Middlesex University London

MSc. Data Science Project Proposal

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MSc. Data Science

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Real-Time Sleep Paralysis Detection and Intervention System with Sleep Camera, AI, and IoT Integration.

Submission Date
30-Jun-2023

Table of Contents

1. Abstract

This thesis project aims to develop a cost-effective real-time sleep paralysis detection and intervention system utilizing sleep camera recordings, AI techniques, and IoT integration. Our objective is to provide an innovative alternative to the current methods such as ECG and sensor based approaches. By harnessing the power of computer vision and AI algorithms, the system aims to accurately identify sleep paralysis episodes and deliver timely interventions in form of custom audio cues and adjusting room temperature to assist patients transitioning out of sleep paralysis. The research will involve the collection of sleep camera recordings from a diverse set of individuals experiencing sleep paralysis. These recordings will be used to train Deep learning models capable of recognizing specific patterns and characteristics associated with sleep paralysis episodes in patients.

The expected results of this research include the development of an efficient and reliable sleep paralysis detection and intervention system. The system's performance will be evaluated through extensive testing and validation, comparing its cost-effectiveness to traditional ECG and sensor-based methods. The conclusions drawn from this research will provide valuable insights into the feasibility and practicality of using sleep camera recordings and AI techniques for real-time sleep paralysis detection and intervention.

2. Introduction

Sleep paralysis is a sleep disorder that is characterized by temporary paralysis and hallucinations during sleep-wake transitions causing distress and impairment in affected individuals. This thesis project aims to address the problem of sleep paralysis by developing a real-time sleep paralysis detection and intervention system. By leveraging computer vision and AI algorithms, the system aims to accurately identify sleep paralysis episodes and provide timely interventions to assist individuals in transitioning out of sleep paralysis. This project seeks to provide a cost-effective alternative by using sleep camera recordings and AI techniques for training and testing purposes. This approach enhances the accessibility and practicality of sleep paralysis management.

The problem addressed in this thesis project is sleep paralysis and is estimated to affect approximately 7.6% of the population in the world. It can cause distress, anxiety, and impaired daytime functioning, significantly impacting the quality of life of those affected. Individuals with pre-existing sleep disorders, such as narcolepsy (brains inability to control sleep-wake cycles) are also more prone to experiencing sleep paralysis. Various factors such as sleep deprivation, irregular sleep patterns, and stress have been associated with the occurrence of sleep paralysis.
By addressing the problem of sleep paralysis through this research, we aim to improve the understanding, detection, and management of this sleep disorder, ultimately benefiting the individuals affected by sleep paralysis and advancing the field of sleep medicine.

Aim 1: Develop a real-time sleep paralysis detection system using live camera feed and AI algorithms.

Objectives:
a) Collect a diverse dataset of live camera feed during sleep from individuals experiencing sleep paralysis.
b) Train and test deep learning models.
c) Accuratelty recognize and classify sleep paralysis episodes captured in real-time.
d) Optimize the detection algorithm for efficient and reliable performance.

Aim 2: Design an intervention system integrated with IoT devices for timely assistance during sleep paralysis episodes.
Objectives:
a) Investigate and implement personalized interventions, such as custom audio cues and room temperature adjustments, based on real-time detection.
b) Establish seamless communication between the detection system and IoT devices for immediate intervention delivery.
c) Evaluate the effectiveness of interventions through user feedback and monitoring of sleep paralysis episodes.

By focusing on live camera feed instead of recorded sleep camera recordings, the system will be able to analyze real-time data to detect sleep paralysis episodes as they occur and enables immediate intervention. This inturn would enhance the system's effectiveness in supporting individuals experiencing sleep paralysis.

3. State of the Art Review

Several research papers have been published on sleep disorders and only a few on sleep paralysis and intervention. Esther Olunu, Ruth Kimo., explores the medical perspective of sleep paralysis in this research paper, including its connection to REM sleep cycle and the physiological changes that occur during this phase.[1] The paper highlights the lack of a standard etiology for diagnosing sleep paralysis in individuals, leading to various interpretations and management approaches across different cultural and ethinic groups. In [2], Muhammad Shoaib Akhtar, Tao Feng, discuss about relationship between sleep quality and sleep paralysis. A smart device was used to collect patients pressure data when lying down on the bed. It was claimed that poor sleep quality associates with occurance of sleep paralysis.

In “Persuasive and Mobile computing” [3] research paper Maria Valero introduce a sleep nursing assistant that could be mounted on the bed frame for continuos sleep monitoring. Maria Valero and Jose Clemente also detected falls from the bed that had never been addressed earlier.Geoff Appelboom spoke about the smart wearable body sensors for patients with sleep disorders.[4] These body sensors were used for self-assessment and continuous monitoring. In 2015, Mukesh Choubisa and Prakriti Trivedi analysed the mind awake and sleep deprivation stages using ECG methods. Using this method brain signals were recorded and analysed from the surface of the scalp.[5]

K.Tang with his co authors proposed an affordable smart sytem that uses an electronic mat called Sleep Mat-e.[6] With the use of body pressure sensors the mat is able to analyze 4 different sleeping postures. Their proposed system achieved an accuracy of 90%. In “Design and development of wearable device for continuous monitoring of sleep apnea disorder”[7] real-time SpO2, BP, HR were detected and used to continuously monitor sleep apnea disorder. With the help of EEG sleep paralysis is detected and the partner is alerted [8].

4. Methods

Data Collection:

For Aim 1, a diverse dataset of live camera feed during sleep from individuals experiencing sleep paralysis or sleep disorders will be collected. Video recordings from youtube could also be used for the training. This dataset will include video recordings of individuals sleep patterns, focusing specifically on the moments during the sleep paralysis episodes. The dataset will include a wide range of individuals from different age groups, genders, and ethnicities, to ensure the system's applicability across diverse populations, higher accuracy and results.

Methods:

a) Collection of Dataset: Patients will be required to sign the consent form before starting the procedure. They would be monitored using sleep cameras placed at different angles in the room. These cameras will capture the live video feed during sleep, including the occurrences of sleep paralysis. Participants privacy and data protection will be strictly maintained throughout the research.

b) Deep learning algorithms, such as CNNs or RNNs, will be trained and tested on the collected dataset. The models will be designed to accurately recognize and classify sleep paralysis episodes in real-time. The training process will involve using snipets of video frames from the videos to train the models on labeled data, including sleep paralysis instances and non-sleep paralysis instances, to enable them to learn the distinguishing features.

c) The developed deep learning model will be integrated into a real-time sleep paralysis detection model. This system will analyze the live camera feed, extract relevant features, and apply the trained models to accurately identify and classify sleep paralysis episodes.

Justification:

The collection of a diverse dataset is essential to account for variations in sleep patterns and paralysis experiences among different individuals. This diversity will help improve the generalizability of the developed system leading to accurate detection and classification. The optimization of the detection algorithm will ensure that the system operates efficiently and reliably, minimizing false positives and false negatives.

Methods: (For Aim 2)

a) Personalized Interventions: The model will investigate and implement personalized interventions based on the real-time detection of sleep paralysis episodes. These interventions may include custom audio cues, such as calming sounds or voice prompts, and room temperature adjustments to create a more conducive sleep environment. The

interventions would vary from person to person as it will be tailored to the individual's preferences and requirements.

b) IoT Integration: Seamless communication between the sleep paralysis detection system and IoT devices will be established via WiFi or Bluetooth. This integration will enable the immediate interventions once a sleep paralysis episode is detected. IoT devices, such as smart speakers, smart thermostats, smart lighting systems, or apple watches will be connected to the intervention system to automate the intervention process.

c) Evaluation of Effectiveness: The effectiveness of the interventions will be evaluated through user feedback and monitoring of sleep paralysis episodes. Participants will provide subjective feedback on the usefulness and impact of the interventions. Additionally, the system will continuously monitor sleep paralysis episodes to assess any changes in their frequency, duration, or intensity, indicating the effectiveness of the interventions.

Justification:
By investigating and implementing interventions based on real-time detection, the system can respond with personalized assistance, potentially alleviating anxiety and distress associated with sleep paralysis episodes.The integration of IoT devices will enable timely interventions without requiring manual interventions for sleep paralysis episodes. This integration ensures that the assistance is immediate and automated, reducing the delay between detection and intervention.

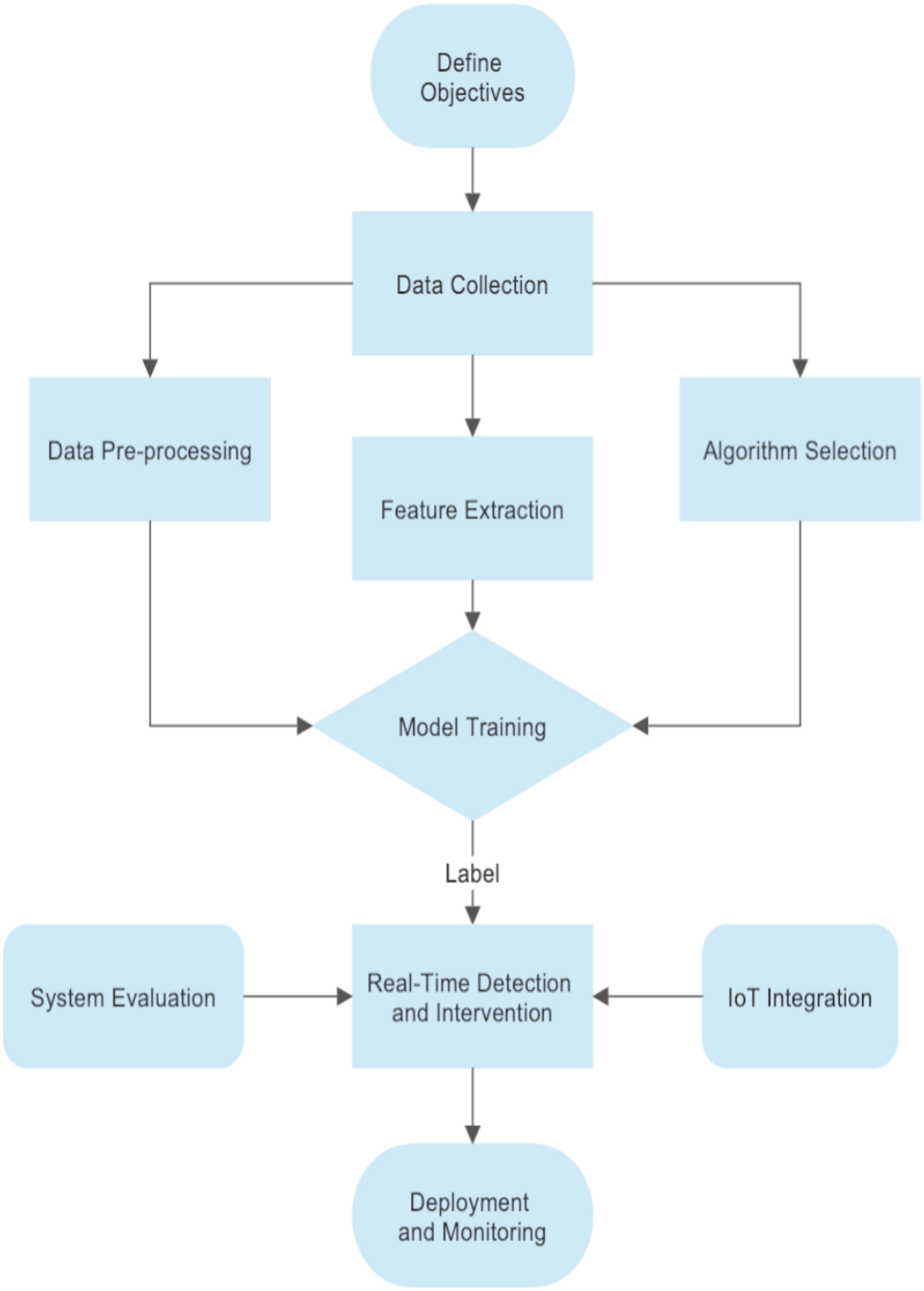

Figure 1-Flowchart for Data Analytics lifecycle.

5. Proposed Work

Here are the different development phases that would be part of this thesis project:
1. Project Planning Phase:
During this phase specific tasks and goals will be set, along with their estimated time of completion. Additionally, the required resources, such as smart sleep cameras, and IoT devices will be procured.

2. Data Collection Phase:
The data collection phase will involve recruiting participants/patients who experience sleep paralysis and capturing their sleep recordings by infromed consent. This data collection process will be conducted over a period of time to ensure that an adequate sample size is collected to build a diverse dataset for training and testing. Videos from Youtube could also be used as part of the training dataset.

3. Deep Learning Model Development Phase:
In this phase, the collected dataset will be preprocessed and annotated, preparing it for training deep learning models. The models will be trained using the labeled data to recognize and classify sleep paralysis episodes accurately.

4. Real-Time Detection System Development Phase:
This system will take the live camera feed as input, extract relevant features, and apply the trained models to detect and classify sleep paralysis episodes in real-time.

5. Intervention System Design and IoT Integration Phase:
Personalized interventions, such as custom audio cues and room temperature adjustments, will be implemented based on the real-time detection of sleep paralysis episodes. IoT devices, including smart speakers, smart thermostats, or smart lighting systems, will be connected to the intervention system to automate the intervention delivery process.

6. Evaluation and Testing Phase:
Participants/patients will provide subjective feedback on the interventions, indicating their usefulness and impact on their sleep paralysis experiences. The system will also monitor changes in the frequency, duration, or intensity of sleep paralysis episodes to assess the effectiveness of the interventions.

7. Dissertation Write-Up Phase (Final Stage):
The final phase will involve summarizing the research objectives, methodologies, findings, and conclusions. The dissertation will also include performance of the developed model and the implications of the research outcomes. Recommendations for future enhancements and potential applications of the system will be provided.

5.1. Intended contribution of the work

The intended contribution of this research is to make a small but meaningful advancement in the field of sleep disorders research. By developing a real-time sleep paralysis detection and intervention system using sleep camera recordings, AI techniques, and IoT integration, the project aims to provide a practical and innovative solution to assist individuals experiencing sleep paralysis. This contribution lies in the application of existing concepts to improve sleep quality and well-being, bridging the gap between sleep research, AI technology, and healthcare management.

5.2. Benefits of the proposed work

Sleep paralysis can occur in individuals of different age groups, but it is commonly reported amongst young adults (late teens to early thirties). However, it is important to note that sleep paralysis can affect people of any age, including children and older adults. The prevalence and frequency of sleep paralysis episodes may vary across different age groups.

The proposed work on a real-time sleep paralysis detection and intervention system brings benefits for people with sleep problems such as improved diagnosis, timely assistance, enhanced sleep quality, automation, generalizability, and potential for further research. By accurately identifying sleep paralysis episodes in real-time and providing personalized interventions using AI and IoT integration, the system aims to improve individuals' sleep experiences and contribute to advancements in healthcare and well-being technologies.

5.3. Procedures and activities of the proposed work

The activities and milestones mentioned below will ensure each objective is addressed resulting in tangible outcomes such as the dataset acquisition, model training, real-time detection system, personalized interventions, and optimized algorithms. The intangible outcomes include the advancement of knowledge, improved understanding of sleep disorders, and potential future research in the field.

Objective	Activities	Milestone/Goal
1) Developing a Real-time sleep paralysis detection system using live camera feed and AI algorithms.	a) Collecting diverse dataset of live camera feed of patients experiencing sleep paralysis episodes.	Completion of Data collection.
	b) Training and testing deep learning models	Trained deep learning models with high accuracy and results.
	c) Implementing Real-time detection	Functional real-time detection system.

	algorithm using the trained models	
2) Designing an Intervention system integrated with the IoT devices for timely interventions.	a) Implementing personalized interventions based on real-time detection	Developing personalized intervention system.
	b) Establishing seamless communication between the detection system and IoT devices.	Successful integration using either Wi-fi or Bluetooth.
	c) Evaluating the effectiveness via user feedback, surveys and monitoring of sleep paralysis episodes.	Collected user feedback and analysed intervention effectiveness.
3) Optimizing the detection algorithm for efficient performance	a) Analyzing and optimizing the detection algorithm for efficient processing.	Optimized detection algorithm with improved performance.
	b) Validating and verifying systems performance through testing and validation procedures.	Successfully validated and verified system performance.
4) Msc. Thesis Final write-up	a) Summarizing the thesis objectives and findings.	Completion and submission of thesis project.

5.4. Evaluation of the project

1) Prototype Evaluation will be done through following steps:

a) User testing and feedback.
b) Participants/Patients will be asked to use the system and provide feedback on its accuracy, effectiveness, and user-friendliness.
c) Surveys would be conducted asking targeted and open questions to understand the response in more detail.
d) Detection accuracy and response time will also be measured to assess the system's performance.

2) Process Evaluation will be done by following the steps below:

a) The feasibility of completion and the goals and objective will be evaluated at the beginning and during the development stage execution of the project.
b) The documentation will be evaluated based on clarity, comprehensiveness, and adherence to project objectives.
c) The project metrics, such as the percentage of the completed tasks, and the quality, will be evaluated throughout the life cycle of the project.
d) Regular project meetings and progress reports will be used to track project milestones and ensure timely completion of tasks.
e) The outcome and the impact of the project will be evaluated after completing the project to check if the objectives are met to make a tangible impact on the project outcome.

3) Evaluation Plan Integration:

a) Prototype Evaluation. (Duration: 10-12 weeks)
b) User testing and feedback collection.
c) Analysis of objective metrics.
d) Process Evaluation. (Ongoing throughout the project)
e) Regular project meetings and progress reports. (Documented in excel file)
f) Review and assessment of project documentation at key milestones.

5.5. Resources needed

- Smart cameras for monitoring.
- Getting the consent from patients.
- Carrying out surveys.
- Finding the population dealing with sleep paralysis.
- Computing resourses to run ML algorithms.
- IoT sensors (Heart rate, Temperature, Thermostat) or use of Apple watch.

5.6. Access to participants and clients

To secure cooperation and access to client organizations and participants for user testing, the following strategies will be implemented:

a) Establishing partnerships: Collaborating with sleep disorder clinics, research institutions, or sleep-related organizations to gain access to participants and potential client organizations.
b) Building relationships: Engaging in effective communication, emphasizing the benefits and significance of the project, and demonstrating a commitment to privacy, confidentiality, and ethical considerations.
c) Gaining trust: Providing clear explanations of the project's objectives, procedures, and potential contributions to the field, fostering trust and willingness to participate.
d) Incentives: Offering incentives, such as compensation, recognition, or personalized reports, to motivate participants and client organizations to engage in the project.
e) Contingency plans: Developing a backup plan (Plan B) in case access to participants or client organizations is not obtained, such as exploring alternative sources of data, seeking collaborations with other relevant stakeholders, or adjusting the scope of the project to work with available resources.

5.7. Ethical Aspects

The proposed project involves direct human participation in the form of data collection during sleep using live camera feed. The ethical aspects for this research paper will be carefully addressed to ensure the protection and well-being of participants/patients.

In terms of ethical consent, informed consent will be obtained from all participants involved in the data collection process. Participants will be provided with detailed information about the project, its objectives, potential risks and benefits, data handling procedures, and their rights as participants. Consent forms will be created, clearly outlining the terms of participation and privacy protection, and participants will have the opportunity to ask questions and provide voluntary consent.

In addition to direct human participation, the project also has potential long-term and indirect consequences. These include advancements in sleep disorder research, the development of AI-driven intervention systems, and the potential to improve the understanding and treatment of sleep paralysis. Ethical considerations will be given to privacy protection, data security, and the responsible use of participant data to mitigate any potential negative consequences and ensure the ethical integrity of the project.

6. Work plan and schedule

1. Research and Literature Review (1-2 weeks)
2. Data Collection (4 weeks)
3. Algorithm Development (2 weeks)
4. Intervention System Design (2-3 weeks)

5. System Testing and Evaluation (2 weeks)
6. Data Analysis and Conclusions (1-2 weeks)
7. Thesis Writing and Review (3 weeks)
8. Finalization and Submission (1 week)

7. Conclusions

In conclusion, this project on a real-time sleep paralysis detection and intervention system holds value due to its potential to improve the diagnosis and intervention of sleep paralysis episodes. The feasible development plan, which includes data collection, AI algorithm training, IoT integration, and evaluation, ensures the project's viability within the given timeframe. The integration of sleep camera recordings, AI techniques, and IoT devices offers a promising solution to address sleep paralysis and enhance sleep experiences.

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9. Appendixes

Figure 2: Gantt Chart

Figure 3: WBS