Blekinge Institute of Technology
Doctoral Dissertation Series No. 2020:10
ISSN 1653-2090
ISBN 978-91-7295-410-6

Detection and Classification Multi-sensor Systems

Implementation of IoT and Systematic Design Approaches

Damian Dziak

Akademisk avhandling
som för avläggande av teknologie doktorsexamen vid Blekinge Tekniska Högskola kommer att offentligt försvaras i sal J1630, Campus Gräsvik, den 2020-112-04, kl. 13.

Handledare:
Wlodek J. Kulesza, Prof., BTH
Sven Johansson, PhD, BTH

Opponent:
Darius Andriukaitis, Prof., Kaunas University of Technology, Lithuania.

Betygsnämnd:
Nicoletta Caramia, PhD, FacilityLive, Italy.
Sven Nordebo, Prof., Linnaeus Universitet.

Suppleanter:
Sharon Kao-Walter, Prof., BTH
Simak Khatibi, Docent, BTH

Cristina Rusu, Adjunct Prof.,
Research Institutes of
Sweden

Blekinge Tekniska Högskola
Institutionen för matematik och naturvetenskap

Abstract

The detection and classification of features or properties, which characterize people, things or even events can be done in reliable way due to the development of new technologies such as Internet of Things (IoT), and also due to advances in Artificial Intelligence (AI) and machine learning algorithms. Interconnection of users with sensors and actuators have become everyday reality and IoT, an advanced notation of a Multi-sensor System, has become an integral part of systems for assessment of people's habits and skills as well as the evaluation of quality of things or events' performances. The assessment approach presented in this thesis could be understood as an evaluation of *multidimensional fuzzy quantities*, which lack standards or references.

The main objective of this thesis is systematical design of multi-sensor systems for *industrial* and *behavioral* applications. The systematization is based on User Oriented Design (UOD), the methodology where stakeholders and future users are actively involved in all steps of the development process. An impact of the application environment on design principles is quantitatively and

qualitatively analyzed. It shows different design approaches, which can be used for developing systems monitoring human activities or industrial processes.

The features identification approach applied in this thesis involves the extraction of the necessary data, which could be used for behavior classification or skills assessment. The data used for these purposes are vision or radio-based localization and orientation combined with measurement data of speed, acceleration, execution time or the remaining energy level.

Background removal, colour segmentation, Canny filtering and Hough Transform are the algorithms used in vision applications presented in the thesis. In cases of radio-based solutions the methods of angle of arrival, time difference of arrival and pedestrian dead reckoning were utilized. The applied classification and assessment methods were based on AI with algorithms such as decision trees, support vector machines and k-nearest neighborhood.

The thesis proposes a graphical methodology for visualization and assessment of multidimensional fuzzy quantities, which facilitate assessor's conceptualization of strengths and weaknesses in a person's skills or abilities. Moreover, the proposed method can be concluded as a single number or score useful for the evaluation of skills improvement during of training.

The thesis is divided into two parts. The first part, *Prolegomena*, shows the technical background, an overview of applied theories along with research and design methods related to systems for identification and classification of people’s habits and skills as well as assessing the quality of things or performances. Moreover, this part shows relationships among the papers constituting the second part titled Papers, which includes six reformatted papers published in peer reviewed journals. All the papers concern the design of IoT systems for *industrial* and *behavioral* applications.

Keywords: Assessment; Behavior Recognition; Classification; Design Methodology; Detection; Indoor Localization; Internet of Things; Multi-Sensor System; Skills Assessment; Outdoor Localization; Wireless Sensor Network