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Doctoral Dissertation Summary
Doctoral Program in Computer and Control Engineering (36th Cycle)

Sleep in Neurodegenerative Diseases: an Integrated Approach to Diagnosis and Monitoring

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Abstract

Sleep disorders encompass a diverse spectrum of motor and non-motor manifestations, representing an exceedingly common condition with a global prevalence of up to 70% in older adults. In recent years, they have emerged as a growing challenge worldwide due to their association with an increased risk of neuronal degeneration.
Indeed, they may serve as predisposing factors of co-morbidities, negatively impacting the quality of life. In particular, REM sleep parasomnias have been acknowledged among the earliest markers of neurodegenerative disorders, such as alpha-synucleinopathies.
In this perspective, sleep embodies a reservoir of significant clinical information, and its role becomes twofold.

First, in light of the development of neuroprotective pharmacological treatment, identifying prodromal conditions, such as REM Sleep Behaviour Disorder (RBD), may offer a potential window for disease-modifying interventions with beneficial effects on the quality of life. Second, an objective characterisation of sleep becomes necessary to deliver effective monitoring strategies for neurodegenerative diseases, resulting in personalised healthcare outcomes and an improved quality of care.

However, state-of-the-art diagnostic procedures entail complex tests and visual, rule-based assessments, ofttimes resulting in protracted manual labour.

Hence, this Thesis addressed two aspects: *Diagnostic Support Systems* and *Monitoring Systems*, by exploiting polysomnographic biosignals and Machine Learning techniques.

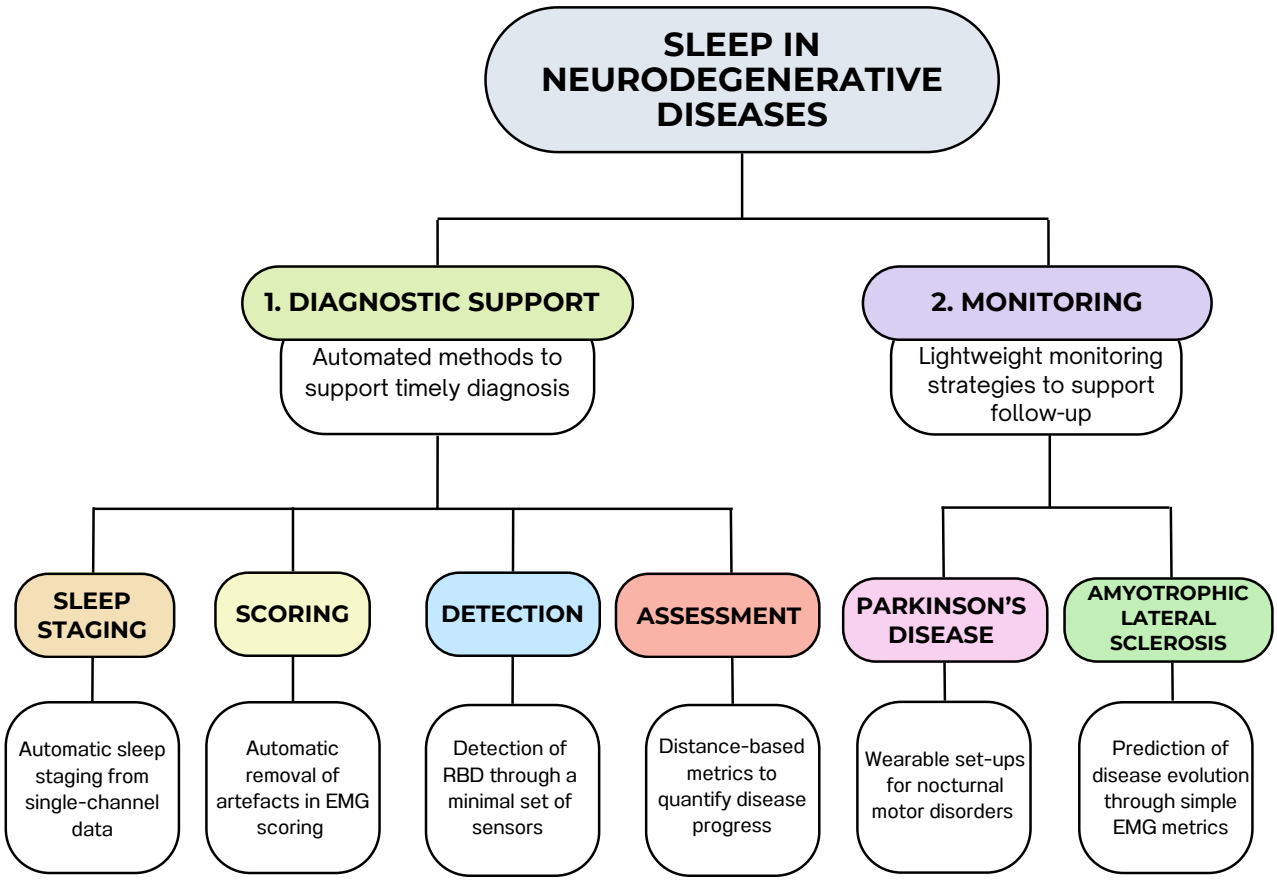
The first part addressed the development of minimally intrusive diagnosis support strategies.
First, a single-channel EEG framework for automatic sleep staging was proposed, to assess the feasibility of lightweight sleep studies. The pipeline yielded encouraging results when tested in healthy subjects and patients with RBD.
Then, a method to support the automatic removal of artefacts in EMG recordings when assessing REM Sleep Without Atonia was proposed. The approach exploited the morphology of EMG activity during sleep and provided high agreement with manual procedures.
Subsequently, biosignals collected during sleep (EMG and EEG, respectively) were exploited to characterise subjects with RBD and highlight the differences with healthy recordings. The extracted parameters exhibited good predictive power and tackled the automatic detection of RBD with reasonably high validation accuracies. Finally, a continuous, rater-independent metric was devised, to assess the extent of disease progression in RBD.

The second part explored lightweight strategies to monitor sleep disorders in neurodegenerative diseases.
First, a set of inertial metrics was proposed to objectively characterise sleep-related motor disturbances and sleep quality in Parkinson's Disease through a wearable set-up.
Second, non-intrusive EMG metrics collected during REM sleep were employed, to build a predictive model of mortality risk in Amyotrophic Lateral Sclerosis in a longitudinal retrospective fashion.

To conclude, the presented research activities explored the feasibility of data-driven approaches for the identification and monitoring of neurodegenerative conditions through the analysis of sleep. The encouraging findings represent possible approaches for minimally intrusive, accessible, and lightweight sleep studies, for an improved quality of care.

Graphical Overview

The conceptual map below represents the research pathway adopted over the course of the PhD.



Additional Information

This Dissertation illustrates the research activities conducted within the PhD Programme in Computer and Control Engineering, at Politecnico di Torino (Italy), and included in 6 scientific contributions.
The Programme had a total duration of 3 years (1st November 2020—31st October 2023).

All experimental activities envisaged a multidisciplinary approach, and were conducted in cooperation with domain specialists in hospitals both in Italy and abroad.

The Regional Centre for Sleep Medicine (Turin, Italy), and the Departments of Neurology and Neuroscience, respectively, of the University of Turin (Italy) were the main partners in the clinical collaborations.
In addition, a part of the research work was conducted at the Medical University of Innsbruck, during a secondment in the period July 2022—October 2022, and continued remotely until the end of the PhD.

The comments provided by the referees were addressed in the revised version of the Dissertation, submitted on June 19th, 2024.

I hereby declare that the contents and structure of this dissertation constitute my own original work and do not compromise in any way the rights of third parties, including those relating to the security of personal data.

Turin, 30th April 2024

Irene Rechichi