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Integration of Information, Communication and Automation technologies in Housing Rehabilitation

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Abstract
This paper addresses the integration of Information, Communication and Automation Technologies (ICAT) in the dwelling space so as to meet the needs of users. ICAT systems can have a very important role in contemporary dwellings because of the benefits they bring to residents both from the ecological and social perspectives. The paper describes an ongoing PhD research that is concerned with the rehabilitation of the existing housing stock to fulfill the new needs of dwellers in the current Information Society and with the consequences of the integration of ICAT in dwellings. The research aims at the development of a rehabilitation methodology devised to enable architects to take user needs and requirements in home automation matters into account from the beginning of the architectural design process. Ultimately, the proposed methodology will enable a compatible and properly integration of ICAT in architectural spaces and in their built envelope. The incorporation of new housing functions calls for a new approach to the design of domestic space, in which the diversity of conventional spaces must interact with the inclusion of new multifunctional areas that accommodate activities such as telework and telehealth in order to respond to the growing demand of information access and of comfort at home. After a brief description of the general methodology, this paper focuses on the ecological and social benefits that ICAT brings to the environment, the construction industry, and the dwellers. Then it describes the impact of ICAT integration on the functional organization of the dwelling and on construction elements and it lays down the strategies for an adequate integration from these two viewpoints.

1 Introduction

This research deals with two fundamental problems: the need to rehabilitate the existing housing stock and the need to integrate ICAT in homes.
Much of the existing housing stock in Lisbon needs rehabilitation due to both constructive pathologies and to emergent conflicts in the use of spaces that result from changes in current lifestyles. New approaches to the design of domestic spaces will answer theses demands and meet the need for accommodating activities such as telework and telehealth, in response to the growing demand of information access, comfort, and safety in homes.

The integration of ICAT in housing is a priority in the quest for improved housing quality, comfort and adaptability and for promoting ecological and social sustainability. ICAT supports the elderly and people with reduced mobility as well as all people in their daily tasks, making everyone's life more comfortable, safe and autonomous.

Ongoing research intends to define a methodology to integrate ICAT in housing rehabilitation so that the existing housing stock responds to new technology demands and to new ways of living. The research focus on a specific building type ("rabo-de-bacalhau") built between 1945 and 1965 in Lisbon, mainly because their typology is very representative of the period and buildings follow clear similar generative principles. In this paper, we will not describe this specific building type since the goal is to lay down the general rehabilitation strategies, particularly from the constructive viewpoint.

Our work started with the development of a knowledge data base regarding the characterization of domestic groups, the identification of new dwelling requirements and the set of existing ICAT for homes. These data will be taken into account during the application of the rehabilitation methodology (Figure 1). Our study on how the use of technology influences the ways of living and creates new dwelling requirements, and how this impacts the spatial and functional organization of dwellings, complements Pedro's [1] and Duarte's [2] frameworks and Oliveira's research [3].

The proposed methodology aims to support architects in the adaptation of existing dwellings and in the incorporation of ICAT and it consists of four major steps highlighted with shaded areas in Figure 1. The first step consists in gathering the data needed for the rehabilitation process: the profile of the future dwellers and a description of the existing dwelling. In the second step the family profile is used to elaborate the ideal functional program of the dwelling as well as the ideal pack of ICAT functions. This pack is a description of an ideal set of systems and functions that respond to a given family profile. This ideal ICAT pack and the ideal functional program are not bound to any existing morphological or construction constrains. If the dwelling is shown to satisfy the area requirements defined in the ideal functional program, one may move to step three. If the dwelling does not fulfil such area requirements, one has to look for another dwelling within the building type that does it. In the third step, the existing dwelling, the ideal functional program, and the ideal ICAT pack are used to derive from the existing dwelling a description of an adapted solution that satisfies the program as much as possible. At the end of this step, if the dwelling does permit transformations to meet the requirements of the functional program and the ICAT pack, it becomes a satisfactory solution for the given family. Finally, from the description of the adapted dwelling it is obtained the layout of a design solution for that family in that dwelling, which includes the ICAT components needed in the dwelling.

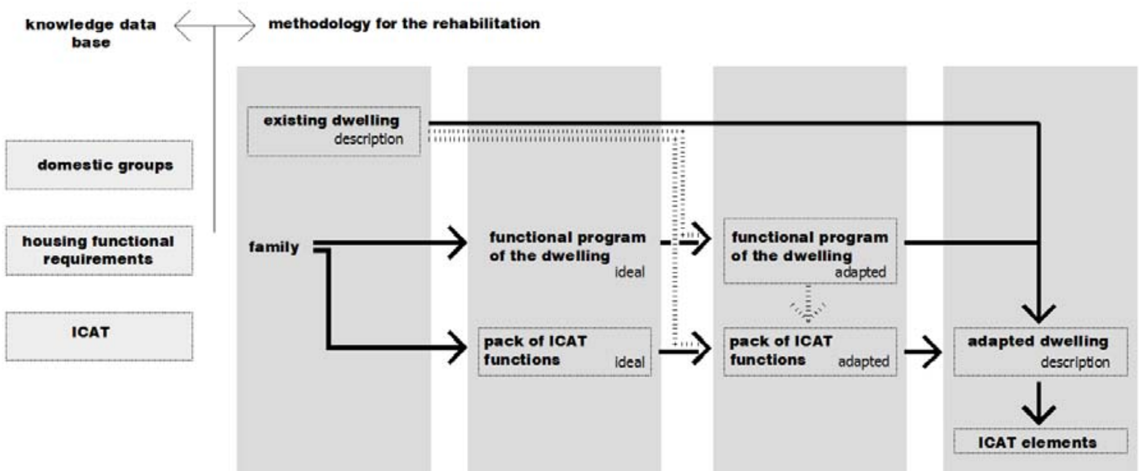

Figure 1: Basic steps in the envisioned rehabilitation methodology.

This paper will focus on the benefits of integrating intelligent features in homes and on the impacts and strategies for that integration from the functional organisation and construction viewpoints. Section 2 identifies the benefits of ICAT integration in dwellings. This was established by two methods. First, the introduction of ICAT in dwellings changes some aspects of living which were taken into account in the definition of today's houses functions and, therefore, are mirrored on the functional program. These changes are described in Section 3 of this paper. Second, the introduction of ICAT in dwellings causes physical changes in the house prompted by the need for accommodating the cabling infrastructure and the terminal equipment. The construction impact of ICAT is described in Section 4. Section 5 summarizes the findings.

2 Benefits of an rehabilitated intelligent house

Intelligent houses must fulfill three essential criteria. The first criterion is the need for dwellings to be intelligently constructed which means to follow environment oriented design strategies, for instance the use of passive systems for heating and cooling the home. The second criterion is the functional adequacy of the dwelling to the needs and lifestyles of its inhabitants. In fact, a house may be called intelligent only if its architecture is conscientiously conceived. The third criterion that will be discussed in this paper is the use of automation to assist in housing management.

Home automation systems can have a very important role in contemporary dwellings because of the benefits they bring to residents from the ecological and social viewpoints.

Regarding ecological aspects, home automation manages household energy use and complements, not substitutes, passive solutions. Domotic enables improved control over heating and cooling systems and over several other domestic automation solutions, including presence detection devices, solar control systems (control of blinds according to the detected orientation and intensity of solar light), and computer controlled ventilation by motorized opening of doors and windows.

In the rehabilitation of existing buildings, attaining ecological sustainability using passive solutions is limited to morphological and construction constraints. In such a context, the use of home automation allows one to overcome such constraints and reach better energy efficiency.

The use of ICAT also helps to improve the lives of dwellers as it can anticipate and respond to resident's demands, thereby promoting social sustainability. Intelligent and assistive technologies serve the elderly and people with reduced mobility assuring greater security and comfort. Assistive technologies can be designed to evolve as the residents require more assistance around the home thereby helping them to live an independent life. Besides helping elderly and handicapped people, domotic is very useful in many other situations, be it while inhabitants are inside the house or while they are away and use remote control on houses functions.

3 Functional organization impact of ICAT on housing rehabilitation and strategies for the implementation

The use of ICAT in houses has increased over the past decades. Such an increased use urges one to study and understand how to design a habitat, traditionally a place of permanence, continuance and slow evolution, to respond to the natural obsolescence of technologies [4].

The technologies that populate our homes are undoubtedly responsible for many changes in the organization, use, and experience of space. These technologies allow large degrees of autonomy and have changed the traditional interdependence between different house areas. In fact, functions such as information access became possible from anywhere in the house, which enables new ways of using the housing space. This fact has implications for spatial hierarchy as private areas have become places of social activity due to recently acquired ability to communicate with the outside world without physical movement. Nowadays, citizens may be extremely socially active from home despite being limited to a small living area.

In this context, the organization of housing spaces should reflect and be adapted to new lifestyles and requirements that arise from an information society where the notions of public and private space has changed dramatically.

The traditional approach to housing as a set of mono-functional spaces has changed profoundly in the sense that, thanks to technology, spaces can be used for new functions. One can work, communicate, play, learn, and participate in society from anywhere in the house due to information and communications technologies brought about by the internet, television, personal computers, and video games, among other technological novelties.

Housing spaces have been redefined either due to social factors, such as longer working hours and housework sharing, or technological factors, among which entertainment technologies play a key role.

Housing social spaces, traditionally living and dining rooms, have been losing their function of family gathering and are being replaced or equalized by the kitchen area where the family can enjoy gathering and cooking all together [3][5]. Nevertheless, living rooms remain multifunctional spaces where all the family gathers. Technologies have played a fundamental role in this matter since several leisure electronic devices like home cinema and multifunction console video games are commonly installed in living rooms. The use of these technologies appeals to inhabitants of all ages.

As for private spaces bedrooms have become multifunctional spaces where their primitive function – sleeping – it is no longer neither the principal one nor the one that drives spatial design. The current trend towards increased individualization within the housing space leads to the adoption of individual bedrooms for children and youth instead of shared bedrooms. As we seek bedrooms with more autonomy, we are led to think that we need additional space. Nevertheless, the facts that these bedrooms tend to be individual and the technology integrated in them tends to be less intrusive are reasons not to assume area as a decisive factor in bedroom design. In the existing housing stock, namely studied building type, it is common to find small bedrooms designed according to dimensional criteria that are lower than the ones in use today.

Housing spaces should be designed to offer redundant functions so that inhabitants may choose freely among several flexible spaces that are not limited to a unique use. Working at home is a current trend, either as a continuation of regular daily work or as the main working activity. To make this reality possible, the technologies used in office buildings have to migrate to home and coexist with traditional domestic activities. Adapting the house to telework involves a functional reorganization to integrate the contradictory concepts of private and public, and permanence and mobility. These contradictions show that assuring continued access to information and communication with the outside world from home is very important but that it stands at the same level as the primitive need to ensure private and resting spaces.

The technology present in current houses has grown in presence but decreased in size. Several electronic devices are becoming less intrusive because of their decreased size. As an example, we can point out the evolution of the television devices from the enormous CRT devices to the elegant LCD, plasmas and LED, as well as the evolution of the PC from a large heavy set of devices to a light tablet PC.

Besides studying the integration of visible technologies as the ones described above, our research aims at understanding the impacts of automation on the functional organization of the house. The use of ICAT in housing enables a range of intelligent functions and systems which aim to guarantee comfort and satisfaction to inhabitants. Domestic automation is composed of a series of domotic systems (or services) that perform several interlinked functions that enable security, safety, comfort, energy management, central control, and assistive technologies. The intelligent house, equipped with ICAT that anticipate and respond to its resident's demands, can also assist the elderly and disabled people, as well as other dwellers, in such a way as to secure their comfort and protect their safety, by allowing them to surpass obstacles and supporting the execution of their daily tasks.

For houses that require a level of control for disabled or elderly residents, the market offers nowadays numerous assistive technologies that can be designed to evolve as the resident requires more assistance around the home. The smart house that provides assistive technologies to help living more independently can assist with: safety and security maintenance, such as effective alarm call and smoke, heat, water and gas detectors; automation or remote control of tasks that an individual is unable to perform, such as turning lights on and off, and opening or closing of doors; external and internal communication; proximity or motion sensing; fall detection; assistance with food preparation and storage; unobtrusive ADL (Activities of Daily Living) monitoring and assessment; and vital signs monitoring.

A few years ago, it was believed that the presence of technology at home implied the need for larger areas but today we can no longer claim the same because the trend is the opposite. Wireless networks have complemented the mobility provided by the new portable technologies and allows one to access services, information and communication from anywhere in the house. The availability of ICT networks access with full coverage throughout the house, the use of mobile devices as well as the use of automation functions are basic requirements to ensure the flexibility and adaptability of the house.

Current technology brings new possibilities of interacting with the housing space and, based on this assertion, we must permit the integratation of technology in a ubiquitous way if this is the desire of its inhabitants.

The aim of our research is to incorporate the informational society requirements in the existing housing stock. While working with existing houses one needs do balance between contemporary requirements and existing morphology and construction constraints.

4 Construction impact of ICAT integration on housing rehabilitation and strategies for the implementation

Today, building services become more quickly out of date than the building itself due to the pace of technological development.

The reasons for upgrading buildings with new ICAT infrastructures are the needs for increasing reliability, efficiency and functionality, so as to adapt houses to new demands. We can meet these goals and satisfy clients' demands on different levels of sophistication, depending on economic constraints. The decision to repair, add, or replace components may depend on budget constraints as well.

The presence of automation in our homes requires physical spa**ce** for the laying of connecting cables among components of the automation system. Besides automation systems, the growing practice of working at home using ICT brings home several informatics equipment, traditionally located in office buildings. Increased technological dependence implies increased infrastructural needs, which do not exist in traditional housing projects. These requirements, combined with current trends towards improved flexibility and adaptability of living spaces, lead to the exploration of innovative construction techniques for rehabilitation. These will differ according to several factors, such as the desired level of ICAT integration, the tolerated visual impact, and the new layout proposed for the dwelling.

In order to guarantee spatial flexibility, it is necessary to implement solutions for placing infrastructures so that these do not constrain the adaptability of the house. The location of technological components must be designed to allow for easy access and maintenance. For this propose, the use of solutions commonly used in office buildings, such as the casing of cables inside walls and floors, suspended ceilings and raised floors, permit upgrading and reconfiguration of the system, as well as inspection and maintenance with minimal impact.

The retrofitting of technical infrastructures items in existing dwellings and buildings, including communications and home automation, is sometimes difficult because the buildings were often not

designed to accommodate such a level of technology. The infrastructure distribution frequently leads to additional architectural and construction difficulties. This fact leads us to strongly recommend the early conception of ICAT infrastructures with the help of specialists, even in rehabilitation projects.
The distribution networks for individual ICAT subsystems must be ascertained. Distribution through the building may be horizontal, vertical, surface-mounted, concealed, in ducts or use a mix of these solutions. Inside the house infrastructures can be concealed behind surface finishes, integrated in the new construction elements, integrated in new prefabricated elements or even intentionally displayed to distinguish new elements, clearly different from the existing [6].
Renewing or adding ICAT installations through the laying of cables entails considerable interventions in construction elements such as walls, floor, ceilings and surface finishes. We establish walls and ceilings as the most recommended places for the laying of pipes and cables, ensuring the possibility for upgrading and reconfiguration of the system as well as inspection and maintenance with minimal impact. Floors also may be also used but with the restrictions explained below. For this purpose several options can be considered and will be briefly developed in following.
In the studied dwellings most of the facilities are located in chases open in the masonry wall or embedded in floors. Vertical distribution is done embedded in walls and only in rare cases there are vertical ducts exclusive for technical infrastructure. The building presents a mix of reinforced concrete structures and load-bearing brick masonry walls. Considering restrictions imposed by this structural system and concerns about seismic stability, the proposed intervention methodology seeks to maintain building morphology and to limit demolitions and additions. Internal walls are made of clay brick masonry and, with the proposed transformation, parts of these walls will be demolished and new walls will be constructed. Therefore, new cabling on walls must go through old and new walls and settle to their differences.
The installation of infra-structures on walls, through the laying of pipes and cabling, can be done in one of the following ways: surface-mounted casing; concealed behind surface finishes (behind existing surface finishes by performing wall penetrations, inside the metal or timber frame structure of partitions and behind finished boards); and intentional architectural featuring to define new elements as clearly different from the existing ones [6].

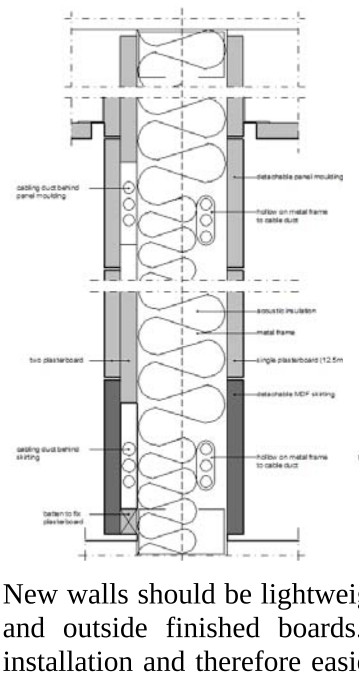

Figure 2: Hypotheses (left and right, top and bottom) for laying cables in a new wall to ensure easier maintenance and upgrading

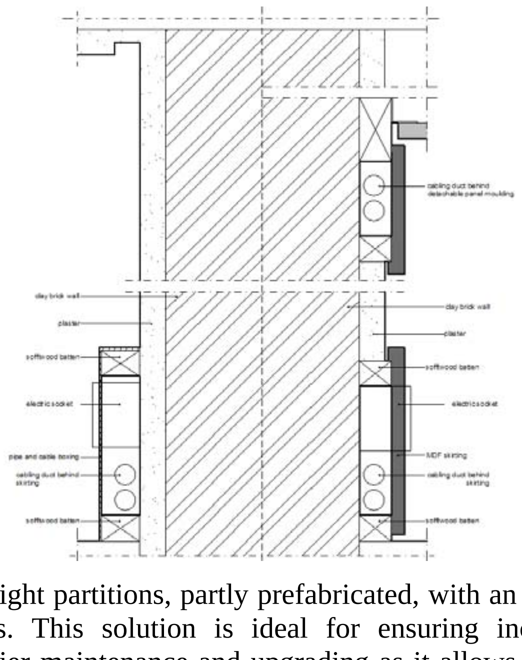

Figure 3: Hypothesis (left and right, top and bottom) for laying cables in an existing clay brick wall to ensure easier maintenance and upgrading

New walls should be lightweight partitions, partly prefabricated, with an inside metal or timber frame and outside finished boards. This solution is ideal for ensuring increased accessibility to the installation and therefore easier maintenance and upgrading as it allows for cable ducting (electrical, ICT and domotic elements) to be fixed to the frame and placed inside walls.

Using detachable skirting increases the easiness of maintenance and upgrading of the network with extra cabling, additional power or internet sockets or even pull a cable to a location near the ceiling. Detachable moulding panels enable one to install more sensors or other automation equipment (Figure 2). In existing masonry walls, one can lay cables and pipes in wall penetrations or surface-mounted using prefabricated and standardised elements. Wall penetrations can be done to lay cables or pipes but is recommendable the use of detachable panels to cover the chases to permit maintenance. Finishes with painted plaster are not detachable which implies brickwork every time one wants to change cables. These chases can be done at skirting level or near the ceiling so that a finishing panel works well (Figure 3, right side hypothesis). Service enclosures profiles provide a versatile and practical solution to the problems of concealing unsightly pipework, electrical, ICT and domotic cabling, and avoid brickwork in existing walls. These casing systems can be mounted at skirting level or at ceiling level (Figure 3, left side hypothesis). The vertical connection between cables at skirting and ceiling levels (behind moulding panels or above suspended ceilings) may be done by concealing them behind door frames, covering panels or in penetrations in plaster.
Suspended ceilings are used primarily to provide a service void between a ceiling plane and the underside of the structural slab above. This void, also called the plenum space, may be used for laying cables and pipes or HVAC air return. The advantages of using a suspend ceiling to lay ICAT networks are: creating concealed space to lay cables; being easily-removed for access to the plenum, greatly simplifying repairs or alterations. However, when ceilings are made of plasterboard, access to the plenum will require the opening of holes. The alternative is to build access hatches but they are difficult to conceal and often not very well integrated (Figure 5).
The use of under-floor infra-structure permits increased space flexibility as it allows cable and pipe network distribution regardless of existing partitions walls. The installation of infra-structures on floors, through the laying of pipes and cabling to facilitate access for subsequent maintenance can be done by concealing them below surface finishes in floor penetrations (concealing in ducts or concealing inside screed) or below raised floors.
In housing rehabilitation, raised floor systems are often impracticable because the required clear height is extremely difficult to guarantee. On the contrary, screed under-floor ducting (Figure 6) will use the existing floor screed thickness. This system is a two-part system comprising a pre-formed tray, for fixing to the surface of the sub-floor before screeding, and a cover. Return flanges give recessed support to the covers, laid flush with the rest of the floor. These covers can be visible and lay flush with the finished floor or they can be hidden and lay flush with the screed. In this last case a floor finishes can be placed upon the tray cover, hiding it.

Figure 4: simulation of the two hypotheses for location a kitchen next to the front façade: creating a plumbing casing on the façade (photo, plan b) or introducing a new internal duct (plan a)

Figure 5: Access hatch in plasterboard suspended ceiling in dwelling rehabilitation (AC 2008)

Figure 6: Trench duct system. Designed for a single run or an entire duct grid. Image from http://www.monosystems.com/

5 Closure

The described PhD research focus on two fundamental problems: the need for rehabilitating the existing housing stock and the need for integrating ICAT in homes. It is a fact that home automation technologies increases comfort in houses and helps inhabitants in daily domestic tasks thereby promoting their independency. Besides new construction, it is of major importance the rehabilitation of the existing housing stock and the integration of ICAT in these houses.

In this paper we pointed out the benefits of home automation both in the promoting of ecological and social sustainability. ICAT can promote efficient energy use when actuating on HVAC management, blinds, and lights among others systems. ICAT also have a great positive impact on promoting independent living to elderly and people with reduced mobility.

We presented the major impacts that ICAT integration has on housing rehabilitation concerning functional organization and construction.

The presented case study, “rabo-de-bacalhau” buildings, needs rehabilitation in order to fulfill new space-use requirements demanded by the information age new lifestyles as well as to meet ecological and social sustainability. In this paper we have propose strategies that permit to achieve an adequate balance between the tradeoffs involved in the rehabilitation of existing dwellings, the compliance with the new demands on housing functions, and the integration of ICAT.

Acknowledgements

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