

Modeling and Simulating Ambient Assisted Living Environments – A Case Study

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Abstract Modeling the layout of an apartment – including different furniture configurations and several moving elements – is a non-trivial task, especially if accessibility has to be assured e. g. for wheelchairs. In this paper, we describe a two-staged example for such a task by connecting two different applications: In the first step, the *YAMAMOTO* toolkit is used to efficiently model the building structure and to plan the furnishing of the environment in 3-D. Afterwards, the desired configuration becomes exported to *SimRobot*, a robot simulator based on rigid body dynamics. Thereby, a realistic evaluation of the physical configuration becomes possible, e. g. by interactively driving an electrical wheelchair through the environment.

1 Introduction

Imagine a person named Mario who depends on an electrical wheelchair and lives in an apartment providing ambient assistance. Mario sits in his wheelchair in the bedroom and tells the system: “*I would like to drink a coffee*”. Thereupon, the wheelchair starts to drive autonomously to the kitchen, bypassing any furniture blocking the way. The doors open automatically and whenever a new room is entered, the light becomes switched on. During the ride, the kitchenette adjusts to a height which suits the height of the wheelchair. When Mario arrives in the kitchen, the wheelchair parks in a position which enables Mario to easily access the cupboard’s content.

This short scenario describing a rather simple everyday task involves a number of different components which together form a complex system. Whenever a change of the environment – e. g. the addition of new furni-

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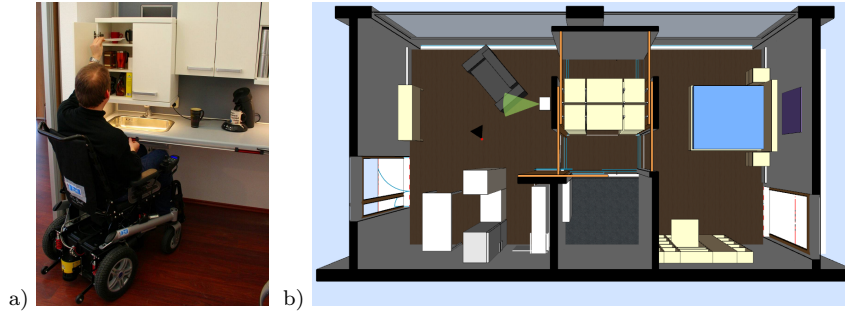


Fig. 1 a) The wheelchair Rolland in the BAALL kitchen. The kitchenette and one cupboard have been lowered automatically. b) The BAALL modeled in *YAMAMOTO*.

ture or a change of the wheelchair model – occurs, the interplay of all parts is not guaranteed anymore. Therefore, careful planning and probably time-consuming evaluation are necessary in advance to avoid any fundamental problems. The contribution of this paper is a first step towards an efficient process for modeling and evaluating new configurations in such a scenario.

This paper is organized as follows: Section 2 describes the necessary preliminary works in the areas of Ambient Assisted Living, rehabilitation robotics, robot simulation, and modeling. The applied process for modeling and evaluation is described in Sect. 3, followed by the conclusion in Sect. 4.

2 Preliminary Works

The Bremen Ambient Assisted Living Lab (BAALL) [1][<http://baall.net>] is an apartment of 60 m^2 suitable for the elderly and people with physical or cognitive impairments. It is situated at the Bremen site of the DFKI. The goal of the project is to investigate how the living environments of seniors to-be can be instrumented with infrastructures that allow incremental upgrades with user assistance systems. In order to allow a wheelchair-dependent user to stay together with their non-impaired partner in the same living environment, user-adaptable furniture has been installed (cf. Fig. 1).

The Intelligent Wheelchair Rolland is a mobility assistant that is able to operate within the BAALL. It is based on the commercial power-wheelchair *Xeno* by Otto Bock Mobility Solutions, see Fig. 1a. The wheelchair is upgraded with two laser range finders, wheel encoders, and an onboard computer. Various driving assistant modes for the wheelchair Rolland are being developed and evaluated to compensate for diminishing physical and cognitive faculties, e. g. the *driving assistant* avoids obstacles and facilitates passing through a door, and the *navigation assistant* guides along a route or drives autonomously.

SimRobot is a robot simulator which is able to simulate arbitrary user-defined robots in three-dimensional space [2]. To allow an extensive flexibility in building accurate models, a variety of different generic bodies, sensors, and actuators has been implemented. One main application has always been the simulation of autonomous wheelchairs but up to now, a variety of legged and wheeled robots has been successfully simulated by *SimRobot*.

YAMAMOTO (*Y*et *A*nother *M*Ap *M*ODELING *T*oolkit) is a graphical editor that we have developed for the geometric modeling of co-located buildings and intelligent environments in 3-D [4]. The toolkit has been designed to efficiently model the building's structure from floor plans. Additionally, the furnishing of the environment can be used through pre-defined shapes (cf. Fig. 1). Furthermore, the toolkit supports the planning and design of intelligent environments by providing various sensor and actuator elements [3].

3 Simulation of Physical Assistance in BAALL

During the course of the planning of BAALL, one practical design problem was raised concerning the furnishing of the living space with shelves and kitchen appliances: How can the storage space be maximized without compromising the maneuverability of the wheelchair? We aimed towards a physical simulation of the wheelchair within the planned BAALL environment. We have already started to model the BAALL environment with *YAMAMOTO* for visualization and documentation purposes. The model comprises the building structure, the sliding doors, and all furnishing items. In order to simulate the dynamic aspect of the sliding doors, we have extended the export module of *YAMAMOTO* to automatically create RoSiML (Robot Simulation Markup Language, used by *SimRobot*) code that specifies a fully functional physical model of the motorized doors. It is important to say that without a semantic knowledge layer of the parametric objects in *YAMAMOTO*, this would not have been possible. If the sliding doors were only represented as geometric primitives (boxes, triangles) without further type information, as usual in 3-D modeling tools, the export module would not know how to create the necessary physical elements. Finally, we have added a physical model of the wheelchair to the *SimRobot* scene. The model provides a realistic driving behavior and can be interactively controlled by the user. The simulated BAALL environment allows the evaluation of the wheelchair's mobility in bottlenecks, such as the kitchen, cf. Fig. 2. We made the experience that it quite difficult to steer the wheelchair into the kitchen – we always needed several trials and often got stuck, despite having an allocentric perspective. In addition, the previously determined wheelchair configurations allowing a convenient access to different kitchen elements also became harder – in some cases not at all – to reach. Based on this result, we gave the advice to rethink the planned kitchen configuration.

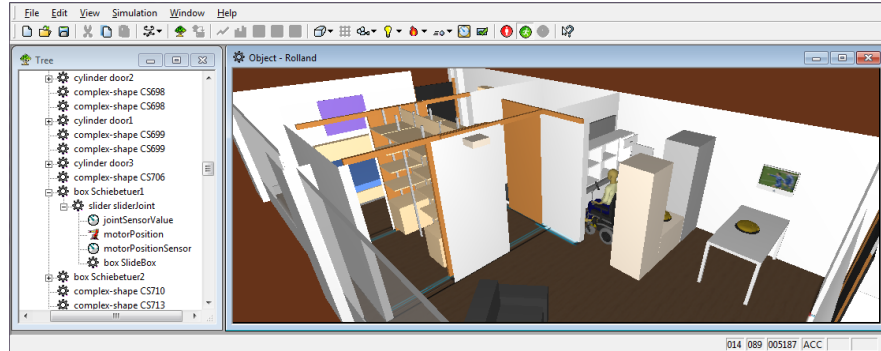


Fig. 2 Assessing the maneuverability of the wheelchair in the dynamic simulation.

4 Conclusion and Future Works

In this paper, we showed how the design of a complex environment such as an Ambient Assisted Living lab interacting with a mobility assistant can be modeled and evaluated using powerful, already existing tools. We have created a virtual model of an ambient assisted living lab that includes physical elements and applied this simulation to assess the maneuverability of a wheelchair in a planned kitchen configuration. However, in this first case study, only the maneuverability of the wheelchair in case of manual steering has been tested. For the future, we plan to extend the evaluation in the simulation from the manual control mode to assisted driving modes provided by the real wheelchair. The virtual environment would be ideal to test how the assistant copes with the kitchen situation as well as to reduce the need for testing in the lab. In case of new environments that have not yet been built, such a virtual simulation environment will become absolutely necessary to test the compliance of the driving assistant with the proposed furniture.

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