Understanding the human behaviors in dynamic urban areas of interest

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Extended Abstract

The fast growth of urban populations across evolving cities is resulting in new types of technical, physical, material, and safety-related challenges and constraints (Chen et al. 2019). Humans perceive, move, and perform actions (called behaviors) in different urban areas, and make interactions with the objects, the other humans, and the environment for achieving their goals for attaining the desired level of satisfaction (Wagner et al., 2018; Chen et al., 2015). More formally, human behaviors are observable actions or reactions of humans in response to external or internal stimuli (Wagner et al., 2018; Hong et al., 2015; Yan et al., 2015). Over the last decade, human behavior understanding has attracted the strong interest of the researchers (Wagner et al., 2018) for better monitoring and controlling the facilities in urban areas. This massive interest in behavior understanding is because of its numerous potential applications which can be divided into three major domains as shown in Fig. 1.

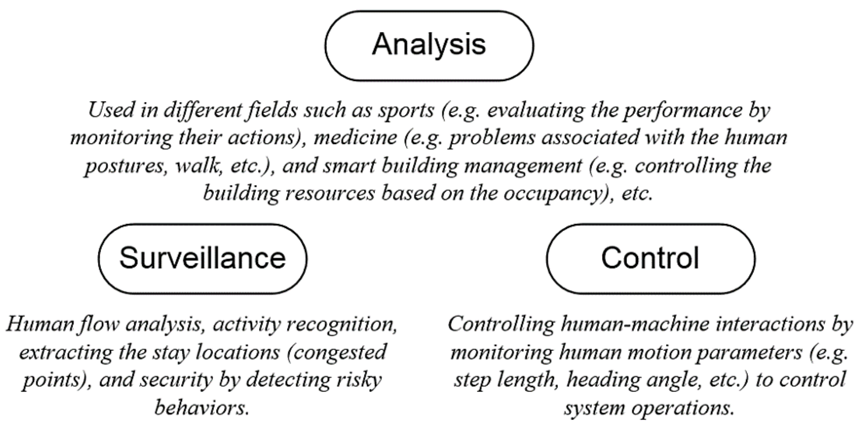

Fig. 1 Applications of understanding human behaviors (Wagner et al., 2018; Chen et al., 2015; Hong et al., 2015; Yan et al., 2015)

To understand the human behaviors for different applications, in the existing literature (Wagner et al., 2018; Chen et al., 2015; Hong et al., 2015; Yan et al., 2015), an extensive range of different types of sensors (wired and wireless) for monitoring humans and the environment are present to acquire rich information for modeling human behaviors and their interactions (energy consumption, carbon footprint, etc.). The sensors are often low-cost nodes and typically connected to the internet for data transmission. After collecting the required sensory data, this data needs to be mapped with the corresponding facility information for analyzing human behaviors (Z. Yan, 2011; Arslan et al., 2019). To employ the facility information, building information model (BIM)-based platforms are utilized and preferred over traditional 3D CAD-based systems in the Architecture, Engineering, and Construction (AEC) industry. A BIM model is a digital representation of the physical and functional characteristics of a facility providing a source of shared knowledge of facility information for the facility managers to use and maintain information throughout its lifecycle (NBS-US, 2019). The adoption rate of BIM in the US AEC industry has risen from 17% in 2007 to 71% in 2012. Whereas, in the UK AEC industry, it has improved to 74% in 2018 (Maltese et al., 2017). Integration of BIM data with real-time sensory data acquired from the Internet of things (IoT), Radio Frequency Identification (RFID), 3D scanning, GPS, etc. has provided us a centralized digital city model to study different types of human behaviors for the management of urban areas (Tang et al., 2019). However, this process of understanding human behaviors gets more complicated when the dynamicity of the urban areas gets incorporated into the behavior extraction process (Cruz et al., 2017). Our physical environments are dynamic environments that evolve in terms of geometry and contextual information.

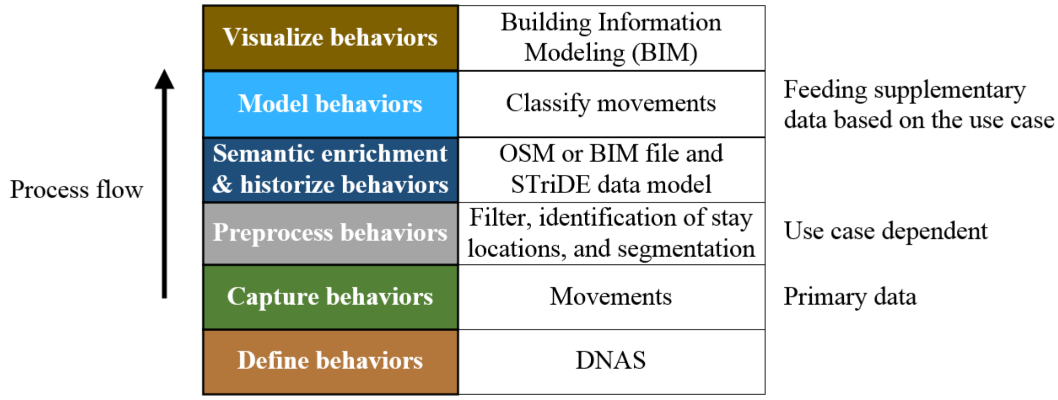

Fig. 2 Human behavioral framework having different processes

To address these requirements of dynamic urban environments, an integrated human behavioral framework is discussed (see Fig. 2). There are six different processes which are involved in constructing this framework that are; *1) Defining human behaviors using DNAS ontology*; In DNAS, 'Drivers' indicate the environmental factors which contribute to stimulating occupants to achieve a physical, physiological or psychological need. 'Needs' define the requirements (physical or non-physical) that must be fulfilled to achieve desired satisfaction. 'Actions' are the set of interactions with the urban systems to achieve the desired comfort, and 'Systems' represent the urban area. *2) Capturing behaviors of humans*; As human` movements and presence are the prerequisites for any kind of human behavior understanding, our framework specifically deals with capturing the spatio-temporal movements of human in dynamic urban areas. *3) Preprocessing the behaviors*; Once the spatio-temporal movements of humans are captured in the form of trajectories, these movements are filtered, segmented (i.e. based on the use case e.g. walk and run segments), and the facility locations having the stay locations of humans are identified (again, it is dependent on the use-case application). *4) Semantic enrichment and storing the movements;* After preprocessing the human movements, the movements are contextually enriched with the corresponding urban areas to add more meaning to the collected trajectories using the context extracted from BIM or an OSM file. Later, these spatio-temporal movements are stored in the STriDE (Semantic Trajectories in Dynamic Environments) data model. *5) Modeling behaviors;* Based on the use-case requirements, human behavior modeling techniques are applied to the processed spatio-temporal data along with the supplementary data of the human or the facility to achieve the desired classification of the human behaviors. Primarily, there exist four major types of approaches to model human behaviors which are: static-deterministic, static-stochastic, dynamic-deterministic and dynamic-stochastic (Wagner et al., 2018; Yan et al., 2015; Chen et al., 2015; Hong et al., 2015). Using these probabilistic approaches, the computation of probabilities of different movements of humans in terms of the evolving urban area of interest is used for enriching a DNAS ontology for an enhanced understanding of human behaviors by categorizing their actions based on their movements. *6) Visualizing the classified human behaviors;* Based on the literature survey (Arslan et al., 2019), BIM is chosen for visualizing the classified movements of humans.

The objective of the framework is to facilitate the development of new systems to enable the standardization of human behaviors` descriptions by incorporating the real-life dynamicity of urban environments during simulations for an improved understanding of human behaviors (Arslan et al., 2019). Here, dynamicity refers to any information about physical space, time and environment utilized for categorizing the situation of humans in urban areas (Yan et al., 2015). Changes in the purpose or the position of the locations in the facility will result in different human behaviors (Yan et al., 2015). The updated context about the locations along with the previous contextual information will be captured using our framework for studying the behaviors of the humans in detail concerning the changes that occurred in urban areas. The historicization of an urban area along with human behavioral (i.e. location) data will help facility managers for conducting 'cause and effect' analysis (Arslan et al., 2019a). The resulted analysis can be helpful for a broad range of applications in the area of city monitoring (Volk et al., 2014; Costin et al., 2015) relating to the management of a changing environment which involves moving objects as well as evolving building geometries such as construction planning, risk and hazard assessment, clash detection, construction logistics, building automation, spatial analysis, etc. (Arslan et al., 2019a).

Keywords:

Smart cities; spatio-temporal; BIM; movements; semantics; dynamic environments

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