Daily-life training and monitoring methodologies for chronic obstructive pulmonary disease patients

The research activities reported in this thesis concern many aspects related to the use of wearable and unobtrusive technologies to monitor and train physical inactive patients such as patients with COPD in daily life. Data mining algorithms and machine learning approaches were deployed both to provide insight into daily activities of patients and to develop accurate support for diagnosis with the goal to pave the way for a pervasive, user-centred and preventive healthcare model, whilst coping with increasing healthcare costs and shortage of healthcare staff.

Two smartphone-based frameworks have been implemented and validated for the rapid prototyping of healthcare applications. The first framework was designed to interconnect external devices and therefore enabling multiple sensing modalities especially suitable for long term patient monitoring. The second framework utilizes only the smartphone internal sensors to monitor patient's exercise execution and provides acoustic feedback on exercise performance and exercise errors.

Driven by the certainty that data acquired in daily life are extremely valuable, data analysis was performed on daily physical activity data from a large cohort of patients with COPD in order to generate insights that may allow the design of more effective physical activity enhancement interventions. Daily physical activity measures and hourly patterns were found to vary considerably depending on the clinical characteristic. Moreover, five clusters of patients were identified, each with distinct physical activity measures and hourly patterns showing that outcome measures need to be clearly delineated when evaluating interventions aiming to promote physical activity in patients with COPD. Moreover, relations between sleep and daytime physical activity data were investigated showing a clear relationship between sleep of patients with COPD and the amount of activity they undertake during the next waking day. In particular, it has been demonstrated that patients having had a better night of sleep spontaneously engaged in more physical activity the following day.

Clinical relevant holistic metrics that integrate physiological parameters were derived using data driven, generative probabilistic models in order to allow a comprehensive and automatic assessment of the patient health status, which is currently non-existent, as an element in new preventive and treatment approaches. A methodology able to integrate and analyse physical activity measures and physiological parameters was developed. The methodology is based on the assumption that any apparently unstructured collection of data hides grouping variables that could be found applying data driven mining algorithms, and therefore organize the collection of data according to thematic coherent groups. The proposed approach was applied to discover the main physical activity routines that characterize the day of the subjects under study. In particular, it has been shown that the discovered physical activity routines are considerably different for COPD patients and healthy subjects regarding their composition and moments in time at which transitions occur. Moreover, they show certain consistent trends depending on COPD clinical characteristics and were found suitable to label, in an unsupervised way, subjects and assessed days according to the pathological condition. In addition, inferring the routine structure on day segments of relatively short duration, it was possible to model activity patterns across the day. Motivated by these results we applied a similar approach to night-time data in order to predict the pathological condition in patients with COPD, and, more in detail, to predict the level of the disease and dyspnoea severity. Compared to daytime hours, sleeping hours may offer a better trade-off between patients' comfort, sensor unobtrusiveness and signal quality. The results showed that, by using probabilistic features extracted from multimodal sensor data during night-time, it is possible to differentiate between healthy and patients with COPD with 94% accuracy and between disease severity and dyspnoea severity with an accuracy of 94% and 93%, respectively.