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Investigating the Potential of Wearables to Automatically Detect Depression

Masterarbeit

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A Program Code **80**
A.1 data_exploration.ipynb 80
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1 Introduction

The use of wearable devices to monitor personal health became increasingly common in recent years. Wearable devices, or *wearables*, are connectable, body-worn computers with integrated sensors capable of measuring physiological and behavioral data to support users in their daily activities. These include steps, heart rate, energy expenditure, sleep patterns, respiratory rate, blood oxygen saturation, skin temperature, and skin conductance [139]. Every day, people collect large amounts of data to improve their quality of life, track their fitness levels, or even change harmful behaviors. A consumer survey in 2022 found that 30% of the German population use wearables in their personal life [155]. Since heart rate and activity levels are often recorded continuously, this data offers significant potential in addition to tracking daily step count or calories burned. There is growing recognition in psychiatry that these activity data are associated with a range of mental disorders, including changes in mood, personality, difficulty coping with daily difficulties or stress, and withdrawal from friends and hobbies [56, 123]. The close association between daily activity, physiology, and psychological well-being makes wearable digital diagnostic devices particularly attractive for diagnosing depression. Such devices can potentially be used to diagnose depression risk and improve mental health screening in the general population. Moreover, due to the high level of granularity of the available data, digital diagnostics have the potential to expand knowledge on the development of depression. To prevent and cure depression, complementary smartphone applications (apps) can be used for digital health treatments and tailored cognitive behavioral therapy.

1.1 Problem and objective

Despite the fact that the market for wearables is constantly growing, the application of wearable technologies for the diagnosis and treatment of depression remains limited. Depression is the third leading cause of lost work years due to disability, affecting around 5% of the adult population worldwide (approximately 280 million people) [49]. Regardless of its high prevalence, depression is misdiagnosed and untreated in 50% of all cases [98]. At the same time, the developing COVID-19 pandemic and related economic crises are worsening the mental health of the population [176]. The economic costs of the disease are considerable: depression is responsible for about one in fifteen days of absence from work in Germany. According to the German Employees' Health Insurance Fund, absenteeism due to depression was 41% higher in 2021 than ten years earlier. During this time, the number of prescriptions for psychotropic medications to treat depression roughly tripled [55].

Changes in motor activity are known to be a symptom of depression. Motor activity generally describes the range of active coordinated muscle activity of the human body controlled from the brain [124]. In psychology, motor activity is viewed as a behavioral phenomenon, while behavior is primarily understood as the observable and measurable activity of an individual. Findings suggest that depressed patients are less likely to be physically active than non-depressed individuals. Numerous studies found that depressed patients tend to have more sedentary lifestyles [47]. Changes in motor activity are associated with changes in the severity of depression. The onset of depression is associated with a transition from physical activity to a sedentary lifestyle [167]. Depression may be related to a decrease in motor activity or an inability to maintain prescribed physical activity after a cardiac event [138]. Physical activity also explains the increased risk of death associated with depression after a cardiac event [172]. Several hypotheses are proposed to explain the association between depression and the development of a sedentary lifestyle. The lower motor activity in depressed patients may be explained by the association between depression and lower motivation and energy. The finding that negative health habits accumulate in depressed individuals may also help explain the association between depression and motor inactivity. Physical activity is associated with successful treatment of unipolar depressive disorder [109] and improves fitness, cognitive function, and overall well-being while reducing or preventing depressive symptoms [3]. Case-control studies found that patients with depression were less active during the day, but longitudinal studies showed an increase in daytime activity and a decrease in nighttime activity over the course of therapy [20]. Wearables are able to record and process motor activity data from their users, giving reason for this master thesis to pose the following research question: *How can wearables be applied to automatically detect depression states?*

The objective of this master thesis was to develop a system for detecting depressive states in patients using motor activity data from a wristband with an integrated accelerometer and a method for automatic classification, allowing diagnosis and immediate treatment. Such a system could potentially be integrated into the smartphone apps of commercial wearables. In this context, it is critical to improve understanding of the variables involved in the development and maintenance of initial depressive symptoms. Information on motor activity can be used for this purpose, as depressed individuals tend to have lower motor activity than healthy controls. Improving these characteristics may contribute to both the prevention of the disorder and the development of effective treatments.

1.2 Methodical procedure

To achieve this objective, a secondary data analysis of the *Depresjon*[1] dataset was conducted. This dataset contains information about patients with depression and control subjects without depression. Motor activity levels were monitored using a wristband worn on the right wrist with an integrated accelerometer. Initially, data preparation was performed for the analysis, selecting samples from the Depresjon dataset and standardizing the data. In the next step, statistical features were extracted for classification. Subsequently, these features were classified using machine learning (ML) algorithms. ML developed as a subfield of artificial intelligence (AI) using self-learning algorithms that derive knowledge from data to make predictions [132].

[1]Depresjon is the Norwegian term for depression.

Due to the fact that the depressive class is underrepresented in the dataset, different data oversampling methods were used and their effects on classification performance were investigated. In a final step, classification results were validated based on the associated confusion matrices and compared with similar work in the research area.

This master thesis is structured as follows: In the second chapter, a theoretical framework is first established by explaining relevant terminology and fundamentals. Subsequently, the methodological procedure for the secondary data analysis is explained in the third chapter. Results from the analysis are disclosed and visualized in chapter four. In the fifth chapter, the results are discussed and recommendations for research and practice are issued that result from the study. Potential threats to the validity of the study are discussed in the sixth chapter. Finally, a summary of the results and an outlook on possible further research is given in the seventh chapter.

7 Conclusion and Outlook

The objective of this master thesis was to analyze the potential in the automatic detection of depression through the use of wearables. With the help of the study, an answer to the following research question should be found: *How can wearables be applied to automatically detect depression states?* For the answer, a secondary data analysis of recordings of the publicly available Depresjon dataset was conducted, including motor activity data of depressed patients and healthy control subjects. The objective of the master's thesis was achieved by demonstrating that it is possible to use motor activity data from a wristband for automatic distinction between depressed and non-depressed states by applying ML methods. Moreover, the way ML finds hidden patterns in data is consistent with previous discoveries in the field of motor activity using statistical approaches. With regard to the research question, it can be stated that secondary data analysis proved to be a suitable instrument for providing an answer.

In the experiment, the RF approach performed favorably in discriminating between conditions and controls, and this performance was further improved with the use of ADASYN to synthetically oversample the positive class. Specifically, this oversampling technique improved the detection of depressive observations, although it should be noted that this slightly increased the number of false positive classifications. Considering that the positive class is the relevant class in the study and that the impact of a false negative classification is thus significantly more fatal than the impact of a false positive classification, a better detection of positive observations under the condition of a slightly worse detection of negative observations in this context is a beneficial result. Finally, using the RF method and the ADASYN approach for oversampling, an accuracy of 93.8%, a sensitivity of 94.1%, and an MCC of 87.2% were achieved. Compared to a baseline RFC, results increased by 2.8 percentage points, 9.6 percentage points, and 6.0 percentage points, respectively.

Wearables are already employed in depression research in a diverse range of approaches and the results of this thesis follow several studies on the Depresjon dataset. In the presented investigation, different methods were used in data preparation and oversampling than those used in previous research. However, given that the sample studied was both small and heterogeneous, caution should be exercised in determining both the most accurate algorithm and the generalizability of the results. Furthermore, the model is only able to discriminate between depressive and non-depressive observations and is not capable of classifying different stages of depression or distinguishing between unipolar and bipolar depression. In this regard, existing research suggests that motor agitated depression, as opposed to motor retarded depression, is more common in BD patients and this is a possible physiological BD marker. The applied actigraph in the primary study is equipped with an integrated accelerometer, which are also used in commercial wearables such as smartwatches and smart wristbands to record human physiological signals and thus enable the user to monitor daily activities such as physical exercise. Therefore, the principle of actigraphy and using ML algorithms such as the RF method to find hidden patterns in the data, based on which an automatic classification into depressed and non-depressed is performed, may be applied to these devices. Manufacturers of commercial wearables currently integrate intelligent health care systems into their IT ecosystem, which automatically evaluate the described physiological signals and thereby support the user's health self-management. These care systems are often implemented in the form of apps that are integrated into the wearable and installed on the user's smartphone to which the wearable is connected. Accordingly, a model such as the one presented in this paper can potentially be integrated into these apps to improve depression screening within the population. This further enhances the health benefits of commercial wearables. At the same time, this approach opens up the prospect of depressed patients sharing data from these health apps with their treating practitioners, enabling better diagnosis and treatment options. Current diagnostic methods rely on subjective data from the patient, primarily symptom descriptions, and manual diagnosis by the practitioner via rating scales such as the MADRS. These methods introduce various biases, such as the patient's recall bias or incorrect data entry and/or interpretation by the practitioner. This study resulted in an objective and automatic method for depression diagnosis, thus eliminating bias due to the collection of subjective patient data. Simultaneously, the proposal in this thesis allows practitioners to observe the patient's motor activity over an extended period of time, allowing for conclusions regarding the possible success or failure of treatment methods. Thus, practitioners are no longer limited to the time of the patient visit to diagnose and evaluate depression.

In this work, a number of possible statistical features from time series data was explored and it was shown how ML models can be trained with these features for automatic depression diagnosis. In the future, the public dataset may be used to explore the application of new statistical features. From the fact that in this work a better classification performance was achieved than in related research on the Depresjon dataset, it can be concluded that the potential classification performance using this dataset with RF methods is greater than previously found. Approaches to further improve performance, for example by undersampling the majority class or applying different classification algorithms such as deep neural networks, are a reference for further research. A study in which the motor activity of depressed patients is recorded with commercial wearables, such as a smartwatch, is certainly an interesting approach for future research projects. Furthermore, developing a model that is capable of discriminating between depression states in MDD and BD patients was beyond the scope of this study given the small sample size. A controlled study comparing cohorts of MDD and BD patients, respectively, in their motor activity is needed for further investigation.

The proposal in this master thesis provides practitioners with an automated tool for depression diagnosis. Since no special software or hardware is required to execute the proposed model, it may be applied in areas where medical care is limited. Finally, it is critical to point out that the primary benefit of recording motor activity may be in tracking changes in the depression state within an individual rather than in comparative case-control studies for future work. Patients can thus be alerted in advance to the risk of relapse, giving them the opportunity to prevent it, or to seek help in time to receive further support. With earlier detection of the transition to depression than with current diagnostic methods, there is hope for the development of more effective treatment and prevention approaches.