ABSTRACT
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A Symbolic Approach to Human Motion Analysis Using Inertial Sensors: Framework and Gait Analysis Study

Author: Anita Pinheiro Sant'Anna

Abstract:

Human motion analysis deals with the automatic detection and description of human movements and activities. Which is particularly important for determining the health status and wellbeing of a subject in health-related monitoring applications. One of the most important everyday activities to monitor is walking, for it can reflect not only the physical but also the cognitive condition of patients. Motion analysis deals with determining what and how activities are being performed by a subject, through the use of sensors. The process of answering the "what" question is commonly known as classification, and answering the "how" question is referred to as characterization. Frequently, combinations of inertial sensor such as accelerometers and gyroscopes are used for motion analysis. These sensors are cheap, small, and can easily be incorporated into wearable systems. The overall goal of this thesis was to improve the processing of inertial sensor data for the characterization of movements. This thesis presents a framework for the development of motion analysis systems that targets movement characterization, and describes an implementation of the framework for gait analysis.

The proposed framework is organized in terms of information abstraction levels, from sensor data, through information and knowledge, to wisdom. It decomposes motion analysis systems into tasks that transform the data from one abstraction level to the next. One substantial aspect of the framework is symbolization, which transforms the sensor data into strings of symbols. This enables the use of many data mining methods which are only available for symbolic data such as Markov models and text mining. Another aspect of the framework is the inclusion of human expert knowledge. This facilitates the connection between data and human concepts, clarifies the analysis process to a human expert, and allows the inclusion of available information without the need for acquiring additional experimental data. The proposed system was compared to state of practice gait analysis systems, and evaluated in a clinical environment.

Results showed that symbolization and the inclusion of expert knowledge can contribute to the development of gait analysis systems. Expert knowledge was successfully used to parse symbolic data and identify the different phases of gait. In addition, the symbolic representation enabled the creation of new gait symmetry and gait normality indices. The proposed symmetry index was superior to many others in detecting movement asymmetry in early-to-mid-stage Parkinson's Disease patients. Furthermore, the normality index showed potential in the assessment of patient recovery after hip-replacement surgery.

In conclusion, this implementation of the gait analysis system illustrated that the framework can be used as a road map for the development of movement analysis systems. The symbolization of sensor data, albeit delicate and under-explored, is a powerful and versatile process. It facilitated not only the inclusion of expert knowledge but also the characterization of movements. In addition, the inclusion of expert knowledge addressed an important aspect of health-related applications, the link between sensor data and human concepts.