A novel MiniOn Agent Assisted Robotic Kitchen Platform

Christos Georgoulas *, Thomas Linner, and Thomas Bock

Department of Architecture, Building Realization and Robotics Lab, Technical University Munich, Germany

** Corresponding author (christos.georgoulas@br2.ar.tum.de)*

Purpose Elderly people tend to have several light, or even severe, disabilities, constraining them from most of every household task. Additionally, they tend to consume much of their daily time in the kitchen environment. A typical kitchen arrangement might be useful to most of us, but the actual arrangement and functionality is of greater importance when it comes to ageing society. The proposed paper deals with a novel robotic kitchen environment specifically designed to assist elderly individuals. **Method** Demographic change design deals with providing design solutions and services oriented on specific population categories. The ageing society receives a non-negligible concern in this area, since this population category requires a quite different design approach in household environment[1]. A compact and modular approach design is proposed, providing enhanced functionality, information technology services, and the ability to accommodate MiniOn individual robotic agents[2], to support the individuals while cooking, serving or cleaning up. Various kitchen design models were studied in order to conclude the design of the proposed prototype. Test cases were conducted in a real kitchen environment to acquire enough knowledge and to depict the actual problems and limitations the ageing society faces, while performing these relevant tasks. **Results & Discussion** The proposed kitchen system comprises a series of robotic actuators and sensors, novel space utilization techniques, and a set of visually guided robotic agents to assist in most of the required kitchen tasks. The performance of such a kitchen environment system, can undoubtedly embrace future design approaches, and strongly contribute in demographic change design.

***Keywords**: Ambient Integrated Robotics, kitchen design, mobile robots*

Introduction

Domestic architecture constantly undergoes changes and transitions. In ancient times it began with an open fireplace. The fireplace was later integrated in the building. That introduced some risky conditions in the home environment considering CO_2 air concentration. The situation hadn't been changed much until the beginning of industrialization, when the first iron stoves, which enclosed the fire completely, were produced. However, the design of the kitchen wasn't influenced by the cooking process. This changed with the Frankfurt Kitchen designed by Margarete Schütte-Lihotzky[3]. She was mainly affected by the ideas of Fredrick Winslow Taylor. Taylor analyzed and synthesized workflows[4]. The Frankfurt kitchen is a designed concept for optimized, fitted kitchen, influenced by the workflows of its time.

The proposed study deals with a new interpretation of the Frankfurt Kitchen. Nowadays, it is necessary to focus more and more on human needs and health care, since the possibilities change due to the recurrent advances in technology. For example household daily activities can be performed by robots and it is possible to develop furniture with sensors for measuring the vital functions[5] (Figure 1).

Initially a survey on various existing technologies was performed. Activities of Daily Living and the Frankfurt Kitchen were concerned. After that, the paper describes the experiments conducted in order to define the proposed implementation specifications. The resulting findings defined the concept and solution approaches.

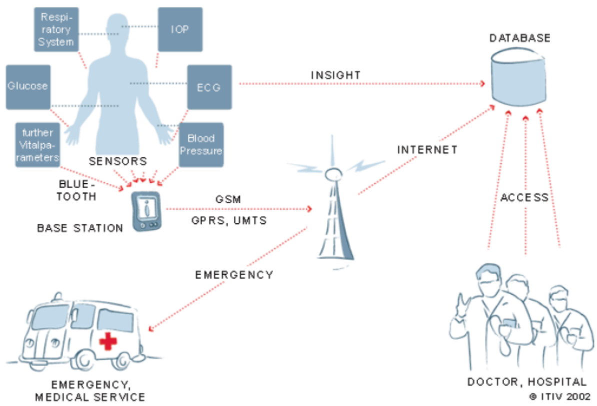

Fig.1. Personal health monitoring system with microsystem sensor technology

Research and Survey

Since spending time in the kitchen is one of the main parts of our daily routine, the research began by collecting information about basics of the modern kitchen. This included the Frankfurt kitchen and the workflow analyses. As an important basis, daily activities and the Frankfurt kitchen will be explained in detail in this section. New ideas and state-of-the-art inventions in this area were collected. The collected information was analyzed into 2 main focus areas: 1) transformation in space and architecture as well as 2) optimization by multi-functionality. For example traditional Japanese-rooms show the transformation process in space, Figure 2. By utilizing sliding doors, the atmosphere and usage of the room can be easily altered. Their specially designed floors which are made from Tatami mats[6], a special flooring material, provide the opportunity to use the room for different activities, for example as lounge at day-time and as bedroom at night time.

Fig.2. Traditional Japanese-room with sliding doors and Tatami mat floors

To increase the multi-functionality of a device or a system, the appropriate workspaces have to be defined, Figure 3. Also the personalization is important to increase the wellbeing of the user. A system that can in some extend be adapted to the personal needs or requirements of a user, provides extended functionality, while at the same time increases its efficiency to a higher degree.

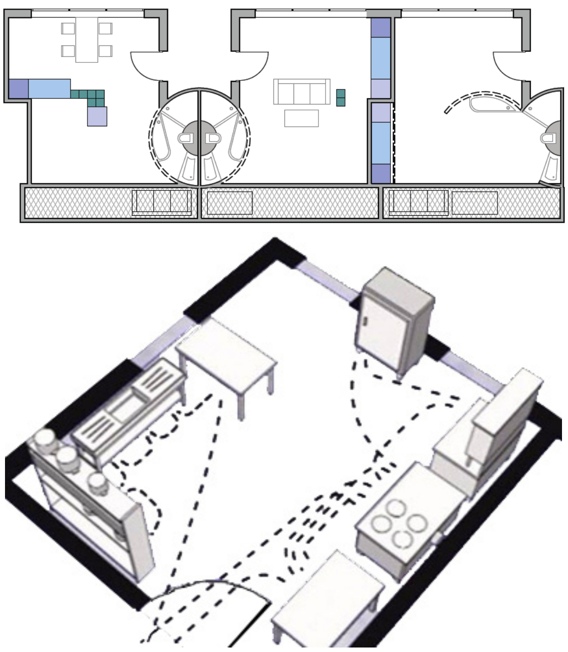

Fig.3. Definition of workspaces, motion analysis

Activities of Daily Living

The term "Activities of Daily Living," or ADLs, refers to the basic tasks of everyday living, such as eating, bathing, dressing, toileting, and transferring. When people are unable to perform these activities, they need assistance in order to cope, either from other human beings or mechanical devices or both. Although persons of all ages may have problems performing the ADLs, prevalence rates are much higher for the elderly than for the nonelderly. Within the elderly population, ADL prevalence rates rise steeply with advancing age and are especially high for persons aged 85 and over[7].

A number of national surveys which measure the ability of elderly people to perform the ADLs have been conducted[8, 9]. Even though all ADLs have a different rate of occurrence, elderly people tend to spent most of their everyday time in the kitchen, in order to prepare their meals or take their medication. The need for feeding themselves becomes dominant, and comprises one of their most important activities in their everyday living. Most elderly people have to prepare their meal more than 4 times a day, which can be considered a pretty time demanding and difficult to accomplish task, in an everyday situation scenario. Additionally, the risk for accidents in the kitchen environment is greater, since the lack of instant reflexes and the presence of fatigue, greatly raises the chances of harming themselves, many times even with tragic consequences.

The proposed Robotic kitchen introduces a novel approach, efficiently dealing with the ADLs considering the ageing society. The main idea is to introduce a kitchen design that can simplify the work process in order to prepare a meal, adapt to the elderly people profile, improve the quality of their living, and reduce the accident risk to a minimum level by implementing an intelligent and safe kitchen environment.

Frankfurter Kitchen

The Frankfurt Kitchen had a long lasting effect on the design of the modern kitchen. Although it wasn't Margarete Schütte-Lihotzky, who analyzed workflows, she was the one who structured the ideas of managing the cooking processes and realized them with the Frankfurt Kitchen. Originally Fredrick Winslow Tailor[4] analyzed and synthesized workflows and this theory of managing the working process is also called Taylorism. Margarete Schütte-Lihotzky was an Austrian architect and her aim was to simplify the daily routine of a housewife and save time by rearranging furniture at the right order. The kitchen was also designed only for one person and included no maid, which was very unusual at that time. Schütte-Lihotzky defined Workspaces and invented space-saving storage elements. Due to mass production she was also able to produce the kitchen with relatively low cost. The Frankfurter Kitchen arrangement is depicted in Figure 4.

Fig.4. Frankfurter Kitchen arrangement

EXPERIMENTS

The study included experiments in a real kitchen environment to acquire enough knowledge and to depict the actual problems and limitations the ageing society faces, while performing relevant tasks. Those experiments analyze the cooking process, the cognitive support and the required space for every cooking step.

Cooking Process

The first experiment aimed to analyze the motion paths performed during cooking, define difficulties and obtain impressions. The experiment subject used a standard kitchen and simulated the usage during preparing an average meal.

Fig.5. Cooking process experiment

Cognitive Support

The second experiment dealt with examining the cognitive support, which becomes more and more important in ageing society. The vast majority of elderly people lack the ability of sharp vision. It is thus very difficult for them to easily identify household items location even if they are stacked in a cabinet. A standard kitchen was accordingly modified to test cognitive support and distraction factors were defined.

Fig.6. Cognitive support experiment

Space Requirement

Finally the required space for every cooking step was examined and stated. Therefore kitchen utensils were assessed on size, number and frequency of use. The use of these utensils was simulated, for example to cut vegetables or to cook with a pan.

Fig.7. Space requirement experiment

RESULTS

This cooking process experiment revealed that the test person multitasked and organized different steps in a parallel scheme. For example during water boiling, the test person prepared vegetables for braising (pot roasting). Important are also significant steps, like cooling off of the stove cookplate. Likewise it is interesting that the test person movements like to bend down to the oven, or stay stood, comprise a challenge for ageing society groups. Disabilities or body stiffness and pain due to old age require a completely different approach than healthy individuals.

To simplify the working process it is important not only to optimize every work step but also to correlate them. Cognitive support aids in this correlation procedure. For example if tags or pictures are placed on the cabinet doors, the person doesn't need to remember were the kitchen utensil are located or redundantly spend time to acquire one, optimizing thus the cooking process.

Minimization of the required space is necessary, because elderly people require increased free space for themselves, in order to move easily and without struggle. The experiment showed that table modules with a minimum size of 35cm x 35 cm, provide the adequate area for implementing the cooking procedure, and at the same time allow sufficient free space for movement. These table modules are combined to increase the efficiency and adapt to the given situation.

CONCEPT

The obtained results induced a concept with a modular system as basis. The challenge was to find the right combination between flexibility and efficiency. The modules were designed into three different variations to handle as well the demanded installations: fixed, semi-fixed, and flexible, Figure 8. Additionally they were designed to enable efficient work and to be adaptable for each user and working process. So every user can apply its own workspace, Figure 9.

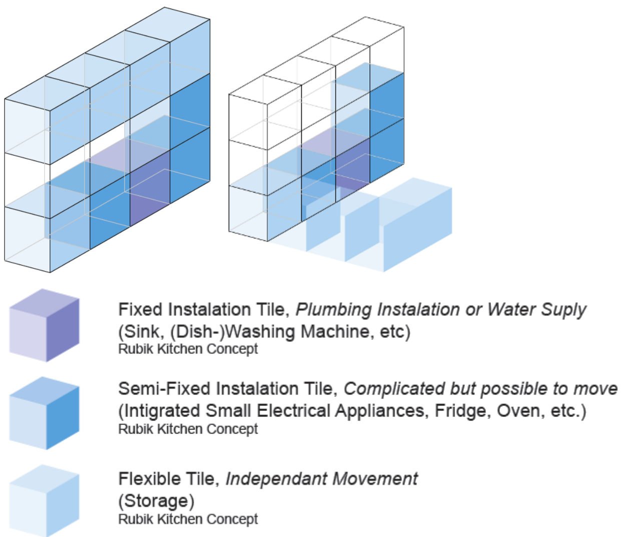

Fig.8. Module arrangements

Fig.9. Workspace realization

SOLUTION APPROACH

The proposed system solution approach followed the concept realization and definition of the system modules. The idea behind the fixed installation modules is to combine them with the storage part and kitchenware. The flexible modules can also comprise autonomous mobile robots with integrated functions.

It seems to be useful to separate the fixed modules into two kinds of modules. One is the main module of the kitchen, which integrates important kitchenware as well as storage for the most frequently used utensils. The second fixed module focuses mainly on storage, but offering the ability to vertically elevate the required compartment to eye-level, in order to assist in easily retrieving an item, without needing to reach high or bend down, which is an activity that introduces struggle to the ageing society. Elderly people tend to use items stored in their kitchen cabinets that are in eye-level, while disregarding all other that are placed in positions that are hard to reach.

Considering the first fixed module configuration, Figure 10, a storage module was designed, where the most frequently used kitchen utensils are stored. Additionally, 3-axis integrated robotic arm acquires objects with an electrostatic gripper and distributes them in the storage cases. A compact size dishwasher can save energy by detection of quantity and dirt level. The work space has an opening for waste. The Waste bin is placed under the opening. The option to sort is also possible. For ease of use the oven has a retractable platform. The dishes will be positioned in place, and then the platform is inserted into the oven by the use of a set of controlled servo-mechanisms.

The fixed module depicted in Figure 10, also houses a touch screen display interfaced to a mini-PC located at the bottom part of the module. The mini-PC is also interfaced via WiFi wireless technology to a vital sign measuring getaway located in the same position. By using a set of tele-monitoring devices[10] (a blood-pressure meter, a blood-glucose level meter, and a scale measuring the BMI index), the user can wirelessly monitor own health status, and present readings on the touch screen display. This offers a user friendly vital sign measuring terminal, which functions as a database to store vital sign readings and at the same time enabling access to them over a remote location by a specialist. Connection to the World Wide Web, allows for ICT services, such as tele-care and tele-medicine, remote health assistance, remote health consultancy. Elderly people due to severe or light disabilities and health problems, usually isolate themselves within their home environment. A visit to the doctor for a regular check up might be impossible by some individuals facing such difficulties. Interfacing a health care terminal with the proposed robotic kitchen platform is undoubtedly contributing to an enhanced service delivery scheme.

The MiniOn robotic agents consist of a square plate with a length of 35cm x 35cm attached to a telescopic base. The telescopic base comprises a visually guided robotic platform[2] which provides the necessary movement and environment perception abilities to the robotic agents. The user can adapt the telescopic base to the individual needs, so that this flexible module assists in cooking, serving and cleaning up.

The operation of the MiniOn mobile robots is based on an onboard optical sensor[11], which has the ability to extract depth information of the acquired optical scene. Depth extraction efficiently deals with problems such as 3D reconstruction, positioning, navigation, obstacle avoidance, etc[12, 13]. The depth sensor consists of an infrared laser projector combined with a CMOS sensor, which captures video data in 3D. Once the MiniOn mobile robots are introduced into their working space, the exact space arrangement must be known, in order to enable autonomous operation. A widely known technique which provides this kind of information to autonomous vehicles is the Simultaneous Localization and Mapping (SLAM)[14]. SLAM is a technique used by robots and autonomous vehicles to build up a map within an unknown environment (without a priori knowledge), or to update a map within a known environment (with a priori knowledge from a given map), while at the same time keeping track of their current location. Such a technique is used in the proposed MiniOn mobile robots, in order to get all necessary details concerning their operating area. Once the map of their environment is composed, the mobile robots can efficiently navigate within its space.

Each MiniOn can autonomously navigate in order to dock itself to different types of walls, or furniture. This is performed using label stickers, attached to the designated locations. The mobile robots scan the surrounding area using images acquired by their onboard optical sensor, and once the appropriate sticker pattern is detected within the optical scene, they are visually guided towards their target. A similar approach is used in order to be linked against each other to form the desired configurations. These modules are equipped with built-in functions, such as cooktops, scales, cutting boards etc. The different configurations of the mobile robots enable a variety of application possibilities to the user, Figure 11. The individual modules can be replaced or upgraded.

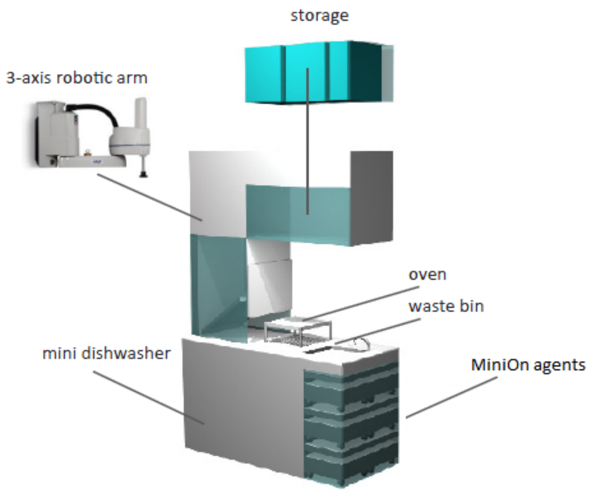

Fig.10. Module design approach

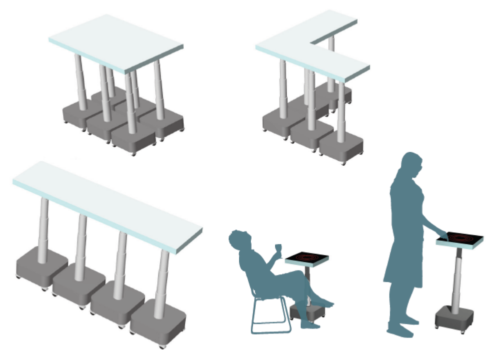

Fig.11. Arrangement configurations of the MiniOn agents

Thus, in this context a self-configuring robotic swarm system introduces a potential towards self-organizing environments, which can counter any unforeseen obstacles over a period of time and yet efficiently serve their intended purposes. The concept of self-configuration is a natural phenomenon and it can be observed even in the level of human biological structure. A lot of activities inside human body are carried out intelligently without the explicit intervention of human itself, e.g. various actions of nervous systems, blood circulation system, etc. Self configuration can be observed even in the microscopic level of cells in the human body. When a new cell is generated or if an existing cell dies within the human body the remaining body automatically self configures itself and adapts to the changes in the system. The advantage of self-configuring systems is widely used in the field of robotics to design robots which operate all possible scenarios and different terrains. To achieve this, the robot is broken down into modules or also called atoms and each module is self sustaining and has all necessary components inbuilt to sustain or perform on its own. So when faced with an obstacle these robots could transform themselves by changing configuration, shape and orientation and the individual modules adapt to the context at specific point of time.

The second proposed fixed module deals with storage, divided into three sections, Figure 12. The middle part consists of two fixed shelves in the back and a free space in the front. The free space can be used as work space, but is also required to place the upper and lower shelves at eye-level. The positioning of the shelves is performed using a set of electric motors. A “Rack and Pinion” type gearing mechanism is used to allow the various modules to move along the vertical axis. This principle enables three varieties to occupy the front middle part of the module.

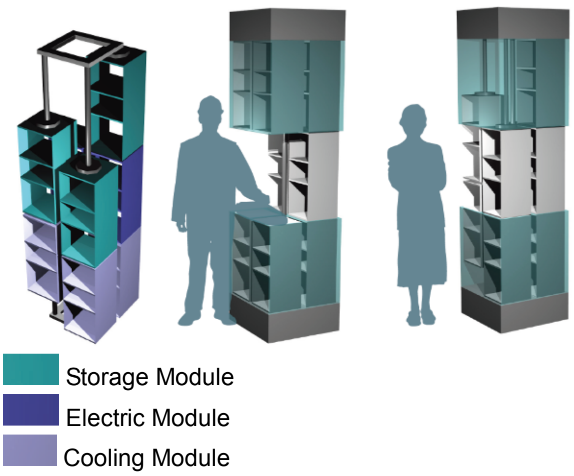

Fig.12. Module design approach

The “Storage Module” simple serves us food storage compartment. The “Electric Module”, is used to interface small electrical appliances, by providing connectors to the electrical grid power supply. Last, the “Cooling Module” houses refrigerator and freezer compartments.

Conclusions

A novel solution dealing with ADLs in the kitchen environment is proposed. The proposed system followed a research and development approach, in order to identify the strengths and weaknesses of the work processes in the kitchen environment. A series of experiments and studies were conducted concerning demographic change. The system was designed according to the needs and requirements of elderly people, since the overall goal was to realize a product assisting in ADLs in the kitchen environment, focusing in the ageing society. The results of the experiments conducted were appropriately evaluated, to adapt the functionality and operation accordingly.

The realized concepts and functions establish an approach, which allows further research and development towards robotic assisted kitchen environments. The ability to log and remotely manage the health status measurements of the user via a touch screen display integrated in the proposed system, offers a direct connection and communication between isolated elderly people and specialists, in order to conduct tele-consulting and tele-care, without requiring the individual to visit an appropriate healthcare facility quite often. Additionally, the use of MiniOn robotic mobile agents, allows reconfiguration according to the user needs, and adaptation to the current required conditions. A dynamic environment is thus proposed, offering customization and reconfigurability, modularity, while maintaining space saving efficiency.

References

1. Frederick, C., *The New Housekeeping, Efficiency Studies in Home Management*, New York: Doubleday, Page & Company, 1913.
2. TurtleBot, Willow Garage, http://turtlebot.com
3. The Frankfurt Kitchen, http://en.wikipedia.org/wiki/Frankfurt_kitchen
4. Taylor, F.W., *The Principles of Scientific Management,* London: Dodo Press, 1917.
5. Kunze, C., Großmann, U., Stork, W., Müller-Glaser, K.D., “Application of Ubiquitous Computing in Personal Health Monitoring Systems”, *36th Annual Meeting of the German Society for Biomedical Engineering*, Karlsruhe, Germany, pp. 360-362, 2002.
6. Tatami, http://en.wikipedia.org/wiki/Tatami
7. Rivlin, A.M., Wiener, J.M. with Hanley, R.J., Spence, D.A., *Caring for the Disabled Elderly: Who*

Will Pay?, Washington, DC: The Brookings Institution, 1988.
8. Wiener, J.M., Hanley, R.J., Clark, R., Van Nostra, J.F., “Measuring the Activities of Daily Living: Comparisons Across National Surveys”, *Journal of Gerontology*, Vol. 45(6), pp. 229-237, 1990.
9. Krapp, K.M., *Activities of Daily Living Evaluation*, Encyclopedia of Nursing & Allied Health, Ed. Kristine Krapp. Gale Group, Inc., 2002.
10. Biocomfort Health manager Platform, Website: http://www.biocomfort.de/telemonitoring_devices_overview.html
11. Microsoft Kinect, http://en.wikipedia.org/wiki/Kinect
12. Murray, D., Jennings, C., “Stereo vision based mapping for a mobile robot”, *IEEE International Conf. on Robotics and Automation*, Albuquerque, NM, USA, pp. 1694-1699, 1997.
13. Murray, D., Little, J.J., “Using real-time stereo vision for mobile robot navigation”, *Journal of Autonomous Robots*, Vol. 8(2), pp. 161-171, 2000.
14. Dissanayake, M.W.M.G., Newman, P., Clark, S., Durrant-Whyte, H.F., Csorba, M., “A solution to the simultaneous localization and map building (SLAM) problem”, *Robotics and Automation, IEEE Transactions on*, Vol. 17(3), pp. 229-241, 2001.