4 Design

4.1 Design Content

Briefly describe what is the design content in your project.

The project aims to leverage artificial intelligence (AI) to predict the occurrence and recurrence of cancer, with the ultimate goal of improving cancer treatment. It also seeks to provide AI training for students, equipping them with the skills necessary to build and train a medical AI diagnosis tool.

4.2 Design Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles

The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

> The project's technical complexity can be justified by the following components/subsystems and their associated scientific, mathematical, or engineering principles:
>
> 1. Data Collection: This involves the application of data science principles to gather and preprocess data from various sources. It requires knowledge of data structures, databases, and possibly web scraping or API usage.
> 2. Model Development: This involves the use of machine learning principles to build an AI model. It requires a deep understanding of algorithms, linear algebra, calculus, statistics, and probability.
> 3. Model Training: This involves the application of optimization techniques to train the AI model on the collected data. It requires knowledge of gradient descent algorithms, backpropagation, and other advanced mathematical concepts.
> 4. Model Evaluation: This involves the use of statistical measures to evaluate the performance of the trained model. It requires understanding of concepts like precision, recall, F1 score, ROC curves, etc. Should we not like accuracy of the simple AI model then, we will be using transfer learning to improve the accuracy and latency of our model.
> 5. AI Training for Students: This involves pedagogical skills to effectively teach students about AI and its applications in medical diagnosis. It requires knowledge of educational psychology and instructional design.
>
> The problem scope also contains multiple challenging requirements that match or exceed current solutions or industry standards:
>
> - The project aims to predict the occurrence and recurrence of cancer, which is a complex problem due to the myriad factors that can influence cancer development and progression.

- The project seeks to improve upon current solutions by leveraging AI for more accurate predictions than human doctors alone.
- The project also aims to equip students with skills to build and train a medical AI diagnosis tool, thereby contributing to the development of future professionals in this field.

4.3 Modern Engineering Tools

- Tensorflow- An open source library for machine learning and artificial intelligence. It will provide us with all the functionalities required for training and adjusting our AI model.
- Keras- An open source library for multiple pre-implemented neural networks. This library will provide us with a neural network model that we will use in transfer learning to adjust the model to better fit our needs.
- GitLab- Track the progress of our project and allow easy sharing of code. It will also allow us to revert back to older implementations of our project and start independent branches to work on specific tasks without interfering with others.
- Python- A programming language that lends itself greatly to the development and training of AI. All neural networks on Keras are implemented in python.
- SQL- A database language that we will use for storing and retrieving data for our AI.
- JavaScript- A programming language we will use for our front end development of the website for our healthcare professionals.

4.4 Design Context

Communities affected

– Patients at risk and those diagnosed with cancer.

– Families of patients, healthcare policy makers, and the general public.

Societal Needs Addressed

– The project addresses the need for early and accurate cancer detection, which often translates to better prognosis and survival rates. It also addresses the need for automation in diagnostics to help with the increasing number of cancer cases globally.

Public Health, Safety, and Welfare

– Positive impacts include, early and accurate cancer prediction could lead to improved patient survival rates, and may reduce the number of unnecessary procedures.

– Negative impacts include, potential false negatives or false positives. This could lead to missed treatments or unnecessary stress and medical interventions.

Global, Cultural, and Social

– Positive impacts: Universal access to such a tool could lead to standardized cancer care across different regions, which would benefit areas with less access to expert diagnostics. The system might also overcome bias in human-based diagnoses.

– Challenges: Cultural skepticism towards AI may make people hesitant to trust the diagnoses. Additionally, if we are too reliant on the technology it could lead to medical professionals to lose a bit of their skill.

Environmental

– Positive impact: If the system reduces the need for other means of testing due to improved accuracy, it could lead to decreased usage of medical resources and chemicals related to cancer screenings.

– Negative impact: The energy consumption of training and deploying the neural network could be significant.

Economic

– Positive impact: Faster and more accurate diagnosis could reduce the overall treatment cost by catching cancers early, leading to less aggressive treatments and shorter hospital stays. For healthcare providers the efficiency of an automated system could lead to reduced labor costs.

– Challenges: There might be potential job displacements if AI takes over roles traditionally held by medical professionals. However the tool will most likely be used as an aid rather than a replacement.

4.5 Prior Work/Solutions

A number of large studies have been done recently to assess the usefulness of AI in the realm of oncology. The resulting conclusion is that AI has strong potential in predicting and diagnosing cancer using pathology profiles and images studies (Zhang et al., 2023). The University of Pittsburgh in 2020 created a very accurate machine learning technique that diagnoses prostate cancer with a specificity of 98% and sensitivity of 98% (cite 1). Another AI technique that has been used recently was based on a Google DeepMind algorithm and was used to predict breast cancer more accurately than human specialists, also in 2020 (McKinney et al., 2020)

Oncology imaging studies using AI have an advantage in that training AI on images is relatively straightforward with huge results, such as the above mentioned case where breast cancer prediction was more accurate than a human specialist in that area. There are several disadvantages of using imaging for cancer research. One is that in some cases it is heavily biased, such as in detecting skin cancer the accuracy varies depending on the color of skin (Wen et al., 2021). Another study done showed that the AI could tell which institution had supplied the images and ended up lumping patients together by institution when training itself on the data which could lead to results based off of the institution rather than individual biology (Wood, 2021).

For AI training based on pathology data there is an issue of procuring good data. Training a model requires massive datasets to create accurate profiles, and this is tricky in the healthcare industry due to issues such as patient privacy, lack of data shared between institutions, and availability of data in general (Khan et al., 2023).

Due to some unforeseen circumstances with our advisor/client we are still in the process of getting information about the data we are using and our exact implementation goal. From what we know so far we will be training our AI model on sparse representation data pulled from images of cancerous and non-

cancerous cells in the form of csv files. Each file is one image and column A gives a position x coordinate and column B is the corresponding value which together can be read as a vector.

The advantage to our approach is that we are specifically training just on the cells, so we can identify any kind of cancer since all cancer cells look the same. We also do not run into any bias such as encountered in skin cancer image studies.

The corresponding disadvantage is we cannot differentiate what kind of cancer it is.

Khan, B. *et al.* (2023) *Drawbacks of artificial intelligence and their potential solutions in the healthcare sector*, *Biomedical materials & devices (New York, N.Y.)*. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9908503/ (Accessed: 22 October 2023).

McKinney, S.M. *et al.* (2020) *International Evaluation of an AI system for breast cancer screening*, *Nature News*. Available at: https://www.nature.com/articles/s41586-019-1799-6 (Accessed: 22 October 2023).

Wen, D. (2021) *Characteristics of publicly available skin cancer image datasets: A …*, *The Lancet Digital Health*. Available at: https://www.thelancet.com/journals/landig/article/PIIS2589-7500(21)00252-1/fulltext (Accessed: 22 October 2023).

Wood, M. (2021) *Artificial intelligence models to analyze cancer images can take shortcuts that introduce bias for minority patients*, *UChicago Medicine*. Available at: https://www.uchicagomedicine.org/forefront/research-and-discoveries-articles/artificial-intelligence-models-to-analyze-cancer-images-can-take-shortcuts-that-introduce-bias-for-minority-patients (Accessed: 22 October 2023).

Zhang, B., Shi, H. and Wang, H. (2023) *Machine learning and AI in cancer prognosis, prediction, and treatment selection: A critical approach*, *Journal of multidisciplinary healthcare*. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10312208/#:~:text=Machine%20learning%20(ML)%2C%20a,in%20predicting%20cancer%20than%20clinicians (Accessed: 22 October 2023).

4.6 Design Decisions

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc

1. Choice of AI Model: The type of AI model to be used needs to be decided. This could be a decision between using a Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), or other types of models. The choice will depend on the nature of the data and the specific requirements of the problem.
2. Data Preprocessing: Decisions need to be made about how to preprocess the data. This could involve dealing with missing values, normalizing numerical data, encoding categorical data, etc.

3. Model Evaluation Metrics: The metrics used to evaluate the performance of the model need to be decided. This could include accuracy, precision, recall, F1 score, etc.
4. Training Methodology: Decisions need to be made about how to train the model. This includes choosing an optimization algorithm, deciding on the number of epochs, batch size, learning rate, etc.
5. Deployment Strategy: The trained model will be integrated into a web service. This web service will allow users to input their data and receive an assessment of their cancer occurrence and recurrence chances. However, it's important to note that this service is intended to be a supplementary tool and not a replacement for professional medical advice. Users are strongly advised to consult with medical professionals for a comprehensive evaluation of their health. This approach ensures that our AI tool aids in the process of medical diagnosis while emphasizing the irreplaceable value of professional medical consultation.

4.7 Proposed Design

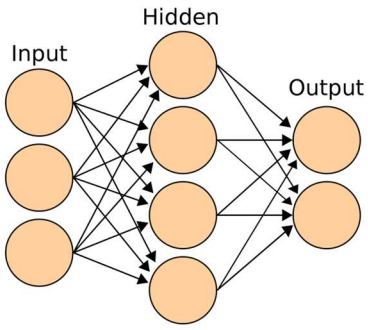
Discuss what you have done so far – what have you tried/implemented/tested?

After some extensive research, we have found one neural network on Keras that we believe to be the most relevant to our project. We have read over the code to begin understanding how this model was trained, and from that, how it was used for predictions. Due to us lacking the necessary data, we have been unable to begin training or testing the model we have selected.

4.7.1 Design 0 (Initial Design)

Design Visual and Description

Include a visual depiction of your current design. Different visual types may be relevant to different types of projects. You may include: a block diagram of individual components or subsystems and their interconnections, a circuit diagram, a sketch of physical components and their operation, etc.

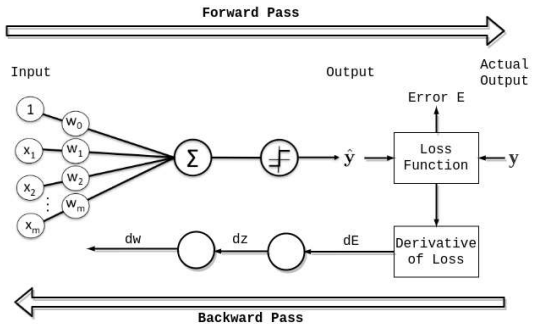


Describe your current design, referencing the visual. This design description should be in sufficient detail that another team of engineers can look through it and implement it.

Justify each component in the design with respect to requirements.

https://stackabuse.com/introduction-to-neural-networks-with-scikit-learn/

- We will have 6 hidden layers in our neural network. The number of layers affects both the accuracy of the AI and the time of completion. The number 6 was selected to keep the runtime low while also giving us a high accuracy.



- We will use 10 epochs. Epochs are the number of training rounds the neural network undergoes with the data. 10 rounds was chosen because as the model is trained, it becomes more accurate at predicting the data, but we also want to avoid overfitting our model to the training data, and so we need a midrange number of epochs to train our data. This will prevent our model from having a higher validation error.

https://www.baeldung.com/cs/epoch-neural-networks

Functionality

Describe how your design is intended to operate in its user and/or real-world context. This description can be supplemented by a visual, such as a timeline, storyboard, or sketch.

How well does the current design satisfy functional and non-functional requirements?

Our project is meant to be used by healthcare professionals to predict the occurrence and recurrence of cancer. Right now, we do not have a working model of any kind, but our completed project will have a website where doctors can input patient data and get back an accurate prediction if the patient has cancer.

4.7.2 Design 1 (Design Iteration)

Include another most matured design iteration details. Describe what led to this iteration and what are the major changes that were needed in Design 0.

Design Visual and Description

Include a visual depiction of this design as well highlighting changes from Design 0. Describe these changes in detail. Justify them with respect to requirements.

NOTE: The following sections will be included in your final design document but do not need to be completed for the current assignment. They are included for your reference. If you have ideas for these sections, they can also be discussed with your TA and/or faculty adviser.

4.8 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available. Discuss possible solutions and design alternatives

Strengths:

1. **Accuracy**: AI models, especially those based on deep learning, have shown high accuracy in pattern recognition tasks. This could potentially lead to more accurate predictions than traditional methods.
2. **Scalability**: Once trained, the AI model can process a large number of cases in a short amount of time, providing scalability that human doctors alone may not be able to achieve.
3. **Continuous Learning**: The model can be continually improved by training on new data, allowing it to adapt to new research findings and trends.

Weaknesses:

1. **Data Dependence**: The performance of the AI model heavily depends on the quality and quantity of the training data. Inaccurate or biased data can lead to inaccurate predictions.
2. **Interpretability**: AI models, particularly deep learning models, are often seen as "black boxes" due to their complex internal workings. This lack of interpretability can make it difficult for doctors and patients to trust the predictions.
3. **Over-reliance**: There's a risk that users might over-rely on the AI tool and neglect professional medical advice.

Trade-offs:

1. **Performance vs Interpretability**: More complex models may provide better performance but at the cost of interpretability.
2. **Data Privacy vs Model Performance**: Collecting more data can improve model performance but may raise data privacy concerns.

Possible Solutions and Design Alternatives:

1. **Ensemble Methods**: Instead of relying on a single AI model, an ensemble of models could be used to make predictions. This could potentially improve accuracy and robustness.
2. **Explainable AI**: Techniques for explainable AI could be incorporated into the design to improve the interpretability of the model.
3. **Privacy-Preserving Techniques**: Techniques such as differential privacy or federated learning could be used to train the model while preserving data privacy.
4. **User Education**: Clear guidelines and disclaimers should be provided to users about the intended use of the tool and the importance of consulting with medical professionals.

4.9 Design Analysis

- Did your proposed design from 4.7 work? Why or why not?
- What are your observations, thoughts, and ideas to modify or iterate further over the design?