Video Mediated Communication for Domestic Environments
Architectural and Technological Design

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Abstract. This paper presents different solutions for the integration of Video Mediated Communication (VMC) into the home environment considering primarily architectural and technical aspects. The context is entitled comHOME, a concept dwelling of the future designed and built as a full-scale model in collaboration with a telecom operator. The principal problem investigated is the various aspects of private and public zones when using VMC in a home environment. The solution concerns the integration of different comZONES (communicative zones for VMC), where the resident can be seen and heard at different levels varying in time and space. The comZONES presented include, for example, a "videoTORSO" - a large vertically mounted flat screen for informal everyday communication and a "mediaSPACE" - a set-up consisting of a wall of screens permitting shared activities in both time and space. The comZONES are mainly described from an architectural (form and function) as well as technological (hardware and software) perspective.

Keywords. architecture, communication, comZONE, design, dwelling, home, ICT, intelligent building, media space, smart home, video mediated communication, VMC

1 Background

This paper presents a piece of work based on the idea of a changing society where work and other activities at home become more closely integrated in both time and space (Junestrand & Tollmar, 1998). The core argument is that information and communication technologies (ICT) are a prerequisite for the transformation process from a society focused on industrial production to a society dominated by information processing and based on communication (Dahlbom 1997). Based on a theoretical framework for how our living could change due to new social movements and new use of the domestic environment, we have designed a concept apartment entitled comHOME, demonstrating a set of design solutions for the integration of VMC into a dwelling. In this way the home becomes, in some aspects, a public place accessible through VMC, while still retaining its private nature for several traditional everyday activities. ICT, directly or indirectly, will free us from a large part of the mechanical work we have been used to for a long period of time. Future work activities will consist even more of talking and interacting with other people (Dahlbom 1997). This and other novel ways of working will be possible from almost any location and will be, to an increasingly extent, supported by ICT. Telework from the home, supported by information technologies, is one of the new ways of working predicted to increase in the near future (Bangemann 1994).

It is without doubt an important consideration that the way to live in our homes in the information society is becoming more complex with increasing integration in both time and space between work, shopping and traditional domestic activities. The actual time we spend in our homes is also on the increase. For many of these activities, ICT can support the process despite a separation in space and time. However, since several of the possible ICT supported activities have a public, or semi-public, character, the limits of private and public in the spatial organization of our environment will have to be opened up (Graham & Marvin 1996). The earlier public character of the traditional farmer's house disappeared in modern planning practices. The dual concept of public and private has developed and become something clearly important during the industrial age. The border between the public and the private sharpened up. Compare, for example, the public character of a staircase in an apartment building and the privacy of the apartment hall in a typical residential building of later decades. However now, in the infancy of the information society, it appears that the creation of public spaces in the private dwelling must be considered once again (Junestrand & Tollmar 1998).

2 Video-Mediated Communication in Domestic Environments

The development of information technologies is very rapid and several trends and tendencies indicate that VMC will become an important part of communication - in our homes as well as our offices (Kraut and Fish 1997). Communication can, in this context, support and complement a wide range of home based activities such as professional work, studies, care of the elderly and leisure activities. Our particular focus is on the integration of architectural and technical designs. Dwellings all over the world are generally not very well suited for VMC due to e.g. unsatisfactory acoustics, light conditions, technical installations, floor-plan layout and spatial design. On the other hand regular VMC solutions used in traditional professional work environments seem to be unsuited to the home without profound redesign. In spite of the great difficulties experienced in establishing a market for video-conferencing in the professional field, we still believe that VMC is a future technology for domestic environments. This is mainly based on the fact that VMC primarily supports social and emotional aspects of communication (Whittaker 1995) and this is the primary requirement for a VMC system in a home environment. It should also be observed that all currently available VMC solutions so far lack significant qualities such as the capacity to transport information concerning gaze awareness, smell, taste and touch among many physical cues that we use. This is an extremely interesting area, but one for which it is no place in this paper or our research at the moment.

3 Theories and related work

The complex design of the VMC solutions presented in this paper have been created by a multi-disciplinary group and span over a number of academic fields, each field with a number of theories and interesting works as possible references. Here, we will limit ourselves to presenting the theories and related work that we have found to be most important, inspiring and encouraging.

3.1 Design theory

The theoretical framework of the project presented in this paper is based on the ideas of the sciences of the artificial, introduced by Herbert Simon (1969) and further developed by Bo Dahlbom (1997). Dahlbom writes: "When we realize that the world we live in is an artificial world, a world of human creation, made up of artefacts of all kinds, becoming even more complex and intertwined, our attention will shift from studying nature to contributing to the design of artefacts." In this future science we become, as designers, a part of the design. Our intention is to investigate what is possible in the design and thereafter structure, analyze and share that information.

3.2 Architectural design

Considering architectural design issues in home environments, the work has a methodological relationship to the explorative and creative development of the functional period of international architecture. This primarily refers to the development of new conceptual and practical ideas for the dwelling that took place at the beginning of this century. A period when the house was referred to as "a machine for living in" (Le Corbusier 1923) instead of being a more traditional central place in peoples’ lives. There is also direct reference to the more formal aspects of architectural design as far as cognitive and psychological aspects are concerned (i.e. Hall 1966 and Weber 1995).

Architectural projects and research related to the use of IT in the home environment, intelligent buildings or smart homes appear to be more focused on the technology than on the architectural design. One exception is the work done by Olindo Caso (Caso & Tacken 1993) that concerns the analysis and classification of different IT supported activities which can be carried out in the home environment. These strictly theoretical studies aim at presenting a conceptual organization and allocation of IT supported activities in time and space within the home.

3.3 Computer Supported Cooperative Work (CSCW)

Within the area of CSCW research, the importance of a medium that could support informal communication has been debated for a long period of time. The presence/absence of a social context deeply influences how conversations proceed and their results. Kraut (1990) suggests that informal communication is an essential form of human communication. Studies of video-communication have suggested that the main contribution of the video-media is the rich social context (Tang and Isaak 1993). Consequently we believe, as is highly likely, that informal network building will become even more important when part of working time is moved to the home, i.e. that VMC will become one of the major communication media when most of us also work at home.

Naturally, as VMC moves from the office environment to the domestic environment, we could learn many important lessons from CSCW research. In the context of video communication for remote collaboration the major focus has been on whether the video media actually improve conversation or not. Much work in this field has moved along the specifics to find and separate variables that could be used in studies to solve the issue – exactly how valuable is the video media. In some cases researchers have been able to separate variables that move along deterministic paths – but overall has it turned out to be very difficult to generalize these results into a wider context (Whittaker 1995).

In more current research in Mediaspace (Bly 1993) we could see a trend towards non-quantitative studies in an attempt to specify users' perception and awareness of others presences (Dourish 1995). Furthermore, mediaspaces appear to be specially well suited for informal communication (Bly 1993ibid.).

3.4 Social aspects of everyday technology

In our new societies, the worlds of work and play, education and entertainment, industry and the arts and the public and private sectors are no longer strictly separated, neither at home nor at work. Transactions and communications continue around the world at the same pace, whether day or night, whether we are awake or asleep. At home too, we perform many activities at the same time. This has become possible partly due to technology. We cook while watching television, monitor children sleeping in the bedroom while entertaining friends in the living room, and work while listening to music (Venkatesh 1997).

Hughes et. al. (1997) has described the role of technology in the home environment from a mainly sociological viewpoint. The authors mean that the effect of using new technology in home environments is increasing. In their studies they found that "The presence of technology within the home is absorbed so completely into the routine practice of homelife that it becomes yet another way in which those routines can be articulated". Although it cannot be said that technology places non-breakable scripts on daily activities. On the contrary the situated nature of home activities is very strong but they are also constrained by negotiated as well as unspoken rules. So even if reconfigurations of rooms often occur, this is carried out within some given boundaries. Hughes et. al. also found that in the cases where technology was a major part in the re-arrangements, this caused great stress and the technology was perceived as being badly designed and less user friendly.

4 Research questions related to VMC use in homes

The research project carried out here aims at exploring, making proposals and defining further relevant research questions about how VMC solutions should be designed and integrated into the home environment. In the longer run of course, also some general conclusions or results might be drawn from the work. From this standpoint the general research problem could be described as follows:

- How should architecture and technology be designed to support VMC in future domestic environments?

Some central sub-issues are then possible to define from this perspective:

- What processes of future everyday activities in home environments could realistically be supported by VMC?
- How should the speciffic VMC set-ups be designed for the activities it is supposed to support?
- How can the demands of private and public spaces be fulfilled in this context using architectural and technological design?
- What interfaces should be used to facilitate interaction with the system?
- How should the VMC be integrated in other advanced domestic technolgies?

In this paper we are describing what has been done and visions of what is going to be done in the near future in the design of the comZONES in the comHOME apartment. We are trying to provide a general overview of the project and the description below does not aim to provide specific answers to each one of these questions, rather to construct a framework in which to place the themes discussed. The design goals are exemplified as short scenarios when we describe the different VMC set-ups. The key part of the remaining text below discusses how to deal with public and private spaces.

5 comHOME - A vision of an apartment of the future

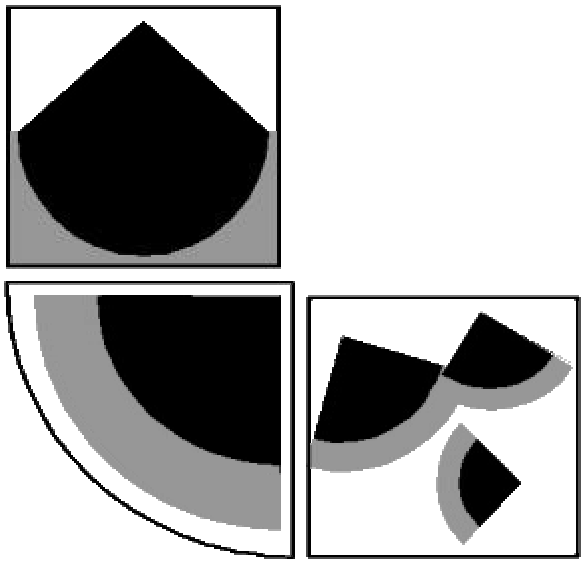
The comHOME apartment is a dwelling of the future, used both as a laboratory and a as a showroom. The comHOME project covers several aspects of future dwellings. Our primary goal in the comHOME project has been to develop and integrate VMC solutions into a home, although we are also working with making the home smart. The authors bear the primary responsibility for the design of the dwelling while the project has been carried out in cooperation between our research lab, a telecom operator and a company providing and developing Lon-Works home-automation technology. We would initially like to point out that the comHOME apartment is not a complete dwelling. It lacks a bathroom and the general floor-plan layout is not suitable for a real apartment. It is best described as a full-scale model constructed from a number of scenario-like room set-ups standing each by itself. As an example the activity "Telework" from the home environment cannot be limited only to a specific area as in the design below, but rather, the whole dwelling should be seen as a potential place for work (Junestrand & Leal 1998). Neither is it intended that anybody should live in this apartment for any extended period of time.

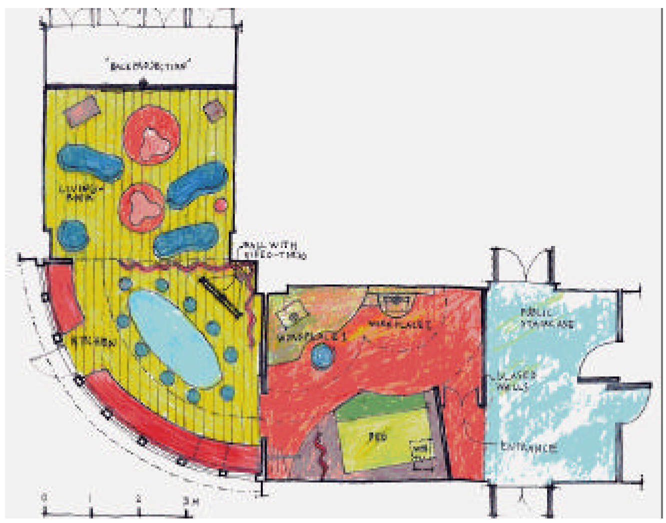
5.1 Architectural design concept

The spatial design of the dwelling is based on the idea of creating different comZONES to support the demands of both private and public digital spaces within the home environment. In an inner zone, a person can be both seen and heard through VMC equipment. In the middle zone the individual can be seen but not heard. In the outer zone the resident can neither been seen or heard. In this way the inner zone is a public zone, the middle zone is a semi-public zone and the outer zone is a private zone. (Junestrand & Tollmar 1998). The zones may vary in time and space. These zones indicate places that Mitchell describes as ”places where you can hear and be heard, or see (on a display) without completely relinquishing the privacy and controllability of the home” (Mitchell 1995).

The principal architectural issue was the establishment of the mental and physical boundaries between the public and the private in the VMC supported communication zones, i.e. to uphold the absolute demand of being secure from being seen or heard when so desired. It can be assumed that locating activities in a way that a good balance is attained with other everyday activities, as well as for the arrangements for general technical installations, will also be important. The design also takes into consideration both the inside-out and the outside-in perspectives. Meaning that it is of interest how the outer world is perceived through VMC from within the home as well as how the dwelling is perceived from places outside the dwelling supported by VMC.

The different comZONES are expressed by technical solutions such as screens and cameras but also by the use of architecture - spatial forms, colors, light, materials. The architectural space can then, in combination with ICT solutions, form an interface to the digital world. Figure 1 shows a drawing of the conceptual floor plan to be compared to the more traditional floor plan sketch in Figure 2. Both these plans have been used to communicate the basic conceptual idea during the design process.





<u>Figure 1.</u> Conceptual design of the floor-plan indicating the comZONES. In the inner black zone the individual can be both seen and heard by the VMC equipment. In outer gray zone the resident might only be seen but not heard. In the sorrounding white zone the person can neither be seen or heard. These zones can vary in time and space.

<u>Figure 2.</u> Floor plan sketch of the dwelling. The entrance is at the lower right. The middle room at the bottom is a combined telework and sleeping room. To the lower left is a kitchen, and to the upper left is a living room.

5.2 Technical design concepts

The technical challenge in deploying VMC in comHOME uncovers multiple layers of complexity. The major difference to be considered is that a home is a radically different place to the more controlled office environment, e.g. poor lighting and audio conditions should be considered as normative rather than rare exceptions.

The technical design of the video and audio space in comHOME is based on several short-range cameras and microphones being mapped and routed through a common media switch. This media switch could be seen as the heart of all incoming and outgoing media streams. The control of the media switch is carried out either via a remote control or a GUI on a terminal. or automatically by the central logic of the smart home. Furthermore, automatic pre-settings could be activated by the central logic of the smart home based on sensor data directed to the media-switch. The video and audio space is hence also closely linked to the design and automation of comHOME as a smart-home. In other words an incoming video call might cause a dimming of the lights or activate the mute command on the radio.

The creation of the different comZONES into the rooms of comHOME is a major technical undertaking. Early works have proposed the use of physical metaphors for control of the video and audio space in VMC systems. One approach, suggested by Kawai (1996), used a GUI with a floor plan to control the field of view of the cameras. Most of these methods suggest using an explicit and direct control of the cameras. In our case, the variation of the zones in space will mainly be controlled by a spatial recognition system that links the physical position with the identity of the person/people in the rooms.

By control of focus depth and field of view combined with the placement of cameras in the rooms we could, using a simple model, fairly well adjust the video space in the different zones. The control of the audio space is actually more complex. Our primary solution is to mix wide range microphones, such as PZM microphones, with directed microphones. Unfortunately the fairly precise video-space is not matched by equally well-defined boundaries in the audio space. We are aware that array microphones and spatial directed loudspeakers might solve part of this puzzle, but these technologies have not yet become available to us. Similarly prototypes of realtime image manipulation that could, e.g. extract actions or allow people in the background be removed from the videostream do not yet exist.

6 The comZONES in comHOME

The *comHOME* dwelling has three rooms: a living room, a kitchen and a combined telework and sleeping room. In our attempt to explore the usability of the comZONES concepts we have designed a set of six places and scenarios for which we are attempting to describe different design solutions.

A **videoTORSO** for informal everyday communication while standing and talking is placed in the kitchen. This VMC system explores the possibility of supporting informal full screen communication standing up, on a vertically mounted flat screen. The area around the kitchen shelves is normally a semi-public zone where the individual can be seen but not heard. However this could easily be changed into a public or a private zone. The public zone is normally located a little closer to the videoTORSO so that the resident must take a step forward to be heard. The screen can also be places in a horizontal position by twisting it. Ongoing activities aim at integrating the camera and the microphone into the videoTORSO at each side of the screen. In this way they are exposed and in function when the screen is in a vertical position for communication, and hidden and not functioning when the screen is in a horizontal position. The twisting of the screen is motor driven and controlled by the central logic. In this way the user can indicate with e.g. a gesture or a voice command, that he/she wishes to communicate and the screen automatically assumes the correct position. The speakers are placed above the screen and are always visible since the screen in the horizontal position can be used as a television, a web browser or ambient media. In this setting the core problem is to zoom into the audio space to a suitable range. This could perhaps be achieved by directed microphones which normally peak at a distance of 2 m and fade off rapidly at distances greater than 2.5 m.

A **comTABLE** located in the kitchen contains a computer and screen. The current uses for this table are two-fold. Firstly it enables a virtual dining guest to be a part of dinner through a video conference session that is displayed on the screen. Secondly it also make it possible to read for example a digital morning paper that appears in the table. This has two results.

Firstly, by placing a large display in the one of the table's unfolding parts it will become easy to adjust the screen for multiple use. In up-folded position the screen could be used for a remote invited dinner guest. In down-folded position could the screen be used for reading the morning paper or doing on-line ordering of groceries.

Secondly, by integrate the camera and microphone into the unfolding part control of the visual view becomes very physical (one interpretation of the ComZoon). By placing the camera into the frame we are hoping to find a natural syntax of adjusting the ComZoon – up-fold the display and the camera will view across the table, down-fold the display and the camera will stare into the roof.

The screen is located in a mobile frame on the rear end of the table. This VMC set-up can be used to read your interactive digital morning newspaper when seated at the rear end. Or the screen could also be placed vertically as a video representation of a guest on the screen during Sunday dinner. The integrated camera is located in the mobile frame so the control of the public space can be manipulated by lifting the frame up and down. This very physical interaction with the comTABLE provides an alternative to software and sensor based solutions.

A **deskTOP** and a **lapTOP** workplace, both for professional work in the home environment, are located in the combined home office and sleeping room. These two workplaces are held together with two boards completing the spatial definition. The public zone, where the resident can be seen and heard for example while participating in a video-conference, is indicated with a false ceiling equipped with integrated illumination. In these two settings, two cameras are used at each place. One is a dedicated handheld document camera for showing physical objects and the other a fixed camera that is adjusted so as to provide the talking head of the person.

Figure 3. A videoTORSO for informal everyday communication.
Figure 4. ComTABLE for VMC in a dinner situation.

<u>Figure 5.</u> The deskTOP workplace with the wooden panel and lowered ceiling that indicates the *private zone.*

An **internetTV** with video communication facilities as well as connection to Internet services is located in the ceiling at the bed place. The border of the public is indicated and expressed by the shape of the wooden structure around the bed and a curtain behind it. Also in this setting, fixed cameras are used to simply define the fixed boundary.

A **mediaSPACE** located in the living room is the extension of the physical room creating a larger social space with the digital representation of another space. This is done on two parallel mounted 80" screens seamlessly integrated into one wall of the small living room. This comZONE is extended, and merged, with another room at distance. This space is primarily a public zone when in use and is limited by a curtain on its back wall. Realizing that this room is a mostly public space – when the VMC is in use - turns the problems upside down. In this case it instead becomes a challenge to both keep a broad overview and provide close-ups within the scene. Here we use a technique from the VideoCafe system (Tollmar et al. 1998) and provide a dual video stream that could be used for both overviews and close-ups.

Conclusions from VMC in comHOME

The construction of the comHOME dwelling was finished during late 1998 and has since been taken into use as a laboratory. At this stage, rather than presenting results from specific evaluations, the points below can be considered as a number of ideas tested within the limitations of this full-scale experiment with no contradictions so far identified. Some early tentative conclusions from the design phase are:

- It is possible to introduce architectural expressions into the dwellings in order to support the resident in his/her understanding of, as well as experiencing the limits of, comZONES in the dwelling as far as the public (where you can be seen and heard) and the private (where you can not be seen nor heard) VMC issues are concerned

- It seems to give an added value to dwellings if information technology and architecture together can support the integration of VMC

- The changing use of the dwelling and the introduction of new ICT technologies seem to demand both new concepts for the general floor-plan layout as well as the specific spatial design

- Solutions for both sound and images are very complex and tend to be crucial for a successful integration of VMC set-ups in homes.
- Using none wearable microphones only, it appears to be difficult to create zones for audio which are as sharp and easily controlled as those of the video.

- In order to achieve a successful result, the development of new VMC set-ups for home environments should be closely linked to the general design of a smart home, both from a user and producer perspective.

- During the complex design process we have experienced, naturally several trade-offs have had to be made in both the general concept and the details of every specific VMC set-up. It has been very difficult to evaluate the effects many of these selections will have on the final real-life situation.

Future work

We still have a lot of work to do both regarding the hardware and software designs in order to make the VMC settings working properly. New directions in our research also include the use of sign/gesture language tracked by video to interact with the technologies in the room. Further integration with the general smart environment is also underway.

Although lacking technical functionality we are at the moment performing user studies evaluating the architectural and technical design of some specific settings. A video, using professional actors and film-team, has been recorded and is now being edited. This video demonstrates putting the different VMC set-ups into a social context of everyday life.

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