Thoth: An intelligent model for assisting individuals with suicidal ideation

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Abstract

Suicide causes approximately 800,000 deaths worldwide every year, which means one death by suicide every 40 seconds. Suicidal ideation is the first stage in the suicide risk scale, in which the individuals have thoughts regarding being dead. Thereby, suicide prevention strategies may focus on identifying and treating individuals with this severity level. Therefore, this article presents the summary of an Academic Master's Dissertation that proposes Thoth, a computational model for assisting people suffering from suicidal ideation. The main scientific contribution of the Thoth is the personalized assistance for individuals at risk of suicidal ideation through the analysis of Context Information for anticipating the identification of future risks. The model gathers sensor, sociodemographic, and psychological data for future risk checking through Machine Learning models. Experiments showed that the models obtained F1-Score up to 94.12%. Based on the experiments, Thoth could act in a personalized manner, sending recommendations and alerts to patients and caregivers, respectively. Thus, this research provides an improvement in the assistance of individuals with suicidal ideation through the proposed model.

Keywords: Context Information, Machine Learning, Mental Health, Patient Assistance, Suicidal Ideation, Suicide Prevention

1 Introduction

This article presents the summary of the results obtained in an Academic Master's Dissertation conducted in the Applied Computing Graduate Program of the University of Vale do Rio dos Sinos (UNISINOS). The research lasted 24 months, and the presentation to the evaluation board occurred on 2022, August 23. This research afforded the publication of three journal articles, which are the systematic review that guided the model proposition [7], the model description and evaluation [8], and one derived undergraduate research [13]. The publication journals were Computers in Human Behavior, Expert Systems with Applications, and Universal Access in the Information Society, respectively.

Approximately one person dies by suicide every 40 seconds, totalizing 800,000 deaths worldwide every year [17]. Suicidal ideation is the first stage in the suicide risk scale [15]. Thereby, approaches that help individuals in this phase may reduce suicide attempts and deaths [1, 11, 15]. Nevertheless, nearly half of the suicidal ideators do not talk about this condition before screening positive for suicide risk in emergency departments [15]. Another factor that increases the risk for this disorder is that the identification of suicidal ideation generally depends on clinical assessment based on experts' knowledge about risk factors [14]. Clinicians may focus only on the strong predictors of suicide in cases of high demands, ignoring subtle indications of risk. In this sense, psychological questionnaires help in the screening, however, assessment cannot consider these tools individually [18].

This scenario demands a proactive computational model for assisting people with suicidal ideation, enhancing suicide prevention and the quality of people's lives. A computational model can apply Machine Learning (ML) techniques for identifying individuals at risk through the analysis of a big amount of data from different sources [9, 10], such as digital and sensor data collected through smartphones and wearable devices structured into Context Histories [2, 4]. Therefore, this article describes Thoth, a computational model for assisting people suffering from suicidal ideation by analyzing Context Information, such as sensor, psychological, and sociodemographic data. The model helps in the early automatic identification of suicidal ideation risks with a daily follow-up through ML and Context Information, thus allowing early intervention when needed.

The organization of the remainder of this article is as follows. Section 2 describes the systematic literature review performed to seek related works. Next, Section 3 covers the proposed model overview and architecture. Section 4 shows the experiments with ML models and model evaluation. Finally, Section 5 presents the conclusions and limitations.

2 Related Works

This research explored a systematic literature review to seek related works [7]. This review provided a mapping of the application domains of suicidal ideation identification, considering aspects from data collection to the explainability

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of the models' predictions. Moreover, the study explored ML techniques, research challenges, and opportunities for more robust approaches to suicidal ideation identification. Through this review, this research found 9 related works that also presented an approach for intervention and follow-up of individuals with suicidal ideation. Considering these related works, the main scientific contribution of this research is the personalized assistance for individuals at risk of suicidal ideation through the analysis of Context Information for anticipating the identification of future risks.

3 Thoth Model

The Thoth assists patients concerning suicidal ideation, assessing the current risk and anticipating possible future risks. Relatives, friends, and health professionals, called caregivers, receive alerts and reports from the model regarding the mental states of the assisted individuals, which allows the assistance of these patients. The model gathers data from different data sources for risk checking, such as sensor data, the *Clinical Outcome in Routine Evaluation - Outcome Measure* (CORE-OM) psychological questionnaire [5], and social network platforms. The model leverages an ontology for knowledge representation, which is the base for data storage. ML models analyze this set of data for checking current and future risks of suicidal ideation.

3.1 Model Overview

Figure 1 illustrates the model overview, where the first stage (1) represents the interaction between the model and a patient. The Thoth collects a set of data regarding this patient, creating the Context Histories. The model stores all information in a database (2), organizing the Context Histories into the structure of the Context-Based Suicidal Ideation Ontology (3). After the data storage, an ML model checks whether the patient presents behaviors that indicate a possible future suicidal ideation (4), sending alerts and recommendations to caregivers and patients when needed (5). Moreover, another ML model analyzes the current risk of suicidal ideation (6). In the case of current risk, the model needs to act as fast as possible, notifying the patient and the caregivers (7) to mitigate this risk. Finally, all alerts to caregivers provide a complete report with the information collected from the assisted individual (8).

3.2 Multi-Agent System

Figure 2 illustrates the *Multi-Agent System*, elaborated using the Prometheus methodology [12]. This system contains autonomous agents that perceive changes in the environment and these components proactively act, making decisions based on the identified changes. The *Data Collector* agent perceives new patients' data every N minutes elapsed. This agent collects and stores the raw data regarding the patients for sending these data to the *Context* agent, which structures

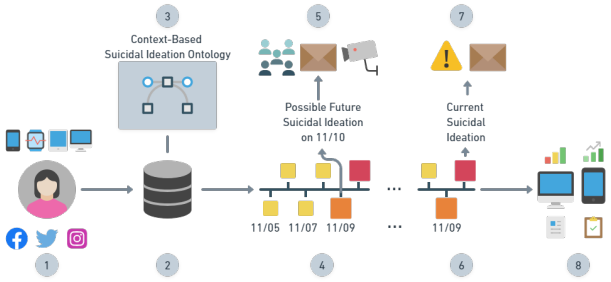

Figure 1. Thoth Model Overview

and stores the collected data in the database of Context Histories, following the ontology structure. The *Risk Checker* agent verifies the suicidal ideation risk analysis. After the risk checking, the results return to the *Context* agent for storing the predictions in the database, joining this information with the respective Context History. In the case of current or future risk, the *Patient Assisting* verifies the patients' rules in the Profiles database for recommending actions, such as social support or the practice of exercises. Furthermore, the *Patient Assisting* checks the caregivers' rules and sends alerts concerning the assisted individuals' mental states. Finally, the agent activates a monitoring process for assisting the individuals according to the rules configured by the caregivers for each patient.

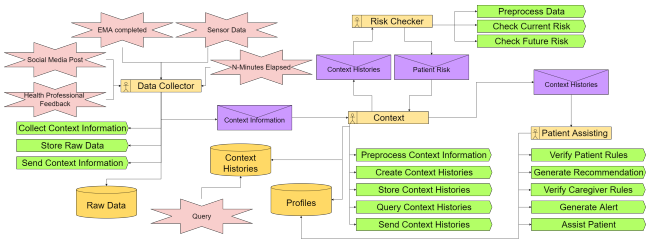

Figure 2. Multi-Agent System

3.3 Context-Based Suicidal Ideation Ontology

Figure 3 presents the Context-Based Suicidal Ideation Ontology, organizing the domain knowledge used by the model through two main classes called *Person* and *Context*. The class *Person* represents the users of the model, which are patients and caregivers, such as relatives, friends, psychologists, and psychiatrists. In turn, the class *Context* encompasses pieces of information concerning the patients at a specific time point. Each Context has an identifier, date, and time. Moreover, this class stores the information collected through sensors, such as sleep quality, heart rate, steps, distance, temperature, humidity, activities, and location. Regarding activities, the model analyzes which activities the patients are performing,

for instance, working, at rest, walking, and cycling. The subclass *SemanticLocation* categorizes relevant places for the patients, for instance, home, relatives' house, and workplace.

The subclass *SocialMedia* arranges posts from social network platforms and virtual environments. Furthermore, the *SmartphoneUsage* entity stands for the users' behavior concerning smartphone usage. The subclass *PsychologicalState* groups psychological information regarding the patients. The entity *SocialRelationship* represents the social relations of the assisted individuals with other people, organized into instances of *SemanticContact*. The subclass *Medicine* stands for medicines taken by the patients. Finally, the entity *HealthProfessionalFollowUp* describes a follow-up of a health professional, such as physical or online consultations, and textual feedback regarding the patients' mental states.

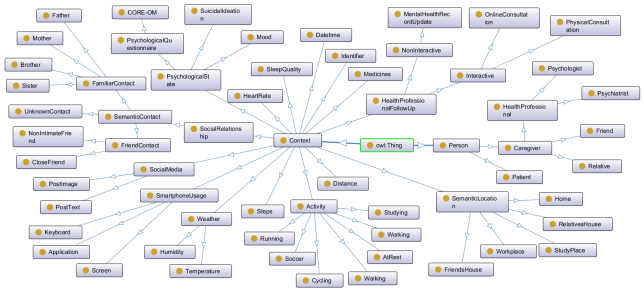

Figure 3. Context-Based Suicidal Ideation Ontology

4 Evaluation Aspects

Three volunteers with a risk of suicidal ideation used a developed prototype (Android application) to collect data for 25 to 36 days. This research employed a short follow-up period, considering that longer intervals do not improve the predictive ability of the model [6].

Based on the data collected from the patients that used the prototype, this research performed experiments to build ML models for identifying future risks of suicidal ideation. Thereby, the experiments assessed whether the data gathered had the potential to predict future suicidal ideation. The evaluation focused on predicting ideations on the next day.

A psychologist with a doctorate in Psychology supported the execution of this work, helping in the conduction of the experiments with the assisted patients, as well as in the evaluation of the model. This specialist helped in the identification of two therapists who assist patients with a risk of suicidal ideation. The selection of volunteers occurred through these therapists.

The design of the experiment with patients passed through an assessment by the Research Ethics Committee of the University of Vale do Rio dos Sinos. This committee approved the execution of the experiment after evaluating the ethical principles in this research, once this study involves human beings. The main researcher registered the research on the Plataforma Brasil[1]. The experiment approval occurred on April 2022 with the Ethical Appreciation Presentation Certificate (CAAE in Portuguese) number 57335722.0.0000.5344.

4.1 Experiments Design and Results

The evaluation process investigated 39 experiment settings. The design of the experiments considered four data augmentation techniques, being these techniques Global Permutation, Local Permutation, Scenarios Simulation, Sampling & Simulation. The need for data augmentation emerged because of the insufficient amount of data for training the ML models [16]. In addition, this research created three approaches for grouping the patients' data, which organized the Context Histories in 3, 5, and 7 days for training the ML models to predict suicidal ideation in the fourth, sixth, and eighth days, respectively. This research also explored different strategies for splitting the original dataset into train and test sets for the ML experiments. At last, the evaluation process considered the algorithms Long Short-Term Memory (LSTM), Gated Recurrent Unit (GRU), and Temporal Convolutional Network (TCN) for each experiment setting.

Most models obtained higher values in the analyzed metrics, achieving more than 90% of accuracy and F1-Scores in the best cases. In the 3-day-based prediction, a GRU model trained with Local Permutation acquired the best performance, with an F1-Score for the "Suicidal Ideation" class of 94.12% and accuracy of 94.44%. Another GRU model achieved the best performance in the 5-day-based prediction, obtaineing 92.44% and 90.63% of F1-Score for the "Suicidal Ideation" class and accuracy, respectively. At last, the 7-day-based prediction also had a GRU model as the best performance. This model achieved 92.61% and 90.83% of F1-Score for the "Suicidal Ideation" class and accuracy, respectively. In sum, the GRU models outperformed other algorithms in this research.

4.2 Assessment performed by patients and therapists

After the period of prototype usage, the three patients evaluated the prototype through 10 questions. The Technology Acceptance Model guided the development of the evaluation form. This model evaluates the users' satisfaction with the technology usage, considering the aspects of usefulness and ease of use [3]. The first aspect consists of analyzing the model capacity in helping the realization of a specific activity by users. In contrast, the second one evaluates whether the system usage requires the minimum effort possible. Considering that the prototype did not provide any intervention, the patients did not evaluate this aspect. Furthermore, a group of 3 therapists evaluated the proposed model in a general way, considering the developed prototype for data collection, the ML models' performance in predicting future suicidal thoughts, and the features available in the model.

[1]https://plataformabrasil.saude.gov.br/login.jsf

The patients felt comfortable using the prototype and sharing personal data. The volunteers also felt encouraged to share true answers to the application, even knowing about the monitoring process. The therapists highlighted the model's benefits, such as the possibility of constant asynchronous assistance, monitoring the process-outcome during the treatment, and the prototype's ease of use and access.

5 Conclusion

This article presented a summary of an Academic Master's Dissertation that proposed Thoth, a computational model for assisting individuals with suicidal ideation. The model contributes to the personalized assistance for individuals at risk of suicidal ideation through the analysis of information from different sources, such as sensor, sociodemographic, and psychological data. This set of information provides an overview of the patients' lives, tracking the social and online relationships, physical markers, activities, places visited, smartphone usage, and psychological state. Based on this data, the model analyzes future risks of suicidal ideation, aiming to anticipate the identification of these risks to avoid individuals experiencing these thoughts in the future.

This study presents limitations in research design and execution. The evaluation did not consider some parts of the proposed model and some types of data and devices specified in the model overview. The experimentation did not encompass current risk checking, only future risk checking. Moreover, since the ML experiments occurred after data collection, the prototype did not receive the features for providing patient interventions, such as the sending of recommendations and alerts. Finally, only three patients used the prototype, which reduced the collected data and generated limitations regarding the analysis of different suicide risk profiles, cultural variations, and geographical locations.

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