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TOWARDS AN ENBEDDED ROBOTIC ENVIRONMENT (ERE) IN EXISTING BUILDINGS

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Abstract

This article analyzes the possibilities for integrating robotic appliances in the built environment. Since the industrial revolution period, services have been integrated into the building's infrastructure. The building elements could be modified in order to get a better interrelation. An interdependent design between a robotic system and the building elements is proposed. Obviously, there are several options and there is also the necessity to implement an Embedded Robotic Environment. In order to establish a financially efficient approach considering the return on the investment, the robotic system should be multitasking. Additionally, the proposed system could be adapted to the forthcoming elderly society's needs, considering the current demographic change issues. For instance, on one hand it could be used explicitly for construction operations, such as building maintenance and interior maintenance and upgrading. On the other hand, it could be also used for servicing the needs of the inhabitants, such as cleaning, cooking, transporting heavy items or generally assisting in the activities of daily living. It must be noted that the weight of the robot should be as relatively limited, in order not to overload the home environment structure. Adapting such a concept into new buildings by integrating it during into the building construction phase could be possible, but integrating it into an existing building environment will be a tougher issue. The robotic systems will be embedded into building subsystems such as primary systems (structure: columns, beams, structural walls, etc.) interior/exterior walls, suspended / ceilings, raised/ floors, service areas, utilities etc.

Keywords: Building, Systems, Transformation, Adaptation, Embedded Robotics

1.INTRODUCTION

Robotic appliances in the built environment are mainly used for:

- Construction and maintenance purposes. On this paper we will deal with the adjustment or refurbishment of old buildings. There is already some experience on that issue (Iturralde, 2012a).

- Assistance to the Activities of Daily Living (ADLs)(Wiener, J.M. et al 1990). The topic has been already developed before with the name of ``Multi Robotic Assistant System´´ (Linner et al., 2012). We will focus on interior self-deployable robotic appliances.

The main research objective is to integrate both robotized processes in the existing building environment. Historically, old buildings have been constantly readjusted. New installation and services have been inserted in the existing built environment. Initially, they comprised water supply, later electricity and heating systems. Initially, they were considered as foreign tools within the building. Later though, building construction technique was re-thought and re-engineered in order to adapt to the new requirements. New construction systems were adopted to host different services. MEP (Mechanical, Electrical and Plumbing) and ICT already appears in nowadays buildings. Nowadays, we come across cutting edge technologies even in hundred years old buildings. Though, the adjustment of existing buildings to the ongoing technologies requires a customization of the so-called universal installation systems. Some of these appliances have been installed in buildings that were not really prepared for such activities. The insertion of installations in the building environment required a modernization of the different layers of the building.

(a) (b) (c)

Figure 1 Different fan systems: (a) portable (b) ceiling suspended(c) embedded or integrated

As an example, we can see how the fan system, depicted in Figure 1. First, it was just a movable appliance, not really integrated in the building system. Then it was suspended from the ceiling, in order not to disturb and to efficiently remove the heat accumulated to the upper levels of the environment. Nowadays, modern heating air-conditioning systems requires extensive installation spread into the building's infrastructure. In best cases, the systems run between building layers. This concept is quite important. All the elements of the system must be designed and installed in order to allow for straightforward access for maintenance and service operations.

It is clear that in many cases such an installation hasn't been integrated during the construction phase, but is rather performed and regarded as a post-interior finishing operation. The causes are several, such as lack of investment leading to simpler reduced cost design, or geometrically limitations that disable such an installation as an embedded system from the beginning.

2. ROBOTIC ENVIRONMENT PREMISES

In order to get an Embedded Robotic Environment (ERE), we have to seriously consider the following three points. Previous research has already addressed such design considerations (Linner et al., 2012).

- It is not recommendable to install the appliance system on the floor. The robotic appliance could disturb the mobility of the building occupants. Therefore, it is recommended to suspend the robotic system from the ceiling.

- This movable hanging robot, normally needs a mechanized environment, with rails and guides. Somehow, a substructure is needed.

- It is better if this substructure is rigid enough for the robot, in order to allow for a seamless and more efficient operation, regarding the various integrated services and features such a system could comprise.

In order to accomplish these premises, a change in the usual refurbishment process is needed. Nowadays, the usual building upgrading process consists of the on-site manual transformation of the material, which most of the times does not offer the required accuracy. Let's consider that a rigid pre-mechanized and accurate customized system is needed.

3. BUILDING SYSTEM PREMISES

Flexibility. The building elements have to be flexible, not only for the appliances, but also for the continuous upgrading according to the inhabitants requirements. Especially for the ageing society, this may be an issue to resolve. The degenerative health situation of inhabitants needs a constant change in their built environment. Plus, maintaining the existing living context could be proper for the elderly people, since elderly people normally prefer to remain as much individual as possible in their own environment.

Adaptability of the system to the existing context. How? The system has to be **modular** and it has to adapt to the requirements of the inhabitant. The system should offer different variety of services. For instance, some people may require functional transfers, i.e. bed to bathroom. But some other people could be assisted just with a proper lighting. The robotic system needs to be modular and customized, in order to efficiently address all these different scenarios..

Converting an entire living unit (apartment, elderly house, hospital), into a robotic environment, won't necessarily mean that it can comprise the most efficient solution, under all circumstances. A customized approach must be followed according to the explicit needs. Integrating a robotic system in all environments may result in a cost ineffective solution. Instead, the robot could move from one space to other. This generates some problems. For instance, a conventional door can be an obstacle if we want to make a bed-bathroom transfer. That is, the door has to be thought and re-designed accordingly.

4. CONSTRUCTIVE SYSTEM PROPOSITION. EMBEDDED ROBOTIC ENVIRONMENT (ERE)

In order to perform an Embedded Robotic environment, a grid is proposed in the previous researches. The system is already quite defined (Iturralde, 2012a) and we already know the impact on efficiency (Iturralde, 2012b). We do have to adapt to existing buildings. This grid is featured with universal guides or profiles in order to accomplish a common solution. If we design a closed industrialized system, it won't adjust easily to different situations. The system should offer a variation on the same theme. For instance: a Timber structure building does not need such a big rigidity such as a concrete structure building. The system for refurbishment could be similar but there must be different approaches and solutions. If the incurred transport loads are big, the rails may require some maintenance.

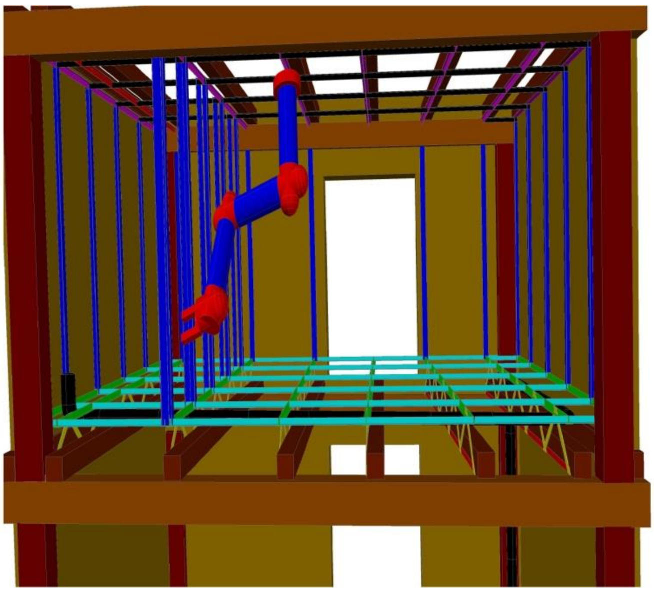

Figure 2: Building renovation using the proposed system. The proposed substructure has different purposes. First it can be used to reinforce the existing structure when needed. Then, it will be used as a support for distribution and services. Finally, the robotic appliances will run along that substructure.

Even more, the structure may need to be reinforced in order to get a more rigid grid in order to avoid excessive oscillation, especially in wooden structure buildings.

The proportion of old houses in a region can also be considered, if there is a need for refurbishment. The automation of the process could greatly assist on the inefficiency of the sector. In regions where a major number of new buildings is required, keeping the existing building functional really does not make an impact.

In order to install the new Embedded Robotic Environment in the existing building, some previous works are needed. Basically they will consist of little demolition works and installation dismantling. How to do all those will be explained further on the next publications.

In Figure 2, we can observe the architecture of the proposed robotic system for refurbishment, where the previously mechanized elements can be assembled by the robotic manipulator. The already installed infrastructure (rail grid) used for the refurbishment process, could be also later used for assistance in the activities of daily living, Figure 3.

5. RESEARCH QUESTION

Which are the facts for getting a successful Embedded Robotic Environment in an existing building?

In other words:

Which are factors for a successful development of an automated Embedded Robotic environment depending to its typology and economical and technological context?

If the proposed system is not competitive, maybe it is only adaptable to certain economic backgrounds. The competitiveness of the system should be compared to manual processes. There are two aspects to consider. First, we have to consider the base construction system with an ordinary refurbishment process. Then, we have to take into account the investment cost f the assistance robot.

Return of the investment:

- Labour cost saving: when could we have a return? Which is the time window?
- Cheaper and more efficient maintenance: when could we have a return? Which is the time window?

6. COST ANALYSIS FOR A SUCCESSFUL IMPLEMENTATION OF THE ERE.

Although the aforementioned assumptions are uncertain yet, we can say that the proposed system requires quite a big investment. So, in order to be competitive, the system has to work in built contexts where there is quite a big expending and there is a big manual work force. We will focus on the elderly nursing homes.

Let’s consider that a person has to move to an elderly residence, leaving his home and acquaintance contest. A person usually stays in such an environment for approximately five years before statistically passes away. According to statistical data (Tortosa et al. 2011)

(Eurostat 2012), the European cost in a nursing home could be considered, as average, 1.875 euro per month. It is also mentioned (Tortosa et al. 2011) that 45% of the cost is related to direct assistance personnel. 20 % is related to non-assistance personnel. 4% is related to building maintenance. Thus, 70% percent of the cost is related to the assistance of the person and the maintenance of the place where the person stays. In one year, those costs could be around 22.500 euro per person, and in five year the cost reaches up to 112.500 euro.

It's easy to say that the proposed system has to be at least cheaper than the 112.500 euro in order to be competitive. What are the expenses we have to cover with that amount?

- Building retrofitting of the existing homes where elderly people live
- Inhabitants assistance

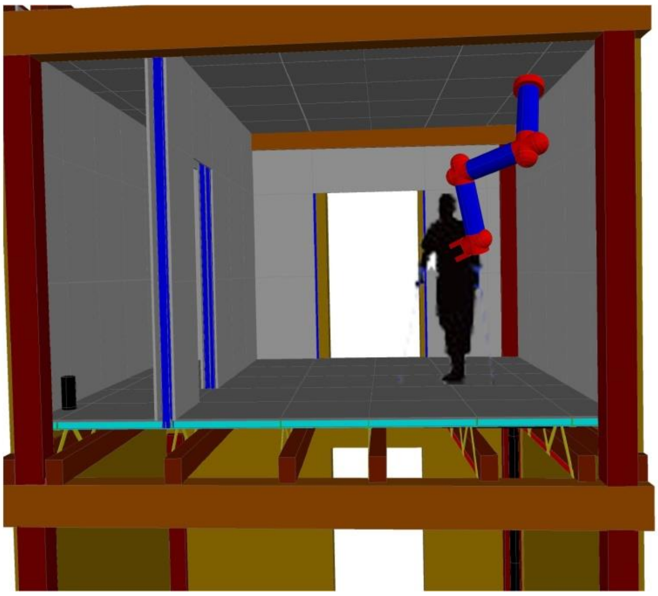

Figure 3: Elderly people assistance using the proposed system.

Using conventional methods, a complete inner-refurbishment process, including new installation, new distribution, insulation etc. could be around performed with an estimated cost of 800 euro per m^2 as an average (Iturralde, 2012a) in Europe (including all expenses). One of the reasons for elderly people to be forced to live in an elderly residence is that their homes are not really prepared for their upcoming needs and effects of aging. An upgrading is required.

Depend in the automation level, the proposed system, will require around 1.200 euros per m^2. If we consider that the elderly live in a flat, comprised with by a big bedroom (24 m^2), a proper bathroom (6 m^2) and a kitchen (10 m^2), we have to adequate a 40 m^2 space, which will cost around 48.000 euro. Thus, the remaining 64.500 euro can be utilized for populating the environment with assistive robotic systems.

We have to take into account that the future maintenance and upgrading will be easier and cheaper. Only new pre-mechanized elements will be required if a transformation of the inner distribution is needed. So the initial investment could be recovered again.

It is a reversal system: if the inhabitant passes away, the home will be needed for some other purposes. We can imagine a young couple enters to live. The distribution system can be easily adjusted with the pre-mechanized element. They can be assembled on site with robotics, or manually.

7. CONCLUSIONs

During history, buildings have changed their original systems in order to adapt to new situations. Next step seems to be an automated or robotic environment. A reasonable adjustment of robotics in the built environment will need an upgrading in the construction system. If we want to achieve a universal system, modularity and customization should be considered.

If we want to achieve a successful system, the application has to be designed according to the technological and economical environment of the region. If we design a system that is too expensive for regional background, it won't succeed. Besides, if we achieve a process that ameliorates the competitiveness of the building renovation and the caring system, the system could feasible.

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