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MASSHA: An agent-based approach for human activity simulation in intelligent environments

Oihane Kamara-Esteban *, Gorka Azkune, Ander Pijoan, Cruz E. Borges, Ainhoa Alonso-Vicario, Diego López-de-Ipiña

DeustoTech - Fundación Deusto, Avda. Universidades, 24, 48007, Bilbao, Spain
Facultad Ingeniería, Universidad de Deusto, Avda. Universidades, 24, 48007, Bilbao, Spain

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ABSTRACT

Human activity recognition has the potential to become a real enabler for ambient assisted living technologies. Research on this area demands the execution of complex experiments involving humans interacting with intelligent environments in order to generate meaningful datasets, both for development and validation. Running such experiments is generally expensive and troublesome, slowing down the research process. This paper presents an agent-based simulator for emulating human activities within intelligent environments: MASSHA. Specifically, MASSHA models the behaviour of the occupants of a sensorised environment from a single-user and multiple-user point of view. The accuracy of MASSHA is tested through a sound validation methodology, providing examples of application with three real human activity datasets and comparing these to the activity datasets produced by the simulator. Results show that MASSHA can reproduce behaviour patterns that are similar to those registered in the real datasets, achieving an overall accuracy of 93.52% and 88.10% in frequency and 98.27% and 99.09% in duration for the single-user scenario datasets; and a 99.3% and 88.25% in terms of frequency and duration for the multiple-user scenario.

1. Introduction

Intelligent environments are thought to be a key resource in assisting older adults and people with disabilities through their daily life by following the ambient assisted living paradigm. The use of sensors and computing devices allows intelligent environments to monitor the activity of inhabitants and plan suitable interventions depending on the activities and behaviour of the monitored person.

There are many challenges to face in the area of intelligent environments and human activity recognition, such as the type and layout of the sensors to be used, or the definition of accurate algorithms for activity recognition and behaviour modelling [1,2]. However, many of the research directed to address these issues finds a common operational problem which, in the best case, slows down the research, hindering the capability of running meaningful experiments in intelligent environments.

This operational problem has already been identified by many researchers [3–6]. Intelligent environments are expensive to build and maintain. Whenever there is a need to test new sensor layouts, it is generally difficult to reconfigure the environment, thus researchers have to be very careful with the initial design. In addition, the existence of a proper

* Corresponding author.
E-mail address: oihane.esteban@deusto.es (O. Kamara-Esteban).

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intelligent environment does not guarantee the generation of needed datasets, since recruiting humans for experiments is a troublesome process. In consequence, many of the datasets generated in intelligent environments do not allow to test and verify complex theories concerning human behaviour [3].

The solution to this problem is not trivial. In this line, many researchers have proposed the development of several simulation approaches for the definition of intelligent environments. Simulated intelligent environments offer many positive features, e.g. the generation of large datasets, total control of the environment and sensor layouts, cost-effective experiments and ability to define very specific experiments. Synnott et al. [7] divide simulators into two main groups: model-based simulators and interactive simulators. The purpose of this paper is to present a model-based simulator to mitigate the problems of experimenting in intelligent environments. Specifically:

- Section 3 presents the MASSHA simulator. MASSHA is an agent-based simulator for human activities in sensorised spaces that, in contrast with previous approaches, is based on environmental multi-agent theories to model and simulate intelligent environments, inhabitants and their interactions. Multi-agent environments allow a bottom-up modelling, where all agents collaborate and compete against each other while interacting with the environment. In this way, a model is defined and run through a simulation, whose results vary depending on both the characteristics of the agents and their decision processes. The advantage of this approach is the feasibility to parameterise different scenarios and evaluate how the agents behaviour and interactions are affected each time. MASSHA's scope goes far beyond the replication of human activities and its functionality can be extended to other scenarios, allowing a myriad of researchers to benefit from it, for cases such as the evaluation of electrical distribution systems, adequate sizing of water and sewerage networks, accessibility studies or traffic simulations.
- Section 6 introduces a rigorous methodology to validate the activity datasets generated by the simulator which also aims to be used by other researchers to assess the validity of their approaches.

MASSHA has been designed mainly for researchers who want to work on human populated intelligent environments. The objective of our simulator is to provide a useful tool to generate all the required realistic data for specific research questions. In this paper, we test MASSHA for activity recognition data generation. More concretely, we explore two scenarios:

- Single-user scenarios, where only one person is being monitored. Sequential and overlapping activities can be performed. The majority of the research in intelligent environments has traditionally been focused on such scenarios, thus the importance of proving the validity of the tool in these conditions.
- Multi-user scenarios, where multiple persons are monitored in the same intelligent environment. Those scenarios are more challenging. However, the full potential of MASSHA is shown in multi-user scenarios, due to the agent-based approach adopted. To the best of our knowledge, this is the first simulator to address the multi-user scenario for activity datasets.

2. Related work

Following the categorisation presented by Synnott et al. [7], simulators for intelligent environments can be classified into two main groups:

- **Model-based approaches:** these approaches use activity models, which can be obtained by diverse ways, to create synthetic datasets that store information about the activation of sensors during the execution of activities.
- **Interactive approaches:** a human user can interact with virtual environments and sensors set up by the simulation; depending on the actions executed by the user, the state of the virtual environment and sensors changes accordingly, storing that information in a synthetic dataset.

For a complete review of both approaches, it is recommended to read the work of Synnott et al. [7]. Since this paper relies on the definition of a specific model-based approach, the related work will be focused on exploring this perspective.

Model-based approaches for synthetic data generation using simulators demand the specification of activity models explaining the generation of events over time, the probability of events occurring, the time taken for each event during the performance of specific activities and the definition of the behaviour of monitored virtual people as a generator of activities over time.

An early example of a simulator called DiaSim was developed by Bruneau et al. [8]. The DiaSim simulator executes pervasive computing applications by creating an emulation layer and developing simulation logic using a programming framework, where the models are defined. It is more focused on simulating applications such as fire situations, intrusions and so on to identify potential conflicts, hence it cannot be used for human activity recognition. In contrast, MASSHA's architecture makes it possible to model human activity/behaviour and simulate these type of situations for analysis.

Helal et al. [9] developed a simulator called Persim, which has been enhanced in the new version Persim-3D [3]. Persim is an event driven simulator of human activities in intelligent environments. Persim is capable of capturing elements of space, sensors, behaviours (activities), and their inter-relationships. The simulator allowed users to define activities by specifying the sensors involved in each activity, the order of sensor activations, the maximum and minimum typical sensor values and activity duration. Based on these parameters a list of sensor data could be generated in the Sensory Dataset Description