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Mobi-DiQ: A Pervasive Sensing System for Delirium Risk Assessment in Intensive Care Unit

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Abstract : Intensive care units (ICUs) provide care to critically ill patients in severe and life-threatening conditions. However, patient monitoring in the ICU is limited by the time and resource constraints imposed on healthcare providers. Many critical care indices such as mobility are still manually assessed, which can be subjective, prone to human errors, and lack granularity. Other important aspects, such as environmental factors, are not monitored at all. For example, critically ill patients often experience circadian disruptions due to the absence of effective environmental “timekeepers” such as the light/dark cycle and the systemic effect of acute illness on chronobiologic markers. Although the occurrence of delirium is associated with circadian disruption risk factors, these factors are not routinely monitored in the ICU. Hence, there is a critical unmet need to develop systems for precise and real-time assessment through novel enabling technologies. We have developed the mobility and circadian disruption quantification system (Mobi-DiQ) by augmenting biomarker and clinical data with pervasive sensing data to generate mobility and circadian cues related to mobility, nightly disruptions, and light and noise exposure. We hypothesize that Mobi-DiQ can provide accurate mobility and circadian cues that correlate with bedside clinical mobility assessments and circadian biomarkers, ultimately important for delirium risk assessment and prevention. The collected multimodal dataset consists of depth images, Electromyography (EMG) data, patient extremity movement captured by accelerometers, ambient light levels, Sound Pressure Level (SPL), and indoor air quality measured by volatile organic compounds, and the equivalent CO_2 concentration. For delirium risk assessment, the system recognizes mobility cues (axial body movement features and body key points) and circadian cues, including nightly disruptions, ambient SPL, and light intensity, as well as other environmental factors such as indoor air quality. The Mobi-DiQ system consists of three major components: the pervasive sensing system, a data storage and analysis server, and a data annotation system. For data collection, six local pervasive sensing systems were deployed, including a local computer and sensors. A video recording tool with graphical user interface (GUI) developed in python was used to capture depth image frames for analyzing patient mobility. All sensor data is encrypted, then automatically uploaded to the Mobi-DiQ server through a secured VPN connection. Several data pipelines are developed to automate the data transfer, curation, and data preparation for annotation and model training. The data curation and post-processing are performed on the server. A custom secure annotation tool with GUI was developed to annotate depth activity data. The annotation tool is linked to the MongoDB database to record the data annotation and to provide summarization. Docker containers are also utilized to manage services and pipelines running on the server in an isolated manner. The processed clinical data and annotations are used to train and develop real-time pervasive sensing systems to augment clinical decision-making and promote targeted interventions. In the future, we intend to evaluate our system as a clinical implementation trial, as well as to refine and validate it by using other data sources, including neurological data obtained through continuous electroencephalography (EEG).

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