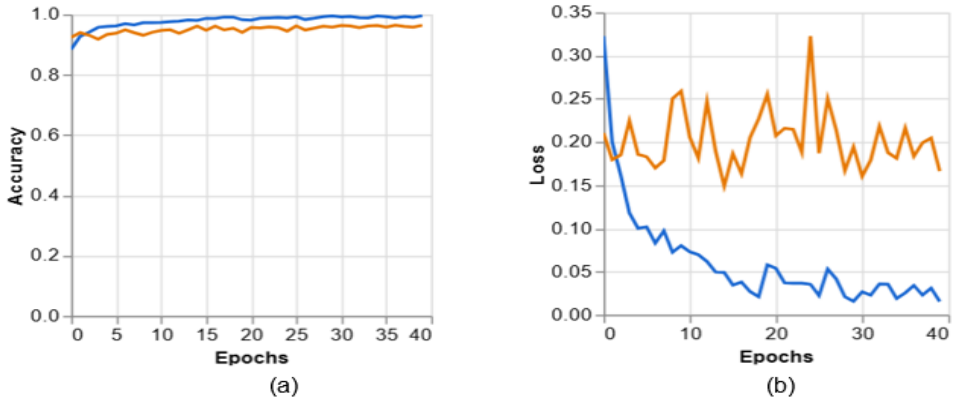


Figure 5.4 Combined performance of MobileNetV3 across epochs: (a) Accuracy per epoch, (b) Loss per epoch

Figure 5.4 (a) makes the illustrate that the training (blue) and testing (orange) performance of the MobileNetV3 model over 40 epochs. In Figure 5(a), training accuracy rapidly approaches 1.0, while testing accuracy consistently remains above 0.90, indicating strong learning and generalization capabilities. Figure 5.4 (b) shows a declining training loss nearing zero, while testing loss stabilizes around 0.15, suggesting that the model avoids overfitting and retains generalization power.

5.3.3 Evaluation Metrics for MobileNetV3 Performance

To make the assessment systematically with the diagnostic performance of the proposed model there were three critical evaluation metrics used: Precision, Recall, and F1-score. These metrics provide insights into the model's accuracy in identifying true positives, minimizing false positives, and maintaining overall balance in performance, especially in datasets with class imbalance. These metrics are calculated using equations 5, 6, and 7 respectively.

The necessary values for **True Positives (TP)**, **False Positives (FP)**, **False Negatives (FN)**, and **True Negatives (TN)** were extracted from the confusion matrix shown in **Figure 6**. The detailed metric results are listed in **Table IV**.

Class	Precision	Recall	F1-Score
MRI Glioma	0.94	0.98	0.96
MRI Meningioma	0.92	0.90	0.91
MRI No Tumor	0.98	0.99	0.98
MRI Pituitary	0.97	0.96	0.96
CT Tumor	0.98	0.97	0.98
CT No Tumor	0.98	0.97	0.97

Table 5.4 Precision, Recall, and F1-Score for MobileNetV3

UNIVERSIDAD DE MÁLAGA

The results in Table 5.4 indicate that MobileNetV3 maintained consistently high performance across all classes. Particularly the MRI No Tumor class achieved a recall of 0.99 and precision of 0.98 which reflects strong and reliable accuracy in identifying the non-tumor images on the basis of parameters. Similarly both CT Tumor and CT No Tumor classes reported precision and recall values between 0.97 and 0.98. These robust F1-scores ranging from 0.91 to 0.98 reinforce the reliability and generalization ability of MobileNetV3 on diverse imaging data.

5.3.4 Confusion Matrix Analysis

Figure 5.5 presents a confusion matrix that visually summarizes the prediction outcomes for each class. The minimal false positive and false negative rates validate the classification. The equilibrium and precision of MobileNetV3 across both imaging modalities. The approach enhanced diagnostic accuracy by successfully combining MRI and CT data using complimentary information. The findings demonstrate that MobileNetV3 has strong classification capabilities across diverse imaging inputs, highlighting its suitability for clinical application.

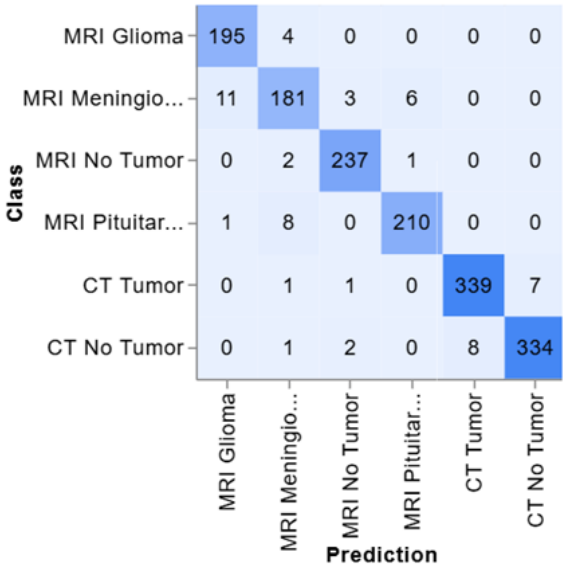


Figure 5.5 Confusion matrix for MobileNetV3 model on combined MRI and CT classification

5.3.5 Computational Cost Analysis

An evaluation of the MobileNetV3 model's computational performance was conducted on a machine that ran Windows 10 Pro (64-bit) without GPU acceleration using an Intel Core i5-6300U CPU (2.40 GHz) with 8 GB of RAM. With the parameters of 32-batch size, 0.005 learning rate and 40 epochs.

Depending on the size of the data set and the inference needs the model trained from 1 to 12 minutes despite the constrained computing resources. On approximation, each image took an average of 30 seconds to 1 minute for inference and processing of necessary actions. The model's computational efficiency, reliability and applicability for resource limited contexts are highlighted by its outstanding accuracy under restricted hardware circumstances.

UNIVERSIDAD DE MÁLAGA

5.4 Conclusion

Early and exact diagnosis significantly improves patient outcomes; hence accurate categorization of brain tumors is essential for developing successful treatment plans. Using both MRI and CT scan images four deep learning models ResNet50, DenseNet, EfficientNetB1, and MobileNetV3 were assessed in this work for their effectiveness in classifying brain cancers. Based on prior literature and experimental results, MobileNetV3 was selected as the optimal model due to its balance of computational efficiency and classification accuracy.

The model was trained using 40 epochs, a learning rate of 0.005, and a batch size of 32. The integration of MRI and CT data into a single categorization system is a major contribution of this research and study. Although the CT scans give thorough structural information that enables strong classification, but MRI pictures provide better soft tissue contrast for tumor detection. Combining both modalities helps the model to get supplementary diagnostic data that results in more sensitivity and less misclassification.

The results demonstrate that the MobileNetV3 model performs reliably across multiple tumor classes and imaging types, indicating its potential for clinical decision support in medical imaging. Future work may focus on enhancing the model by incorporating more advanced architecture, optimizing hyperparameters, and expanding the dataset to include more diverse and complex samples for improved generalizability.

UNIVERSIDAD DE MÁLAGA

Chapter 6: Conclusions and Future Work

6. Conclusions

This dissertation has provided a thorough investigation into the creation and assessment of a CXR-DNN model for the diagnosis of COVID-19 utilizing images of chest X-ray. The study's main goal is to employ the EfficientNetB7 CNN model to classify instances of COVID-19, pneumonia and normal patients. The main discoveries of this study are:

6.1 Development of the CXR-DNN Model

The EfficientNetB7 model was chosen because it is efficient and performs well in image classification tasks. The model was trained using the images of a wide range of chest X-ray from COVID-19, pneumonia and normal categories. The architecture was especially developed to maximize speed while reducing computational expenses.

6.2 Model Evaluation and Performance Metrics

The model's performance was evaluated using a variety of criteria including accuracy, precision, recall and F1-score. The model performed competitively, especially in detecting COVID-19 according to the results from the training, validation, and testing datasets. These findings demonstrate that the model has the potential to be used in real-world applications for automated medical diagnosis.

6.3 Comparison with Other Models

In order to determine how successful EfficientNetB7 the comparisons were done with various popular deep learning architectures including Inception v3, Xception and ResNet50. This

UNIVERSIDAD DE MÁLAGA

comparison underlined the better performance of EfficientNetB7 notably in terms of diagnostic accuracy for COVID-19 identification.

6.4 Contributions to Medical Imaging

This study adds to the existing knowledge in the field of medical imaging, particularly in the area of COVID-19 diagnosis. The work reveals that deep learning models, especially CNNs may deliver consistent and accurate results for image based diagnostic tasks indicating potential for deployment in real time clinical settings.

6.5 Future Work

Despite the success of the CXR-DNN model in COVID-19 diagnosis, there are several areas in which this research can be expanded and improved. Future research could focus on the directions described below.

6.5.1 Model Optimization

Even while EfficientNetB7 produced encouraging results the model's performance might be further improved by further optimization efforts such as hyperparameter tweaking and the application of advanced methods like transfer learning. Future studies might investigate ensemble approaches which combine the capabilities of different models to improve diagnosis accuracy.

6.5.2 Expanding the Dataset

The model would be better able to generalize across various populations if it were trained on a bigger and more varied dataset. The robustness of the model could be improved by including photographs from different demographic groups, geographic areas, and degrees of disease severity.

6.5.3 Multi-Modal Diagnosis

In future studies researchers may combine chest X-rays with additional diagnostic data such as CT scans, patient histories or biomarker data. Diagnostic accuracy might be improved by using multi-modal models that incorporate these multiple sources of data.

6.5.4 Real Time Deployment

In order for the model to be used in a clinical setting, it needs be improved for real time application. It will be important to decrease the time it takes to make forecasts and to ensure that predictions can be produced fast and correctly in real world situations. To make the system more accessible to healthcare practitioners, user-friendly interfaces should be created.

UNIVERSIDAD DE MÁLAGA

6.5.5 Expanding Beyond COVID-19

This study concentrates on COVID-19, however the methods that have been created here might be applied to other illnesses including pneumonia, TB and lung cancer. These modifications might make the model more adaptable and useful for a wider variety of respiratory illnesses.

6.5.6 Future Research in the SOS Application

In addition to the SOS Application Help Pro discussion further study might investigate how to include artificial intelligence and machine learning into emergency response systems. If real-time decision-making skills are added and the app is optimized for more complicated emergency circumstances the potential effect of such apps on public health and safety might be enormous.

6.5.7 Advanced AI Techniques

Future research might use reinforcement learning or generative adversarial networks (GANs) to enhance diagnostic skills and data augmentation. Investigating vision transformers for medical image processing may provide new opportunities to enhance diagnostic accuracy and model efficiency.

This dissertation makes a valuable addition to the area of COVID-19 diagnosis by deep learning, however there are still many intriguing potentials for future study and growth. If the recommendations mentioned above are expanded upon then it is possible that future breakthroughs in AI-based diagnostic systems and their integration into real-life applications might lead to major improvements in healthcare delivery throughout the globe.

UNIVERSIDAD DE MÁLAGA

Appendix A

Curriculum Vitae

Education

- Ph.D. in Telecommunications Engineering (submitted June 2025), University of Málaga, Málaga, Spain.
- MS Information Technology, Hamdard University, Karachi, Pakistan, 2013.
- BS Computer Engineering, Sir Syed University of Engineering and Technology, Karachi, Pakistan, 2002.

Professional Experience

- Assistant Professor: Software Engineering Department at Sir Syed University of Engineering and Technology, Karachi, Pakistan - from December 2018 – Current.
- Assistant Professor: Computer Engineering Department at Sir Syed University of Engineering and Technology, Karachi, Pakistan - from July 2014 – November 2018.
- Lecturer: Computer Engineering Department at Sir Syed University of Engineering and Technology, Karachi, Pakistan - from November 2005 – June 2014.
- Demonstrator: Computer Engineering Department at Sir Syed University of Engineering and Technology, Karachi, Pakistan - from July 2004 – October 2005.

Journal Publications

- Ali Yousuf Khan, Miguel-Ángel Luque-Nieto, Muhammad Imran Saleem, and Enrique Nava. 2024. "X-Ray Image-Based Real-Time COVID-19 Diagnosis Using Deep Neural Networks (CXR-DNNs)."*Journal of Imaging* 10, no. 12: 328. https://doi.org/10.3390/jimaging10120328.
- Ali Yousuf Khan, Miguel-Ángel Luque-Nieto, Samiya Batool, Hammad Ahmed, Abdul Hadi Saeed, Zaid Asif, “SOS Application Under Android: Help Pro.” *Wireless Personal Communications*, vol. 128, pp.: 987-1002, Jan. 2023, Issue 2. https://doi.org/10.1007/s11277-022-09985-4.

Conference Publications

- Ali Yousuf Khan, Miguel Ángel Luque-Nieto, Hifsa Ansari, Ubaid-ur-Rahman, S. I. Waris and S. u. Z. Durrani. "Augmented Reality EleReactor Organic Chemistry," 2022 Global Conference on Wireless and Optical Technologies (GCWOT), Malaga, Spain, 2022, pp. 1-9. DOI: 10.1109/GCWOT53057.2022.9772917.
- Ali Yousuf Khan, Pablo Otero, Samiya Batool, Hammad Ahmed, Abdul Hadi Saeed; Zaid Asif. "Help Pro," 2020 Global Conference on Wireless and Optical Technologies (GCWOT), Malaga, Spain, 2020, pp. 1-5. DOI: 10.1109/GCWOT49901.2020.9391618.

UNIVERSIDAD DE MÁLAGA

Bibliography

[1] Yu Lu, Xudong Gao, and Narasimhan Venkateswaran. 2022. The Impact of Artificial Intelligence Technology on Market Public Administration in Complex Market Environment. Wirel. Commun. Mob. Comput. **2022** (2022). https://doi.org/10.1155/2022/5646234.

[2] Liu X, Yao C, Chen H, Xiang R, Wu H, Du P, Yu Z, Liu W, Liu J, Geng D. **2023**. BTSC-TNAS: A neural architecture search-based transformer for brain tumor segmentation and classification. Comput Med Imaging Graph. 2023 Dec; 110:102307. doi:10.1016/j.compmedimag.2023.102307. Epub 2023 Oct 27. PMID: 37913635.

[3] Balamurugan, T., Gnanamanoharan, E. **2023**. Brain tumor segmentation and classification using hybrid deep CNN with LuNetClassifier. Neural Comput. Appl. 35 (6), 4739–4753. http://dx.doi.org/10.1007/s00521-022-07934-7.

[4] Farajzadeh, N., Sadeghzadeh, N., Hashemzadeh, M., **2023**. Brain tumor segmentation and classification on MRI via deep hybrid representation learning. Expert Syst. Appl. 224, 119963. http://dx.doi.org/10.1016/j.eswa.2023.119963.

[5] Hussain, T., Ullah, A., Haroon, U., Muhammad, K., Baik, S.W. **2021**. A comparative analysis of efficient CNN-based brain tumor classification models. Chapter 11. pp. 259–278, 2021. http://dx.doi.org/10.1142/9789811218842_0011.

[6] Neelima, G., Chigurukota, D.R., Maram, B., Girirajan, B. **2022**. Optimal DeepMRSeg based tumor segmentation with GAN for brain tumor classification. Biomed. Signal Process. Control 74, 103537. http://dx.doi.org/10.1016/j.bspc.2022.103537

[7] Pinaya, W.H., Tudosiu, P.-D., Gray, R., Rees, G., Nachev, P., Ourselin, S., Cardoso, M.J. **2022**. Unsupervised brain imaging 3D anomaly detection and segmentation with transformers. Med. Image Anal. 79, 102475. http://dx.doi.org/10.1016/j.media. 2022.102475.

[8] Rehman, A., Naz, S., Razzak, M.I., Akram, F., Imran, M. **2020**. A deep learningbased framework for automatic brain tumors classification using transfer learning. Circuits Systems Signal Process. 39, 757–775. http://dx.doi.org/10.1007/s00034-019-01246-3.

[9] Sadad, T., Rehman, A., Munir, A., Saba, T., Tariq, U., Ayesha, N., Abbasi, R. **2021**. Brain tumor detection and multi-classification using advanced deep learning techniques. Microsc. Res. Tech. 84 (6), 1296–1308. http://dx.doi.org/10.1002/jemt.23688.

[10] Sehgal, A., Goel, S., Mangipudi, P., Mehra, A., Tyagi, D. **2016**. Automatic brain tumor segmentation and extraction in MR images. In: 2016 Conference on Advances in Signal Processing (CASP). pp. 104–107. http://dx.doi.org/10.1109/CASP.2016.7746146.

[11] Sobhaninia, Z., Karimi, N., Khadivi, P., Samavi, S. **2023**. Brain tumor segmentation by cascaded multiscale multitask learning framework based on feature aggregation. Biomed. Signal Process. Control 85, 104834. http://dx.doi.org/10.1016/j.bspc.2023.104834.

[12] Wang, S.-Q., Yuan, Q., Zhang, G.-T., Qian, H.-P., Liu, Z.-D., Wang, J.-W., Cai, H.-Q., Wan, J.-H. **2022**. Preoperative blood testing for glioblastoma, brain metastases, and primary central nervous system lymphoma differentiation. Transl. Cancer Res. 11 (1), 63. http://dx.doi.org/10.21037/tcr-21-1957.

[13] Yang, Y., Yan, L.-F., Zhang, X., Han, Y., Nan, H.-Y., Hu, Y.-C., Hu, B., Yan, S.- L., Zhang, J., Cheng, D.-L., et al. **2018**. Glioma grading on conventional MR images: a deep learning study with transfer learning. Front. Neurosci. 12, 804.http://dx.doi.org/10.3389/fnins.2018.00804.

[14] Zhang, L., Liu, X., Xu, X., Liu, W., Jia, Y., Chen, W., Fu, X., Li, Q., Sun, X., Zhang, Y.,et al. **2023**. An integrative non-invasive malignant brain tumors classification and Ki-67 labeling index prediction pipeline with radiomics approach. Eur. J. Radiol.158, 110639. http://dx.doi.org/10.1016/j.ejrad.2022.110639.

UNIVERSIDAD DE MÁLAGA

[15] Zhu, Z., He, X., Qi, G., Li, Y., Cong, B., Liu, Y. **2023**. Brain tumor segmentation based on the fusion of deep semantics and edge information in multimodal MRI. Inf.Fusion 91, 376–387. http://dx.doi.org/10.1016/j.inffus.2022.10.022.

[16] Sultan, H.H.; Salem, N.M.; Al-Atabany, W. **2019**. Multi-Classification of Brain Tumor Images Using Deep Neural Network. IEEE Access, 2019, 7, 69215–69225. [CrossRef]

[17] Sahoo, L.; Sarangi, L.; Dash, B.R.; Palo, H.K. **2019**. Detection and Classification of Brain Tumor Using Magnetic Resonance Images.In Advances in Electrical Control and Signal Systems: Select Proceedings of AECSS, Bhubaneswar, India, 8–9 November 2019; Springer:Singapore, 2020; Volume 665, pp. 429–441. [CrossRef]

[18] Kaur, R.; Doegar. **2019**. A. Localization and Classification of Brain Tumor using Machine Learning & Deep Learning Techniques. Int. J.Innov. Technol. Explor. Eng. 2019, 8, 59–66.

[19] Luo, Q.; Li, Y.; Luo, L.; Diao,W. **2018**. Comparisons of the accuracy of radiation diagnostic modalities in brain tumor. Medicine 2018, 97, e11256. [CrossRef]

[20] Borole, V.Y.; Nimbhore, S.S.; Kawthekar, S.S. **2015**. Image processing techniques for brain tumor detection: A review. Int. J. Emerg.Trends Technol. Comput. Sci. (IJETTCS) 2015, 4, 2.

[21] Amin, J.; Sharif, M.; Yasmin, M.; Fernandes, S.L. **2017.** A distinctive approach in brain tumor detection and classification using MRI.Pattern Recognit. Lett. 2017, 139, 118–127. [CrossRef]

[22] Islam, A.; Reza, S.M.; Iftekharuddin, K.M. **2013.** Multifractal texture estimation for detection and segmentation of brain tumors. IEEE Trans. Biomed. Eng. 2013, 60, 3204–3215. [CrossRef]

[23] Gurbina, M.; Lascu, M.; Lascu, D. **2019**. Tumor detection and classification of MRI brain image using different wavelet transformsand support vector machines. In Proceedings of the 2019 42nd International Conference on Telecommunications and Signal Processing (TSP), Budapest, Hungary, 1–3 July 2019; pp. 505–508.

[24] Kaplan, K.; Kaya, Y.; Kuncan, M.; Ertunç, H.M. **2020.** Brain tumor classification using modified local binary patterns (LBP) feature extraction methods. Med. Hypotheses 2020, 139, 109696. [CrossRef]

[25] Gurusamy, R.; Subramaniam, V. **2017.** A machine learning approach for MRI brain tumor classification. Comput. Mater. Contin. 2017, 53,91–109.

[26] Hooda, H.; Verma, O.P.; Singhal, T. **2014**. Brain tumor segmentation: A performance analysis using K-Means, Fuzzy C-Means and Region growing algorithm. In Proceedings of the 2014 IEEE International Conference on Advanced Communications, Control and Computing Technologies, Ramanathapuram, India, 8–10 May 2014; pp. 1621–1626.

[27] Khan, M.S.; Lali, M.I.U.; Saba, T.; Ishaq, M.; Sharif, M.; Saba, T.; Zahoor, S.; Akram, T. **2019**. Brain tumor detection and classification: A framework of marker-based watershed algorithm and multilevel priority features selection. Microsc. Res. Tech. 2019, 82, 909–922.[CrossRef]

[28] Ye, N.; Yu, H.; Chen, Z.; Teng, C.; Liu, P.; Liu, X.; Xiong, Y.; Lin, X.; Li, S.; Li, X. **2022.** Classification of Gliomas and Germinomas of the Basal Ganglia by Transfer Learning. Front. Oncol. 2022, 12, 844197. [CrossRef]

[29] MUNIR, Muhammad Wasim; OMAIR, Syed Muhammad; HAQUE, M. Zeeshan Ul. **2015**. An Android based application for determine a specialized hospital nearest to patient's location. *International Journal of Computer Applications*, *118*(9), 43–46.

[30] Chao Wang, Wei Duan, Jianzhang Ma and Chenhui Wang. **2011**. The research of Android System architecture and application programming. In: Proc. of 2011 Int. Conf. on Computer Science and Network Technology, Harbin, 2011, pp. 785–790.

UNIVERSIDAD DE MÁLAGA

[31] Ghayyur, Shahbaz Ahmed Khan., Ahmed, Salman, Naseem, Adnan, & Razzaq, Abdul. **2017**. Motivators and Demotivators of Agile Software Development: Elicitation and Analysis. *International Journal of Advanced Computer Science and Applications (IJACSA), 8*(12), 304–314.

[32] Khan, Arsalan, Bibi, Farzana, Dilshad, Muhammad, Ahmed, Salman, & Ullah, Zia. **2018**. Accident Detection and Smart Rescue System using Android Smartphone with Real-Time Location Tracking. *International Journal of Advanced Computer Science and Applications, 9*(6), 341–355.

[33] Magar, Shyamsundar, Jadhav, Vinayak, & Raut, Omkar. **2020**. Ambuitec: ambulance booking application for emergency health response, blood inventory. *Test Engineering and Management, 83*, 12068–12075.

[34] Coronavirus Disease (COVID-19) pandemic. https://www.who.int/emergencies/diseases/novel-coronavirus-2019 . Last access: Feb. 2023, 14th.

[35] A. Kumar, P. K. Gupta, and A. Srivastava. **2020**. A review of modern technologies for tackling COVID-19 pandemic. Diabetes Metabolic Syndrome Clin. Res. Rev., vol. 14, no. 4, pp. 569–573, 2020.

[36] A. Dhere and J. Sivaswamy. **2022**. COVID Detection From Chest X-Ray Images Using Multi-Scale Attention. In: IEEE Journal of Biomedical and Health Informatics, vol. 26, no. 4, pp. 1496-1505, April 2022. https://doi.org/10.1109/JBHI.2022.3151171.

[37] Alexandra C Walls et al. **2020**. Structure, function, and antigenicity of the SARS-CoV-2 spike glycoprotein. In: Cell 181.2 (2020), pp. 281–292.

[38] Prabira Kumar Sethy, Santi Kumari Behera, Pradyumna Kumar Ratha, and Preesat Biswas. **2020**. Detection of coronavirus disease (covid-19) based on deep features and support vector machine. In: International Journal of Mathematical, Engineering and Management Sciences, Vol. 5, No. 4, 643-651, 2020. https://doi.org/10.33889/IJMEMS.2020.5.4.052.

[39] Muhammad E. H. Chowdhury et al. **2020**. Can AI Help in Screening Viral and COVID-19 Pneumonia? In: IEEE Access 8 (2020), pp. 132665–132676. DOI: 10.1109/ACCESS.2020.3010287.

[40] Md Mamunur Rahaman et al. **2020**. Identification of COVID-19 samples from chest X-Ray images using deep learning: A comparison of transfer learning approaches. In: Journal of X-Ray Science and Technology 28 (2020). 5, pp. 821–839. ISSN: 1095-9114. DOI: 10.3233/XST- 200715. URL: https://doi.org/10.3233/XST-200715.

[41] Talha Anwar and Seemab Zakir. **2020**. Deep learning-based diagnosis of COVID-19 using chest CT-scan images. In: 2020 IEEE 23rd International Multitopic Conference (INMIC). 2020, pp. 1–5. DOI: 10.1109/INMIC50486.2020.9318212.

[42] Sheetal, R.; Kumar, N.; Rajpal, A. **2020**. COV-ELM classifier: An Extreme Learning Machine based identification of COVID-19 using Chest-ray Images. arXiv 2020, arXiv:2007.08637.

[43] Abdelkader, B.; Ouhbi, S.; Lakas, A.; Benkhelifa, E.; Chen, C. **2021**. End-to-End AI-Based Point-of-Care Diagnosis System for Classifying Respiratory Illnesses and Early Detection of COVID-19. Front. Med. 2021. [CrossRef]

[44] Liang, S.; Mo, Z.; Yan, F.; Xia, L.; Shan, F.; Ding, Z.; Song, B. **2020.** Adaptive feature selection guided deep forest for covid-19 classification with chest ct. IEEE J. Biomed. Health Inform. 2020. [CrossRef]

[45] Das, A.K.; Ghosh, S.; Thunder, S.; Dutta, R.; Agarwal, S.; Chakrabarti, A. **2021.** Automatic COVID-19 detection from X-ray images using ensemble learning with convolutional neural network. Pattern Anal. Applic. 2021. [CrossRef]

[46] Rajpurkar, P.; Irvin, J.; Zhu, K.; Yang, B.; Mehta, H.; Duan, T.; Ding, D.; Bagul, A.; Langlotz, C.; Shpanskaya, K.; et al. **2017.** Chex-net: Radiologist-level pneumonia detection on chest X-rays with deep learning. arXiv 2017, arXiv:1711.05225.

UNIVERSIDAD DE MÁLAGA

[47] Jung Cheng. Figshare Brain Tumor Dataset. **2017**. Available online: https://figshare.com/articles/dataset/brain_tumor_dataset/1512427/5 (dataset posted on 2017-04-02. Accessed on 13 May 2022).

[48] Gordillo, N.; Montseny, E.; Sobrevilla, P. **2010**. A new fuzzy approach to brain tumor segmentation. In Proceedings of the 2010 IEEE International Conference, Barcelona, Spain, 18–23 July 2010; pp. 1–8. [CrossRef]

[49] Almahfud, M.A.; Setyawan, R.; Sari, C.A.; Setiadi, D.R.I.M.; Rachmawanto, E.H. **2018**. An Effective MRI Brain Image Segmentation using Joint Clustering (K-Means and Fuzzy C-Means). In Proceedings of the 2018 International Seminar on Research of Information Technology and Intelligent Systems (ISRITI), Yogyakarta, Indonesia, 21–22 November 2018; pp. 11–16.

[50] Chen,W.; Qiao, X.; Liu, B.; Qi, X.;Wang, R.; Wang, X. **2017**. Automatic brain tumor segmentation based on features of separated local square. In Proceedings of the 2017 Chinese Automation Congress (CAC), Jinan, China, 20–22 October 2017.

[51] Gupta, N.; Mishra, S.; Khanna, P. **2018**. Glioma identification from brain MRI using superpixels and FCM clustering. In Proceedings of the 2018 Conference on Information and Communication Technology (CICT), Jabalpur, India, 26–28 October 2018. [CrossRef]

[52] Razzak, M.I.; Imran, M.; Xu, G. **2018.** Efficient Brain Tumor Segmentation with Multiscale Two-Pathway-Group Conventional Neural Networks. IEEE J. Biomed. Health Inform. 2018, 23, 1911–1919. [CrossRef] [PubMed]

[53] Myronenko, A.; Hatamizadeh, A. **2020**. Robust Semantic Segmentation of Brain Tumor Regions from 3D MRIs. In Proceedings of the International MICCAI Brainlesion Workshop, Singapore, 18 September 2020; pp. 82–89. [CrossRef]

[54] Karayegen, G.; Aksahin, M.F. **2021.** Brain tumor prediction on MR images with semantic segmentation by using deep learning network and 3D imaging of tumor region. Biomed. Signal Process. Control. 2021, 66, 102458. [CrossRef]

[55] Ullah, Z.; Usman, M.; Jeon, M.; Gwak, J. **2022.** Cascade multiscale residual attention CNNs with adaptive ROI for automatic brain tumor segmentation. Inf. Sci. 2022, 608, 1541–1556. [CrossRef]

[56] Wisaeng, K.; Sa-Ngiamvibool, W. **2023.** Brain Tumor Segmentation Using Fuzzy Otsu Threshold Morphological Algorithm. IAENG Int.J. Appl. Math. 2023, 53, 1–12.

[57] Zhang, Y.; Dong, Z.;Wu, L.;Wang, S. **2011.** A hybrid method for MRI brain image classification. Expert Syst. Appl. 2011, 38, 10049–10053. [CrossRef]

[58] Yang, G.; Zhang, Y.; Yang, J.; Ji, G.; Dong, Z.; Wang, S.; Feng, C.; Wang, Q. **2015.** Automated classification of brain images using wavelet-energy and biogeography-based optimization. Multimed. Tools Appl. 2015, 75, 15601–15617. [CrossRef]

[59] Tiwari, P.; Sachdeva, J.; Ahuja, C.K.; Khandelwal, N. **2017.** Computer Aided Diagnosis System—A Decision Support System for Clinical Diagnosis of Brain Tumours. Int. J. Comput. Intell. Syst. 2017, 10, 104–119. [CrossRef]

[60] Sachdeva, J.; Kumar, V.; Gupta, I.; Khandelwal, N.; Ahuja, C.K. **2013.** Segmentation, Feature Extraction, and Multiclass Brain Tumor Classification. J. Digit. Imaging 2013, 26, 1141–1150. [CrossRef]

[61] Jayachandran, A.; Dhanasekaran, R. **2014.** Severity Analysis of Brain Tumor in MRI Images Using Modified Multitexton Structure Descriptor and Kernel-SVM. Arab. J. Sci. Eng. 2014, 39, 7073–7086. [CrossRef]

[62] El-Dahshan, E.-S.A.; Hosny, T.; Salem, A.-B.M. **2010.** Hybrid intelligent techniques for MRI brain images classification. Digit. Signal Process. 2010, 20, 433–441. [CrossRef]

[63] Ullah, Z.; Farooq, M.U.; Lee, S.-H.; An, D. **2020.** A hybrid image enhancement-based brain MRI images classification technique. Med. Hypotheses 2020, 143, 109922. [CrossRef] [PubMed]

UNIVERSIDAD DE MÁLAGA

[64] Kang, J.; Ullah, Z.; Gwak, J. **2021.** MRI-Based Brain Tumor Classification Using Ensemble of Deep Features and Machine Learning Classifiers. Sensors 2021, 21, 2222. [CrossRef]

[65] Díaz-Pernas, F.; Martínez-Zarzuela, M.; Antón-Rodríguez, M.; González-Ortega, D. **2021.** A Deep Learning Approach for Brain Tumor Classification and Segmentation Using a Multiscale Convolutional Neural Network. Healthcare 2021, 9, 153. [CrossRef] [PubMed]

[66] Badža, M.M.; Barjaktarovi´c, M. **2020.** Classification of Brain Tumors from MRI Images Using a Convolutional Neural Network. Appl. Sci. 2020, 10, 1999. [CrossRef]

[67] Khan, H.A.; Jue, W.; Mushtaq, M.; Mushtaq, M.U. **2020.** Brain tumor classification in MRI image using convolutional neural network. Math. Biosci. Eng. 2020, 17, 6203–6216. [CrossRef]

[68] Özcan, H.; Emiroˇ glu, B.G.; Sabuncuoˇ glu, H.; Özdoˇgan, S.; Soyer, A.; Saygı, T. **2021.** A comparative study for glioma classification using deep convolutional neural networks. Math. Biosci. Eng. MBE 2021, 18, 1550–1572. [CrossRef]

[69] Hao, R.; Namdar, K.; Liu, L.; Khalvati, F. **2021.** A Transfer Learning–Based Active Learning Framework for Brain Tumor Classification. Front. Artif. Intell. 2021, 4, 635766. [CrossRef]

[70] El Hamdaoui, H.; Benfares, A.; Boujraf, S.; Chaoui, N.E.H.; Alami, B.; Maaroufi, M.; Qjidaa, H. **2021.** High precision brain tumor classification model based on deep transfer learning and stacking concepts. Indones. J. Electr. Eng. Comput. Sci. 2021, 24, 167–177. [CrossRef]

[71] Khazaee, Z.; Langarizadeh, M.; Ahmadabadi, M.E.S. **2022.** Developing an Artificial Intelligence Model for Tumor Grading and Classification, Based on MRI Sequences of Human Brain Gliomas. Int. J. Cancer Manag. 2022, 15, e120638. [CrossRef]

[72] Amou, M.A.; Xia, K.; Kamhi, S.; Mouhafid, M. A **2022.** Novel MRI Diagnosis Method for Brain Tumor Classification Based on CNN and Bayesian Optimization. Healthcare 2022, 10, 494. [CrossRef] [PubMed]

[73] Alanazi, M.; Ali, M.; Hussain, J.; Zafar, A.; Mohatram, M.; Irfan, M.; AlRuwaili, R.; Alruwaili, M.; Ali, N.T.; Albarrak, A.M. **2022.** Brain Tumor/Mass Classification Framework Using Magnetic-Resonance-Imaging-Based Isolated and Developed Transfer Deep-Learning Model. Sensors, 22, 372. [CrossRef] [PubMed]

[74] Rizwan, M.; Shabbir, A.; Javed, A.R.; Shabbr, M.; Baker, T.; Al-Jumeily, D. **2022.** Brain Tumor and Glioma Grade Classification Using Gaussian Convolutional Neural Network. IEEE Access 2022, 10, 29731–29740. [CrossRef]

[75] Isunuri, B.V.; Kakarla, J. **2021.** Three-class brain tumor classification from magnetic resonance images using separable convolution based neural network. Concurr. Comput. Pract. Exp. 2021, 34, e6541. [CrossRef]

[76] Kaur, T.; Gandhi, T.K. **2020.** Deep convolutional neural networks with transfer learning for automated brain image classification. J. Mach. Vis. Appl. 2020, 31, 20. [CrossRef]

[77] Khan, A.Y., Luque-Nieto, MÁ., Batool, S. *et al.* **2023**. SOS Application Under Android: Help Pro. *Wireless Pers Commun* **128**, 987–1002, 2023. https://doi.org/10.1007/s11277-022-09985-4.

[78] Khan, A.Y.; Luque-Nieto, M.-A.; Saleem, M.I.; Nava-Baro, E. **2024.** X-Ray Image-Based Real-Time COVID-19 Diagnosis Using Deep Neural Networks (CXR-DNNs). *J. Imaging* 2024, *10*, 328. https://doi.org/10.3390/jimaging10120328

UNIVERSIDAD DE MÁLAGA