COMPUTER INTEGRATED ASSISTIVE TECHNOLOGY SYSTEMS FOR DISABLED PEOPLE

A Thesis by:

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Declaration:

No portion of this work has been submitted in support of an application for another degree or qualification in the Dublin City University or in any other University or Institute of learning.

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: ______________________ **Date:** 25th Sept. 1995

Candidate

Date: 25th Sept 1995

Acknowledgements

Embarking on this course of study, following a period of some years away from the position of "student" was something that filled me initially with a degree of trepidation. It required a re-alignment of my thinking processes. Indeed, whilst I had had the ambition to carry out this work for some time, I postponed actually doing it until I was encouraged to do so by a number of people.

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1 INTRODUCTION

1.1 Computer Assistive Technology

1.1.1 Current Problems in Applying Assistive Technology

Computer based systems can be used as extremely effective assistive tools by people with disabilities. They can help disabled people communicate, work, learn, and control their immediate environment. Unfortunately, the process of selecting and applying the most appropriate system for a given person, is too compartmentalised, due mainly to the way in which such problems have been addressed traditionally.

The confused current situation is likely to lead to a number of completely separate systems being recommended for a user, without any significant degree of co-operation or rationalisation among the various professions involved in the assessment process. The user can find themselves expected to employ different systems, for different applications, using different input devices, different output systems and quite often, completely different user interfaces.

In addition to the above points, people using assistive technology are very poorly supported. They require guidance in the use of their machines, help with technical problems, and assistance in re-configuring the equipment when their needs change.

1.1.2 How the Situation can be Improved

This thesis proposes a methodology to overcome the problems outlined in section 1.1.1. Several new practices need to be adopted, or existing ones changed. These may be summarised as:

1. The use of computers as integrated, assistive devices, incorporating the users' global needs into one system with common inputs and outputs, and a single, user-friendly interface. Equipment should be used with the most adaptable technical base.

2. A modification of the assessment team to allow the user's needs to be assessed overall. The team must work together focusing on the requirements of the client, endeavouring to arrive at a solution that can accommodate all needs in the most efficient, clearest, and cost effective way.
3. Support to the client must be improved by considering such needs as an integral part of the equipment specification. Equipment can be designed to include contextual help, on-line assistance, or to include a mechanism for remote diagnostic and software modification.
4. A network is required through which regional or local supporters, clients, and expert centres can communicate easily with each other and obtain help and advice. This network should employ new technology systems as well as traditional mechanisms.
5. Professional staffs themselves need to be trained and supported. This requires that suitable course material be produced, validated and used, both in normal undergraduate training, and as part of in-service development.

The following references refer to these points [A98b], [A98a], [A97a], [A97b], [A96b], [CRC97a].

1.1.3 How Justified is this Approach?

The integrated assessment and integrated technology idea has arisen as a natural consequence of service delivery work carried out by the author, as Director of the Technical Division of the Central Remedial Clinic in Dublin over a period of 15 years. On numerous occasions, the assessing team was faced with a situation where a disabled person was required to use many differing systems for different tasks. Due to the geographic spread of the Irish population, many equipment user's, experienced difficulties due to the fact that they lived considerable distance from the nearest point of assistance.

Experience with users has shown this method to be the most cost effective and user-friendly way of exploiting assistive technologies. In addition, this approach allows for the ready inclusion of emerging interface standards, and the use of commonplace, low cost, technologies wherever possible.

The methodology suggested is directly referred to, in the report of the European HEART project. This group was set up to specifically examine issues relating to service delivery of assistive technologies, and to identify good practice already in existence in Europe and North America. [CEC94a].

1.2 Personal Work Undertaken To-Date

As previously stated, the author has acted as leader of technology activities at the Central Remedial Clinic (CRC) in Dublin, since they started in 1982, and has also been involved in a number of multi-national research and development projects and initiatives.

As stated, involvement in the process of applying assistive technologies to help disabled people began in 1982. They began with the establishment of the Microelectronics Resource Centre at CRC. As well as normal day to day service delivery tasks, a research and development role was established from outset, requiring involvement in a number of actions both national and international. The following references refer, [A83a], [A83b], [A84a], [A84b], [A84c], [A84d], [A85a], [A86a], [A87a], [A89a], [A90], [A91], [A94b], [A96c], [A97c], [CEC96a], [A96b], [CEC93a], [H94].

The work has allowed for a continual flow of information between state-of-the art development, and service delivery. Due to the innovatory nature of the activities, and the fact that the department is operating at the cutting edge of development, CRC Technical Division, through the author, have become involved in a number of EU Committees and programmes in the capacity of Irish National representative.

1.3 Personal Research Relevant to Thesis

From the beginning, it was realised that Ireland could not afford to simply adopt the service delivery model used in similar European States. Lack of resources, and a considerably dispersed population meant that a more rationalised approach was necessary. In addition, by virtue of personal background and training, a more analytical and modular approach to the problem was brought to bear than had previously been the case. In other Countries the work developed from normal medical or para-medical activities.

A methodology gradually took shape and has been published and developed over the last eight to ten years. In addition to the general references listed in section 1.2, the following specific contributions apply. [A94a], [A94c], [A95], [A96a], [A96b], [A97a], [A97b], [A97d], [A97e], [A97f], [A98a], [A98b], [CEC94b], [CEC97a], [CRC97a], [CRC97b].

The original Microelectronics Resource Centre has been reformed into a complete Technical Division supporting activities on a number of fronts, both inside and outside of CRC. The author continues to act as Research Director of the Unit, determining the direction and co-ordination of all the activities that take place.

The methodology of integrated assessments and on-going support has been partially implemented through the direct employment of a multi-disciplinary assessment team. This group consists of, an Occupational Therapist, a Speech and Language Therapist, a Technician, a team co-ordinator and a Special Education Technical Specialist [J97]. The latter functions as a National Advisor and part time team member. Part of the approach has therefore been implemented on a pilot basis, allowing some measure to be made of the effectiveness of the methodology.

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2 FOCUS OF THE WORK

2.1 Overview of Thesis

The thesis sets out a philosophy and practical approach to solve the problem of effectively and efficiently applying computer systems, and associated technologies, to meet the special needs of disabled people whilst also providing users with systems that can be readily understood and used. The methodology proposed, has been determined by the author over the last five to ten years and partially put into practice whilst functioning as Director of Technical activities at the Central Remedial Clinic in Dublin.

Due to the rising expectations of the disabled community, it is necessary to ensure equipment recommended is cost effective so that funding agencies can finance a sufficient quantity of systems of the required type. It has long been recognised that the major difficulty in helping disabled people through the application of computers lies in poor service delivery, not in the development of higher levels of technical capacity [CEC94a].

This thesis will establish the background situation in Chapter three. It will explain the ways in which disabled people currently use computers as assistive tools, and the service delivery demands made within Ireland and Europe. It will give a brief explanation of the of the problems that physically disabled people encounter when using assistive technologies or when accessing mainstream systems required for work, education or other activities of daily living. Examination will be made of new emerging thinking, and demographic trends that are likely to affect the process of helping disabled people in their use of technology. An overview is presented of the type of problems that clients experience. The Chapter also looks at other barriers to the use of computers caused by poor overall design, social behaviour patterns, and the lack of appropriate standards.

Chapter four examines the new methodology proposed. Its benefits are considered, from the point of view of the clients, the clinicians that work with them, local carers and families, equipment providers and the technical designers and manufacturers. It considers the advantages of holistically assessing the needs of an individual and of addressing them in a single, integrated assistive tool. Consideration is made of the advantages of integrating technologies and facilitating assessment personnel to help the client most effectively.

The needs of disabled equipment users are considered within a proposed "three-environment" model. This idea, splits the needs of the client into: (a) a Direct Environment, allowing control of systems and devices within the person's immediate vicinity such as mobility, communications etc., (b) a Fixed Environment, permitting control of home or workplace systems through such technologies as Smart Housing, and (c) a Distant Environment, through which the disabled user gains access and control of functions within the larger world of their local town or village.

Chapters five, six, and seven go on to examine each of these environments in more detail. Consideration is made of the user's needs within that environment, how they can be assessed efficiently and how they can best be implemented using current or emerging technologies. This concept builds upon ideas presented by the author at a number of International forums, and represents the foundation upon which recent project work has been based.

Chapter eight will attempt to give an analysis of the recommended methodology, drawing heavily upon experience gained with the Central Remedial Clinic, and other organisations in Europe with which CRC and the author have been associated.

Even if this methodology were adopted immediately on a National scale, there would still be areas requiring attention in order to maximise the advantages of computers to disabled people. Chapter nine will examine these remaining issues, and try to identify areas requiring work by others. In some cases, the issues can only be addressed at International level, while in other cases, the full magnitude of the problem may not yet be apparent, and will only become so, as new technologies and computer interfaces emerge onto the commercial scene.

Finally, Chapter nine summarises the lessons learned, in the course of this work, and of that that has preceded it. [A87a], [A94b], [A97a], [A97b], [A97d], [A97e], [A98a], [ASP96], [CEC94a], [CEC96b], [CRC97a], [CSPD96a], [K91].

2.2 The Integrated Technology Methodology

The whole basis of the approach proposed in this thesis is that a holistic view be taken of a disabled person's technical equipment needs, including their physical access problems and their difficulties in undertaking activities of everyday living, such as education, employment, social interactions and artistic endeavours.

Once these needs have been assessed overall, an integrated solution should be sought to provide them with the most comprehensive, user friendly and cost effective means of achieving their goals. This final system should include their support needs – achieved by supporting both the users directly, and their carers. As needs change, the equipment and carers must be allowed to change as well.

The approach can be summarised as one of considering the disabled person centrally, and of allowing the equipment to be adapted in response to their needs as complete people. This is in contrast to the current position in which there is a tendency to isolate and compartmentalise needs; more to fit in with traditional service delivery practices than for the benefit of the end-user.

3 BACKGROUND

3.1 What are Assistive Technologies?

The International Standards Organisation (ISO, 1992) defines assistive technology ("technical aids" in their terminology) as:

> *"..any product, instrument, equipment or technical system used by a disabled person, especially produced or generally available, preventing, compensating, relieving or neutralising the impairment, disability or handicap."*

Equally, the term Assistive Technology (A.T.) is applied to any device or system, technically based, which has been designed to help a disabled person overcome problems associated with their disability. At one extreme, a pair of spectacles could be referred to, as an assistive technology device. Therefore, for the purposes of this thesis, the term is taken to refer to a device that is computer based. In particular, since the work is drawn largely from experiences gained with the Technical Division of the Central Remedial Clinic; considerable emphasis is placed upon the particular problems associated with various forms of physical disability.

Special examination will be made later of the detailed functions carried out by existing devices. At present, they can be taken to fall into one or more of the following application areas:

- Inter-personal communication systems – devices designed to assist the user communicate face to face with another individual using either written text or artificially uttered speech.
- Environmental control systems – devices designed to permit the user exercise a greater degree of control over devices and functions within their immediate vicinity
- Curriculum access systems – those devices designed to allow a person with a disability take part more fully in the conventional learning process.

- Vocational or Employment access tools – as previously, but specifically designed to interface with existing business systems, e.g. normal computer systems.
- Leisure access systems – specialised devices that allow the user access to recreational systems or artistic endeavours.

3.2 The Role of Computers

Computers form the basis upon which most modern assistive technology systems are built. Access to a computer means access to many important activities of everyday living. If a user can successfully employ a computer, they can communicate, live independently, access mainstream educational activities, work, play and express themselves artistically. However, if modern demographic trends continue, there will be more computer users in the future with access problems by virtue of their age and the difficulties that it brings. Both hardware and software designers are well advised to consider this prospect now, and to prepare for it by gaining a better understanding of the problems, and carefully designing systems to take them into account.

The reality of the situation today is that computers form both the means of implementing an assistive technology system, and the target of the action. Computers are employed as the basis or enabling mechanism at the heart of an assistive device. In addition, due to the extensive application of machines in everyday life, gaining access to them is itself, often the objective desired by the disabled user. The edges of division between the machine being considered as a tool and as a normal application are blurred making it very difficult, sometimes, to see where one ends and the other begins.

This leads to two different approaches to the problem of providing disabled people with computer access.

Firstly, the objective device (hardware and software) can be examined and modified to allow alternative forms of access. This approach has lead to a range of alternative keyboards, mouse systems and screens being made available. It has also lead to the inclusion of alternative access software systems within operating systems. Examples of this are represented by the "CloseView" and "Stickeykey" options available as standard with the Apple Macintosh system and with the access tools included as standard with Windows 95.

Secondly, if the application areas outlined in section 3.1 are re-examined, it can be seen that many of the mechanisms required are best realised by dedicating a machine to the task. Common communication systems are little more than normal computer platforms with appropriate software. The same can be said of environmental control mechanisms and each of the other applications as well. Taking the second approach – using a machine specifically as an assistive technology tool – allows the target mechanism to remain standard. Manufacturers can minimise the special versions they produce and thereby minimise cost. This second approach also allows the technical clinician to combine many differing pieces of application software onto one platform going someway toward achieving the goal of equipment integration referred too previously.[A96b].

There is merit in adopting elements of both approaches. If software designers can be made more aware of the problems experienced by some users in accessing their programs, there are often simple low cost approaches which can be incorporated at design that incur little or no extra cost. Consideration of these “special needs” can often result in advantages for other users who consider themselves “normal”. This would include those with problems resulting simply from old age, and not from a recognised disability. A classic example of this spin-off effect is seen in considering the development of the telephone which was originally designed to be a piece of assistive technology to help people with hearing impairments function more effectively.

Currently the W3C [W3C1] group is examining the whole question of Internet web page accessibility through its Web Accessibility Initiative (WAI) and is producing guidelines for web authors that will ease the problem of Internet access for people with certain kinds of disability.

3.3 Assistive Technology Service Delivery in Europe

3.3.1 The European HEART Report.

The HEART (Horizontal European Activities in Rehabilitation Technology) study was commissioned by the EC under the TIDE (Technology Initiative for the Disabled and the Elderly) program.[CEC94a]

The study was carried out in sixteen countries, which included all EU countries, EFTA countries and Canada (the Hugh Macmillan Centre). Its aim was to propose improvements in the process of assistive technology service delivery to improve the quality of service and to develop the European market. Professionals in the health services believe that the demand for assistive technology and related services will be greatly increased in the future. [CEC97a], [CEC96a], CEC94b], [CEC93b], [CRC97A]. At the same time European countries are facing economic restrictions and public spending cuts which will be felt in the health and social sectors. There are likely to be fewer resources available and it is believed that assistive technology can enable people to live more independent lives.

Information was gathered from the sixteen countries and good features of service delivery were chosen, identifying good examples or 'best practices'. The researchers assessed the services using the following criteria:

- Accessibility (from the user's perspective),
- Competence (knowledge and skills of the professionals involved),
- Co-ordination (professionals and services working together),
- Efficiency (from the user's perspective) and co-ordination of services),
- Flexibility of the service delivery system (SDS) and user influence (on the SDS).

After the information was compiled professionals from the Centres and experts from each country were brought together to agree on 'best practices'. The results of this intensive study were published by the EC in September 1994 and can be summarised as:

> *The SDS should be* ***accessible to all potential users,*** *and they should know that the service exists. Once approached, the process should be as short and easy as possible to access. Funds should be available for assistive technology and the process of obtaining it should be clear and understandable. Information services and umbrella user groups should work together and the user must be considered a partner in the process of service delivery.*

There are many different kinds of professionals active in the field of assistive technology and it is crucial that there is a high level of **competence**. It is recommended that the prescription of assistive technology not be based solely on a medical model. A multi-disciplinary assessment team should take into account medical, functional and social aspects. Centres of excellence should co-operate in order to increase competence, disseminate information and provide ongoing educational programmes for all professionals A multi-disciplinary approach should be used to plan research and development in assistive technology and the results disseminated.

Good **co-ordination** is essential and should be viewed on three levels. At an individual level, all aspects of the process should be co-ordinated to meet the individual's needs. On the level of the professionals, working together good co-ordination is necessary for the multi-disciplinary approach. At a global level it is essential that the SDS co-ordinate with the assistive technology market as well as with other sectors of society

Considering the increasing demand for assistive technology combined with the current economic restrictions, it is of the utmost importance that the service be as efficient as possible. **Efficiency** is defined as the capacity to find the best solutions for the most people using available resources at the least cost and in the shortest time. The initial assessment should provide the user with enough information to decide whether they wish to continue the process, that a backup service is provided, that there are protocols available to guide professionals and that there are clear goals and methods for evaluation.

Systems need to be flexible in order to respond to change. In the field of assistive technology, flexibility is especially needed because of the diverse mature of disability and the continual advances in technology. There should be a multi-disciplinary rehabilitation plan, which is tailored to the needs of the individual and a system of quality control. A SDS is flexible when a user can obtain a device when it meets their needs. This is true whether or not it is on a 'list' or is produced or marketed in that country, nor whether it is a conventional device. It should be available regardless of income or age or disability etc. and should allow both the user and the professional time to change their decision.

The report recommended that the user be the best judge of whether a specific technical solution to functional limitation is good. Users should be empowered to make their own choices, professionals should be educated to have an attitude of equity towards clients, who in turn, should be allowed to try out devices for a reasonable length of time. It was also recommended that user feedback is essential in order to improve the service.

National contact Centres supported the work enthusiastically and it was strongly recommended to continue the work started by the study.

To summarise

- It is fundamental that no one is excluded from the services, and that "one door to knock" should be sufficient to gain access to the system and start the procedure.
- There are many different kinds of professionals active in the field of assistive technology, which makes competence a very crucial quality criterion
- Centres of excellence e.g. specialised in disability groups or specific aspects of technology should co-operate in order to increase competence and disseminate information on an international basis.
- Recommendation of appropriate technical aids should not be based upon a medical model. In the selection process medical, functional, social and other aspects should be taken into account. The multi-disciplinary team is the best approach
- There should be co-ordination of research and development of assistive technology and service delivery within the team and information should be disseminated
- Service delivery systems should include systems or procedures for self-correcting quality control of the process and the outcome. A good service delivery system involves the use of a multi-disciplinary rehabilitation plan and is tailored to the needs of the individual.
- A good service delivery process is designed in a way that empowers users to make their own choices. This can be done by educating professionals to have an attitude of equity towards users, providing as much information to users as possible, allowing users to try out systems for a reasonable time and providing the means for both users and professionals to change decisions
- The rights of the disabled persons to appropriate assistive technology should be ensured by adequate legislation, accompanying financial means, platforms or advisory committees at local, national and/or European level promoting and monitoring practices and statutory bodies to ensure and protect their rights.

3.4 Assistive Technology Service Delivery in Ireland

3.4.1 Report of the Commission for the Status of People with Disabilities

In October 1996 the Commission for the Status of People with Disabilities produced a major report entitled "A Strategy for Equality", [CSPD96a]. The Minister of Equality and Law Reform had originally set up this group, and the final report was envisaged as being a cornerstone upon which new enabling legislation and services would be based well into the next century. The group carried out their work by means of an extensive listening exercise among disabled people, their representatives and service providers. Many individual working groups were set-up, the most significant from the viewpoint of this thesis, would be the working group on Technology and Telecommunications [CSPD96b]. Individual reports were produced and published from each group.

The report was a major event from the point of view of disabled people and those working on their behalf. In all, over three hundred recommendations were made, many in the area of technology application and service delivery. The following have been singled out as having particular relevance to the subject of this work:

> *4.13 The primary responsibility for assistive technology services must be removed from the medical context*
>
> *4.13.1 At present the primary service providers for assistive technology in Ireland are the regional Health Boards, supported by voluntary bodies. This places the service within a medical context and a charity ethos. The status of people with disabilities would be better served by taking a "whole person" approach to the provision of assistive technology and removing it from the medical context.*

4.15.10 In general, there needs to be more emphasis on training, assessment and support staff. Training should be validated and include: -

- *training on information sources and how to access them*
- *training on equipment*
- *the importance of listening to the referred client*
- *how to work in multi-disciplinary teams.*

In addition, the report highlights the following problems existing within the present situation:

- Insufficient resources provided to the assessment function (e.g. Staff, Equipment, and Training.)
- Poor operation of multi-disciplinary teams.
- Assessments are not "Person Centred".
- Poor collaboration between different organisations.
- Poor provision of service to regions.
- Poor approach, due to "Medical Model" administration.

Many of the above cannot be resolved by the application of technology alone. It is important, however, to understand the nature of the problem that this new approach sets out to address.

3.4.2 The Demand for Independent Living Support

A rise in demand for independent living support systems has become apparent to technical assessment centres such as the Client Technical Services unit of CRC, over the last 10-15 years. Over the last five years, this demand has rapidly increased, due partly to more effective lobbying by disabled clients, and by those working on their behalf. One significant example of such a lobby group would be the Center for Independent Living (CIL). This is an organisation set up by people with disabilities for people with disabilities. CIL have 18 centres and are expanding to 26 (one for each Irish county).

CRC and CIL have now embarked on a new EU venture to develop the skills of people in regional centres to allow them become the technical supporters, [CRC97b]

3.4.3 Irish Demographic Trends

In Ireland, demographic trends have largely followed those in other Western States. The average age of the population has increased. This trend is set to continue.

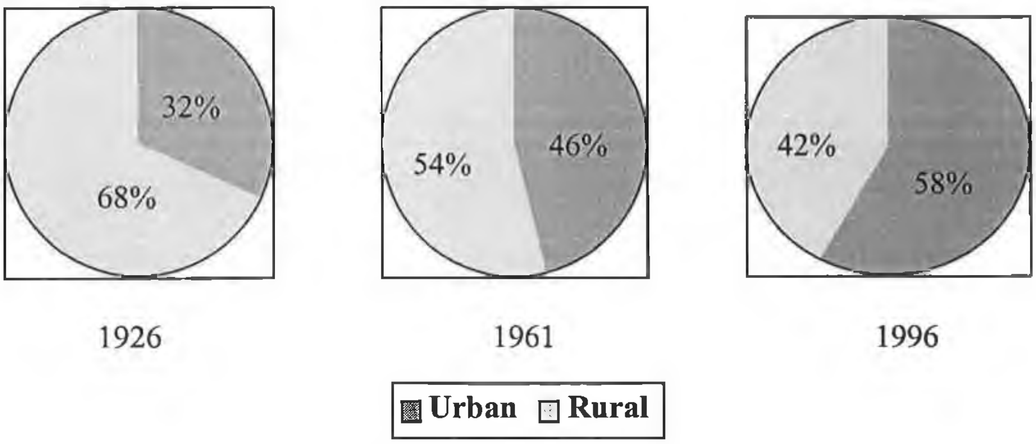
Average age:

1996 = 33.6yrs

1981 = 30.8yrs

This change is not as pronounced as that in other Western States, and when coupled with a fall in birth rate, Ireland, unique in Europe, has a dependent population ratio that is set to fall over the next 10-15 years.

The Country is becoming more Urban based:



Source 1996 Irish Census Report

Figure 3.4-1 Variation in Irish Population between Urban and Rural Base

3.5 Problems to be Overcome

3.5.1 Mobility Impairments

Physically disabled people suffer from impaired mobility to a greater or lesser extent depending on the nature and severity of their disability. Some people with congenital disabilities such as cerebral palsy, muscular dystrophy or multiple sclerosis experience problems due to poor muscle ability or poor co-ordinating ability required to control movement. Such disabilities cause problems in a variety of muscle control activities, not just mobility.

Similarly, people that have a disability because of an accident or other trauma, find muscles, and therefore mobility, difficult to control. These disabilities are referred too, as acquired disabilities.

The disabled person requires help in walking, or more commonly, in controlling their wheelchairs.

3.5.2 Visual Impairment

Visual impairments can accompany other physical disabilities, or be present because of difficult viewing angles or positions. For example, a severely disabled person reclined in a wheelchair with no ability to remove mucus from their eyes will suffer a degree of visual impairment. This is a particular problem if the person is required to operate fine controls or interpret instructions from a screen, as would be the case in using a computer.

3.5.3 Speech and Communication Limitations

Poor muscle co-ordination and control can result in poor speech and communication ability. Vocalisation requires muscle control as does keypad operation or normal writing. Again, the degree, to which a person is affected, varies greatly. Communication problems divide into two distinct types:

a) Problems in vocalising particularly in conversational situations as would be required for face to face inter-personal communication, or in the use of the telephone.
b) Problems in written communication.

Communication problems are amongst the more difficult for a disabled person to cope with. They are cut off from society, their friends, their families, and, in case (b) above, from work and education.

3.5.4 Cognitive Limitations

People, who do not suffer from a physical disability, develop from an early age, by trying things and noting the result. If a button is pressed, it produces some result. The same cause and effect relationship is experienced in a number of situations and allows for the refinement of many other senses and abilities. Disabled people may not have had the chance to experience this cause and effect relationship in the same way. As a result, they reach relative maturity with a limited ability to understand what will happen in certain situations, or what they must do to initiate a desired result.

3.5.5 Manipulative Difficulties

Manipulative difficulties arise from poor motor control as described previously. In addition, it can mean that a person is unable to operate standard devices in the normal way. Examples of devices, which can cause problems, would be: -

- A Computer mouse
- A Computer keyboard
- Inserting and removing disks and paper.
- Using normal communication systems, e.g. telephones, radios, etc.

3.6 Computers Applied to Overcome Physical Limitations

3.6.1 Assistive or Augmentative Communication

Communication takes place on a number of different levels and in many differing situations. Some of these rely heavily on the use of speech. Its purpose is not only to convey information, but also to attract attention to the person wishing to communicate. It makes the difference between active and passive communication.

If the process of speech communication between non-disabled people is examined a little closer, these protocols can be seen in use. It can be observed that speech ability allows the intending communicator, seize the opportune moment for a comment. In short, the protocol of normal speech means that those wishing to communicate take turns, or more bluntly, people politely interrupt each other on a continuing basis.

Written communication is different. It allows for a more considered and passive method of imparting information. Spontaneity is not required; indeed, it is a facet of written communication that it should be this way, allowing for a more precise and considered, transfer of information.

Computers used as alternative or augmentative communication systems must reflect the above. There are systems better designed for one purpose than another. Alternatively, a given device may need to be operable in various modes. Software is in a continually changing state, and experienced software designers, in conjunction with speech and language therapists, and the users themselves, can best carry out its development.

3.6.1.1 Speech Output Devices

What distinguishes a good speech output device from a bad one is not only the quality of its output, but also the software and interfaces presented to the user. Early systems - limited as much by the technology as by lack of development experience - tended to consist only of stored, pre-formed phrases or words. These would have either been pre-programmed using phonetic spellings to achieve accurate output, or would have been produced by pre-recording words or phrases, uttered by another person. The first method was easier to carry out, but the second allowed for more accurate "user typing". That is, a young Irish lady did not have to sound like an American male.

Currently prescribed systems use state-of-the-art speech synthesisers, capable of being altered to suit the user, combined with interface designs that allow easy utterance of appropriate sentences quickly, supplemented by the ability to construct needed words as quickly as possible. The systems have become context sensitive, presenting the user with words or phrases appropriate to their current situation and what has gone before. Intelligence can be included, allowing the system adapt to the user's style and vocabulary over a period of time and use.

The combination of better speech output and better interface design has led to a range of devices capable of use in spontaneous, conversational situations.

3.6.1.2 Speech Input Devices

As well as technology designed to augment a user's speech output, systems are available to interpret spoken words and use this as a normal method of information input. This facility allows the user to construct text from normal speech and control other functions of the computer in a transparent, noninvasive way when accessing commercial software. Typically, voice input systems can function with vocabularies of 60,000 to 100,00 words, deriving one word from another which shares a similar root.

Speech input devices are less well developed than speech output systems for a number of reasons. For many years, the need for such systems was not apparent, and available processors were not able to cope with the extensive routines and algorithms required to even approach a useable system. Even modern systems can have difficulty coping with high speed, continuo speech, due the device's inability to distinguish the beginning and end of words. Normal conversation consists of one word slurring into the next giving rise to this problem.

Available systems are improving rapidly, spurred on by the need to find alternative forms of computer input to avoid the incidence of Repetitive Strain Injury (RSI), featuring commonly in litigation, in addition to the special needs of some disabled people.

3.6.1.3 Writing Systems

Typically, writing systems are applied in work or school situations as well as the user's home. They are required to be portable enough to be easily moved. In general, disabled people find it much harder to make keystroke entries than a person with relatively normal abilities would. Systems are therefore designed to minimise the number of entries required, by the use of macros and word predication techniques. Sometimes writing aids can be easily combined with conversational, speech output ones, simply requiring the user switch modes of operation.

Notebook or laptop computers are the favoured option for this application. The user can easily move the system, and can attach other devices for alternative input or output.

3.6.2 Environmental Control - Smart Housing

Environmental control systems are employed to give the disabled user a greater degree of personal independence and the ability to control devices around them. They are used as part of the normal activities of daily living, at work, school or in the home place. The approach can be piecemeal, tackling small, individual difficulties that cause particular problems, or a more global and holistic analysis can be made of the complete living/working/learning situation. This later approach often leads to the consideration of intelligent homes or workplaces employing techniques that have now come to be termed, “Smart Housing” [A94c], [A96a], [A97g]. Smart House implementation implies the use of a central controlling processor, accepting inputs from sensors and in turn, activating various controllers to meet needs. The method by which the input and output information is conveyed and processed, leads to a consideration of the many commercial “Fieldbus” systems on the market; their availability; their support and the extent to which they have already been tested with disabled clients. A study on this, carried out by the author in 1997, is contained in Ref. [A97f]. The controller can be programmed to operate on a purely sequential basis, or to react to certain stimuli. It can also be a combination of both, with a degree of artificial intelligence to make decisions and prompt actions, if that is appropriate.

Whether the piecemeal or Smart Home approach is taken, it is useful to look at the kinds of functions that require control, and where the user is likely to require special assistance.

3.6.2.1 Control of Information Systems and Telephones

Communication is of importance to all people. Previous mention has been made of the difficulties experienced, and the assistive devices available that are designed to help in face to face communication. This has been referred too, as inter-personal communication. However, in addition to this, disabled people require access to mechanisms designed to allow communication at a distance, or to allow access to modern sources of information.

This problem, and its implications, has been the subject of a European Union collaborative project for the last 11 years. The project is named COST 219 (Collaboration On Science and Technology) and has recently completed the second five year cycle of its work. [CEC96b], [A96c], [A97c]. Activities are now proceeding into a third, five-year cycle.

The Telecommunications Access Advisory Committee (TAAC), part of the Architectural Transportation Barriers Compliance Board, have produced a detailed analysis of access problems experienced by people with disabilities, and have suggested guidelines for providers. The final report of the group is available [TAAC97].

Motor co-ordination problems make operation of normal telephones and information terminals very difficult. Computer systems are employed to assist by removing the need to physically hold a receiver, dial, or operate keypads in the normal way. The computer and telephone become one unit, producing a telephone or information terminal with intelligence, and with the possibility of it being controlled in a non-standard way. With suitable adaptation and software, the computer can become a video telephone, allowing for lip reading, sign language, gesture recognition and application sharing.

The new cordless telephone standard DECT allows the disabled user the flexibility of cordless telephony coupled with security and the ability for data and speech to be integrated. The cordless telephone handset becomes a remote control mechanism in addition to its normal function.

3.6.2.2 Control of Electrical Appliances

Electrical appliance control can be simple or complex. Many existing systems allow a computer switch devices on or off comparatively easily, anywhere within the user's immediate environment. Sophisticated control of devices, such as video recorders, televisions, washing machines etc., where more than simple on-off operations are required, is more difficult.

The control of more complex systems is best accomplished using home or Fieldbus technologies. [A94a]. These will be examined in more detail later, but it should be said at outset that application success is governed as much by market acceptance as by technical capability. For a fully successful implementation, third party manufacturers of equipment such as video recorders etc., would have to be prepared to incorporate a standard interface suitable for the purpose. This has obvious cost implications, and would be greatly influenced by whether the product has wide market appeal.

Finally, it is important the user be able to interrogate the system to establish, with reasonable certainty, the current state of devices. For example, the user should be able to find out whether a heater upstairs is on or off without having to physically go and see. For this facility to be truly accurate, it must be capable of establishing current states, not, it should be stressed, the last command sent.

3.6.2.3 Door Entry/Exit

Disabled people are vulnerable to attack, and have a greater than average need for personal security systems. Users need to be able to control access to their premises in a simple, safe way. This was addressed by the European Union project MECCS (**M**odular **E**nvironmental **C**ommunication and **C**ontrol), [CEC94b]. In this project, three organisations, under the direction of Central Remedial Clinic, Dublin, developed a remote control system, using radio technology, that linked the mobile user to a base control system, giving access to communications, device control and entry/exit verification.

The use of DECT technology, referred to previously, provides an avenue by which a user using a remote link can operate intercoms and access controllers.

3.6.2.4 Door Opening and Closing

Simple mechanisms exist that allow the user open and close both internal and external doors. Software has been written, with an evaluated user interface, under the MECCS project activities [CEC94b]. The mobile computer or controller provides the user with the ability to operate opening and closing mechanisms via direct links or through an overall home control system.

3.6.2.5 Automation and Customisation of Functions

Examining operations that are often carried out in sequence, and then combining these into a single routine or computer command can improve Independent living capability. In this way, a user can, for example, execute a "bed time" macro to close and lock all doors, turn off non-essential devices, turn down heating levels and inform a carer. At a more advanced level, the computer software should be capable of gradually learning the user's routines and suggesting actions if required.

An example of this latter approach has been under development at the BT Laboratories in Ipswich, UK, where a home monitoring system is being piloted that learns the person's activity pattern using infra-red movement/proximity detectors coupled to a specifically written program. Unexpected lack of activity, or an unusual pattern of activity, triggers an alarm or awareness call to a pre-programmed carer.

3.6.3 Access to the Curriculum

In addition to the physical access problems outlined previously, disabled people can experience difficulties in understanding or conceptualising in the same way other people do when learning. These difficulties have been referred too, before and are often partly alleviated by the application of well designed and written educational software. Western societies have moved toward a process of mainstreaming disabled people into normal schools wherever possible, often leaving the teacher with the task of educating a person with a significant level of physical disability. Student's can be supplied with technical aids to help them read standard texts or complete written assignments.

Support is all-important. This implies support for the teacher, the disabled person, and their families. Well designed software is of great assistance in achieving the desired goals, and can be made available to schools from specialist centres or from more general ones such as the Centre for Teaching Computing at Dublin City University, through their school computer task force activities.

Central Remedial Clinic, with the support of the Department of Education, has been providing a National advisory service to Irish schools for over two years. [J97]. The service advises staff and parents on appropriate software and systems that can be applied to help disabled individuals; particularly those in integrated class situations.

3.6.3.1 Provision of Special Software

Software is required to fit (a) with the student's physical disability, (b) with their cognitive and conceptual disabilities and (c) with the mainstream curriculum. It is used as an assist to normal teaching methods, complementing face to face communication. Some software aimed at disabled pupils, includes alternative input or output mechanisms to help overcome elements of the disability, and reinforces the subject matter in a manner that would be very difficult given modern day staff-pupils ratios.

Computer Assisted Learning (CAL) software systems are distributed through both publicly funded and commercial sources. As multi-media capabilities improve in entry level machines, there is a tendency to utilise these features as another way of stimulating and retaining interest.

3.6.4 Access to the Employment Market

Computers themselves represent an area of employment opportunity that disabled people have a reasonable expectation of aspiring too. The machine can be made accessible to many, and, by this mechanism, so can employment. Special employment measures, both at National and European Union level, have identified this area as worthy of exploitation, and have targeted resources at direct training and placement schemes. Examples of these, are represented by the HORIZON programme, overseen by DGV of the European Commission, which has supported, and continues to support, actions aimed at ultimately placing disabled people into paid employment. [CRC97a], [CRC97b]. A significant number of these project actions have focussed on the use of new technologies. Additionally, direct tuition courses, such as those run under the SKILLBASE endeavour, have also been based on technical applications to a large degree.

Finally, disabled people employ modern information systems, as do those working on their behalf, to identify work opportunities through both on-line and CD-ROM based databases.

3.6.4.1 Telework

The increasing movement toward employees working remotely from their employers is very favourable to disabled people. They become indistinguishable from the majority of the work force, suffer no transport difficulties, and can work at their own pace. This practice is perfectly viable in a Country with good communication links; given an adjustment in mindset on the part of both employer and employee. In the case of Ireland, with state-of-the-art telecommunications, and a population spread over a comparatively large area, such an approach makes eminent sense.

Employer's concerns often include fear of lack of supervision, security, and a worry that the normal daily interactions required between staff and employer will be made more difficult. These concerns can best be answered by examining comparisons with the real situation that exists today. Firstly, the lack of supervision is best judged in terms of the output produced, and whether deadlines are met. This worry is no greater with tele-workers than others, and is best judged by the performance of the individual. Secondly, security of commercial information can be assured by training and routine monitoring – at least to the extent that it can with any employee. Finally, routine communications are easily enabled by a combination of telephone, video communication, application sharing, fax, electronic mail, and, last but not least, periodic face to face meetings.

3.6.4.2 Adaptations to the Workstation

In the case of employees in a regular working situation, workstations can be easily modified to accommodate most physical disabilities, at minimal cost and inconvenience to the employer. Modified keyboards, document and disk feeders, screens and movement sensing systems are readily available and often publicly funded.

Most required adaptations are simple, and do not require high technology solutions. The exact details of the changes needed are best decided by normal therapeutic assessment techniques as part of the holistic process referred to previously. Occasionally, there is a need to consider more complex solutions, extreme examples of which have formed to basis of European project activities such as RAID, in which a large multi-National consortium produced a prototype system which included robotic arms to move paper and disks as required.

3.6.4.3 Mobility within the Workplace

Mobility within either a working or a living situation is very important. Not only are essential movements made for food, drink, to attend meetings etc, there is a need for any employee to feel free to simply change their immediate environment temporarily, take a break, enjoy social contact with colleagues. Such movements can be broken into two groups (a) routine, work related or those required for normal daily living, and (b) unplanned journeys to relieve monotony or to conduct a task not often required.

An employee with some degree of ambulatory capability requires little more than time, space and a little guidance occasionally.

The needs of a disabled person confined to a wheelchair are a little more complicated but can often be met by providing two different solutions. Routine movements or journeys can be programmed into an intelligent wheelchair controller as a set of macro actions. One selection can then execute the required manoeuvres to go to the toilet, fax machine or dinning area. The second required set of actions could be tackled using more intelligence in the wheelchair controller, sensing obstacles, distance from walls or tables etc.

In both the above cases, the factor determining a disabled person's ability to function in a normal employment situation, is their ability to access the controlling mechanism – a computer.

3.6.5 Remotely Delivered Education and Training

An obvious alternative method of delivering required educational courses or other training is to use the concept of distance learning. This technique is not new, having been well tried and tested with a range of courses and users, and by organisations such as the Open University in the U.K., Fern University in Berlin, Germany or the Distance Education Department of Dublin City University in Ireland. Whilst disabled people were often student participants on these programmes, the courses were essentially delivered to students with normal abilities, using delivery techniques such as the post, supplemented by summer school sessions.

Computer delivery of material, both to and from the student, can ease the problem greatly. In 1991, an innovatory pilot study was undertaken by Kenny & Murray [K91] to examine this specifically with disabled students. The study was entitled "Home-Delivered Training" and involved The National Rehabilitation Board (NRB), The FAS Centre in Louglinstown, Co. Dublin, and The National Distance Education Centre of Dublin City University. Course material was delivered to students using data transfer, but did not employ the Internet, as it was not generally accessible at that time.

The study concluded that the method was perfectly viable for people with physical disabilities, given the following conditions:

- That students admitted to the course have a definite interest in computers. This need not be accompanied by previous experience of their use.
- That students admitted to the course show the ability and self discipline to work on their own.
- That a student's disability is stable and unlikely to interfere with his or her progress through the course.
- That the student has access to an environment conducive to study
- That tutorial support is provided on a flexible, individualised basis – whether on-line or through home visits to the students, as appropriate.

The pilot study went on to make the following recommendations:

- Home delivered Training based on the use of computers and leading to an Internationally recognised qualification should be made available by mainstream training agencies.
- This training should be provided on an on-line basis. This extends the options to cover all the Country.
- Pastoral care and advice for the students should be provided and co-ordinated locally.
- The on-line messaging system used in the Home Delivered Training course should include the possibility of student networking.
- Where students have special needs, advice is required on the choice of specially adapted hardware or software and training is needed in its use.
- On completion of the course, students should be assisted in their search for employment.

Although this study took place in 1991, many of its recommendations and findings are valid now. If the work were to be reproduced today, it would seem obvious to use the Internet as the inter-connecting, on-line channel. This would allow easy access to a local point of presence, and the mechanism by which the work can be made International in operation and nature.

3.6.5.1 Assistance in Contacting Family and Friends

Providing an appropriate mechanism by which a disabled person can use a computer can also provide them with a means of contacting family and friends, where such contact would otherwise be difficult, inappropriate or impossible. The computer can allow control of normal telephone functions, can allow numbers to be looked up and dialled easily, can provide e-mail access or can become the basis of a video communication link.

Such facilities enable a person to work, enjoy a normal social contact or remove a sense of isolation. Collaborative work to explore the communication potential of suitable computer systems has taken place between Finland, The Netherlands and Ireland [A95].

The trend would appear to be toward making greater amounts of bandwidth available to all users. This has already led to the practicality of providing disabled people with acceptable quality video links using either ISDN, fast modem point to point, or Internet related links.

3.6.5.2 Access to the Arts and Leisure

The recreational and creative needs of the person with a disability are often overlooked in the rehabilitation field. It is important, however, to consider the needs of the whole person, so consideration is required to address artistic outlets using computer systems. Examples could be systems to allow users play games, draw or play/compose music.

This latter need has resulted in special work being undertaken at the Central Remedial Clinic, in conjunction with the Drake Music Project of Ireland. The Drake project recognises these needs and provides for them in the form of music composition and performance. The work identified the need for a programme that would allow disabled musicians to compose music via a single switch.

The resultant instrument exploits the electronic music format, MIDI, in order to achieve switch access to composing and performing music. The instrument is part of an electronic music set-up, which is illustrated below.

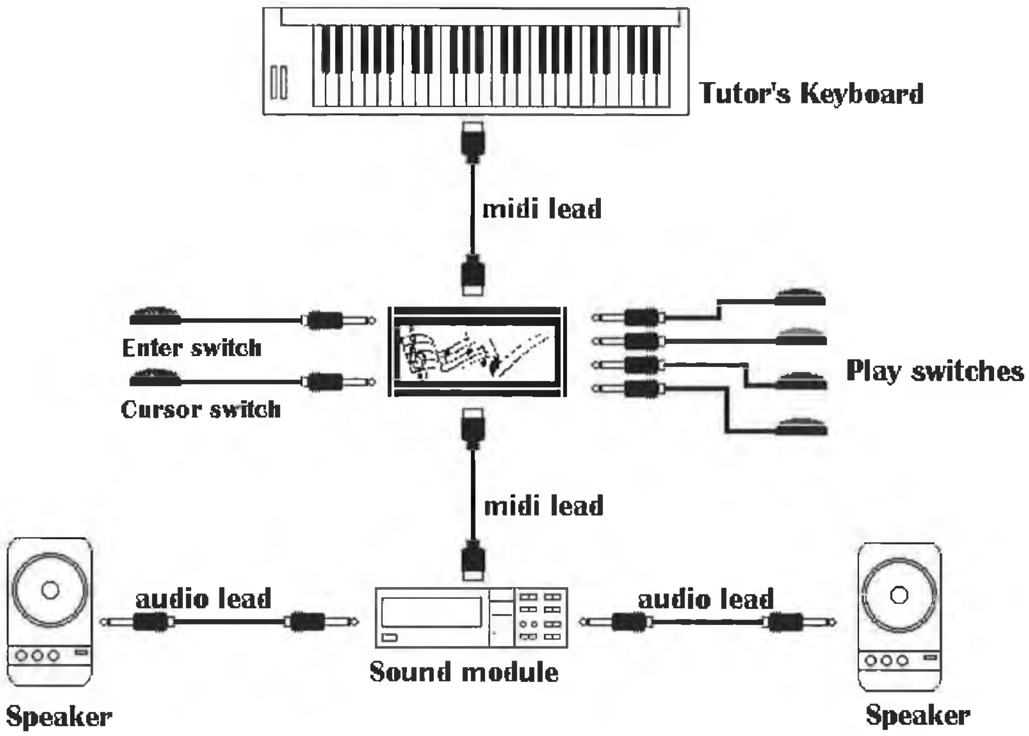


Figure 3.6-1 CRC/Drake Music System for Disabled Users

The instrument is placed between the keyboard and the sound module. In simple terms, the instrument is like a second keyboard. The switches connected to it are used to play music that would normally be played on the keys of the keyboard. The keyboard is therefore optional and is included to allow a tutor to accompany the student.

The interface has been used successfully in the Drake music workshops at the CRC. It has been found very useful indeed allowing those with disabilities to take part in playing music.

3.6.6 Manipulative Control

Experiments have been conducted over the last few years to see if it is feasible to employ robotic systems as assistive manipulators for disabled people. Most of this activity has taken place in The Netherlands, [CEC93a], [CEC96a], but CRC have been partly involved through the SPRINT IMMEDIATE project [CEC97a].

The problem has largely been to find a suitable system that could be financed for an individual user, to produce a useable interface and to mount the equipment in such a way that it does not pose a stability problem. Neither should it look unduly ridiculous from the user's point of view nor in the way other people perceive them.

The model most used to-date is the Manus Robotic Arm, produced by Exact Dynamics, which is currently in use by over thirty disabled people in the Netherlands.

Figure 3.6-2 A Disabled Man using a Manus Robotic Arm

Such systems are still in experimental or prototype stage, although they have been successfully integrated with other equipment using the M3S wheelchair bus, which will be explained later.

3.7 Problems Experienced in using Computers

3.7.1 Social Exclusion

To enable people to live more independently, learn through distance teaching methods or Telework may sound like the complete answer to all problems. Unfortunately, these very technologies can cause other problems by cutting disabled people off from normal social activity, such as they would enjoy if these actions were conducted conventionally. If the whole process of helping disabled people by applying computers is not to fail, provision must be made to include mechanisms for social contact into their lives, both through further use of technology and by normal face-to-face means.

The above problem was seen during trials conducted in Finland using Smart House technologies. The impetuous to use such systems was greater there, due to the severe weather conditions experienced in the winter, which particularly prevent disabled people from journeying from home. Technology provided them with a means to work, but is balanced with the ability for disabled people to communicate with others including special care centres.

3.7.2 Reaction of Others to Excessive Technology

A wheelchair bristling with computer equipment does not look exactly typical. The more technology, the more the user tends to stand out from the crowd. This can have the effect of making others regard the assistive technology user as freakish or artificial. Minimising the quantity of equipment reduces this, as does using the kind of technology employed by others as far as possible.

For the above reason, CRC and others are about to start a three-year project to produce integrated controllers for disabled people using small, hand-held computers. This project has been assigned the acronym ICAN (Integrated Control of All Needs) and is directly in line with the overall philosophy of this thesis.

3.8 Barriers to Access of External Systems

There is a trend toward the greater availability of public information and service systems for members of the public. Examples include Automatic Teller Machines (ATM), direction finding and navigation systems and terminals providing routine information such as bus or train timetables. It is reasonable to assume that the providers of these systems will gradually withdraw older more traditional service methods in favour of the newer systems. If people with disabilities are to be allowed a degree of independence within this public environment, it is necessary to consider their needs when providing the service, if they are not to find themselves further disadvantaged by technology instead of being assisted by it.

These matters have featured within the work of the European collaborative project COST219 [CEC96b], which has produced its own guidelines in this regard.

If the disabled person is using special communication equipment, it may be necessary to consider the general question of how it will be interfaced to public systems. This point will be examined in more detail later when consideration is given to the public operating environment of disabled people.

3.8.1 Positioning Difficulties

The most obvious consideration is the position of the device. Wheelchair users cannot access keypads above a certain height, nor, in many cases, can they extend their hand reach to the same degree as normal users. In addition, the wheelchair may prevent the user even approaching the device unless it is correctly positioned. These comments would apply particularly to public telephones, ATM's, and road crossing controls.

3.8.2 Screen Design

The screen design should allow for users viewing at different angles than normal and for use by people with less than normal sight capability. Cognitive impairments may also result in the inability to use the equipment unless the information and instructions are presented in the clearest most intuitive way. When using coloured text or graphics, it should be remembered that between 15 – 20% of users suffer from a degree of colour blindness.

3.8.3 Menu Complexity

Menu driven systems rely on the user being able to understand logical processes and information patterns. This is not always the case. Work associated with the COST219 project has looked at the feasibility of presenting information in different ways to different users depending upon their needs. The use of Smartcards has been suggested, which carry information relating to the special needs of the user in a way similar to that employed on Eurocheque Cards to identify the most appropriate language to present to the person.

There are a number of possible ways that menu systems can be designed depending upon the person using the system. If there is a degree of cognitive impairment, then simple designs are best, alternatively, the user may have no difficulties in understanding the system, only difficulties in entering key presses or commands. The latter user would be best assisted by presenting as much information per screen as possible minimising the number of options that have to be selected.

3.8.4 Provision of Appropriate Information for Disabled People

The last consideration is of the nature of the information itself. An example could lie in the use of public information terminals to provide transport timetable information or directions. It would be important for the user to know that the next bus to arrive was or was not wheelchair accessible, or to know that certain path ways or entrances were passable or not.

4 A NEW APPROACH

4.1 Advantages of Integrating Assistive Technologies

4.1.1 Why Integrate Systems?

The methodology proposed by this thesis is that all the assistive technology needs of a disabled person should be combined, as far as possible, into one integrated unit. The end device becomes the user's 'tool for life access', customised to their needs, and follows on, an integrated, holistic assessment of those needs, by a multi-disciplinary team of clinicians. The result can be considered as follows:

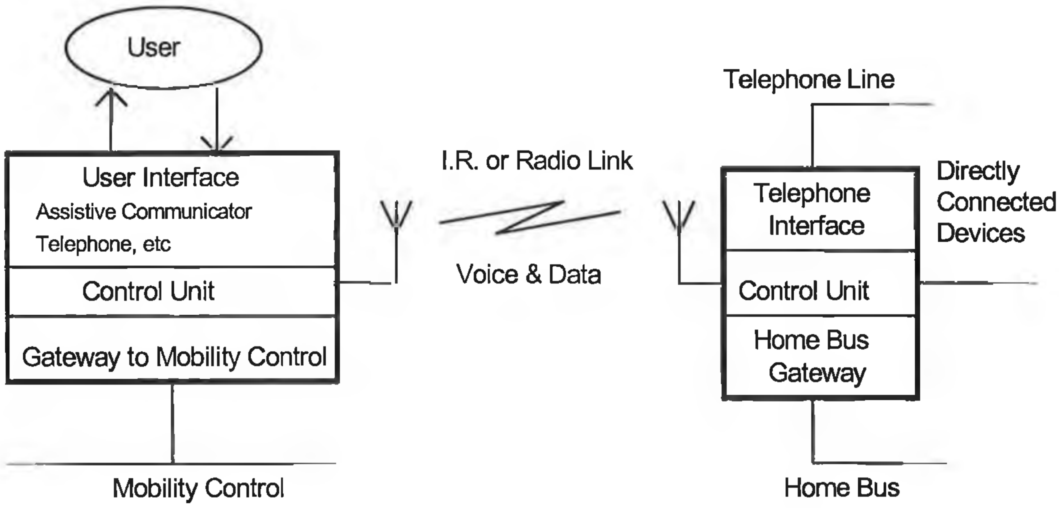


Figure 4.1-1 A Conceptual Model of an Integrated System

The disabled person is provided with a single platform and user friendly, consistent, interface, that allows control of functions both close to, and further away from the user [A94c]. Obviously, the design of the interface and the precise functions to be controlled, will be customised to the disabled client, as will the method of access to the terminal. A series of gateways are necessary to allow access to more distant functions.

It is argued later that the above picture is a natural consequence of considering the disabled person as operating within three distinct spheres of operation, or 'environments'. Before developing that theme, however, it is necessary to first overview the advantages of providing the user with an Integrated system rather than taking a more conventional or compartmentalised approach to the provision of assistive technology.

4.1.2 Economic Benefits

Integrating assistive technologies has an immediate benefit for the equipment financier. Since each item of discrete equipment requires both an input and output mechanism, there is a distinct advantage if an integrated system is employed requiring only one of each. In addition, and as stated previously, many of the individual devices are basically computers at heart and, with the power and cost of modem technology, it is perfectly feasible to have one computer carrying out a number of different functions.

If a compartmentalised approach is taken to assessment and provision, there is an additional cost incurred in the duplication of assessment time required. A single team comprising professional staff from various disciplines, removes this need whilst also making the assessment process a lot less arduous and tedious for the person being assessed.

4.1.3 Cognitive Benefits

Many people are familiar with the problem of trying to use several software applications in which different conventions or guidelines have been adopted. This was particularly apparent ten to fifteen years ago when many people were using computer programs written by different Companies; where there was no reference or co-ordination one with another. In one program, the F1 function key may mean "Help" in others it may have an entirely different designation. Gradually, some order was imposed, resulting in software that was considerably more intuitive than previously. Few people would argue that this was the wrong approach. The resultant "standard" helped users and software developers alike.

The same thinking can, and should, be applied to systems designed to be used as assistive technology tools by people with disabilities. Interfaces and functions must be consistent to minimise the difficulties that are experienced in learning to use the equipment. If, however, the recommending agencies for A.T. continue to operate and think in a compartmentalised way, there is little to encourage the development of the same level of standardisation in this application area. Given that many users already have a degree of cognitive impairment, it makes very little sense to add complexity to the system, indeed the reverse is true, and every attempt should be made to simplify it.

The proposed methodology seeks to produce a single, user-friendly interface, with a single input, and a single output mechanism (appropriate to the user's needs). In this regard, however, simplicity can be the hardest thing for the designer to achieve, and again a comparison of older computer systems with those of the present day, shows that to make things look easy is difficult, but to make them look difficult is easy. The greater the level of intelligence that can be incorporated into the software, the better, provided it is implemented in a professional way, in liaison with the users. These considerations lead to software that can anticipate needs, make suggestions, and learn from previous examples and patterns.

An ideal solution may therefore have a changing interface, altering itself to suit the situation the user is in, the time of day, or anticipated requirements. If this task is tackled properly at design stage, the software, which is the key to achieving the ideal, may require more design effort to include artificially intelligent systems. The result should be a system that is far easier for the average disabled user to understand (and the average clinician) and will be accessible to people with a degree of cognitive impairment.

4.1.4 Aesthetic Benefits

Disabled people are already aware that they look different to others. Their disability makes them stand out, and this is not usually something they welcome. For example, a wheelchair immediately identifies a person as disabled. Adding other equipment makes the situation worse. If technology is to be accepted by the users, this fact should be considered and every attempt made to minimise equipment clutter.

It is easier to reduce obvious differences if the amount of equipment is kept to a minimum. Integrated systems allow clinicians to do this. If the above problem is placed within the context of a World in which ordinary people are using more technology (mobile telephones, notebook computers etc.), it may even be possible to imagine a situation where the disabled user merges into normal society – at least as far as appearance is concerned.

4.2 Integration of Technical Assistive Systems

4.2.1 The Computer as a Central Controller

Many of the individual systems currently used by people with disabilities, have a computer at their heart. Whether the device is intended to aid face to face communication; to assist with mobility; or to function as an independent living control system, intelligence is a necessary feature. The task of integrating functions to share a single input/output mechanism and interface becomes one of computer system design. This in turn calls upon the skills of programmers, system analysts, interface designers and hardware engineers. Depending upon the exact nature of the system provided, intelligence may be centralised or distributed, but in either event, the solution can be realised using conventional computer system design techniques.

The above representation is true at a number of levels. For example, interfacing an assistive device with a Fieldbus driven Smart Home, requires that the individual actuators and sensors within the home are efficiently networked to the controlling system. It is obvious that a standardised approach must be taken to allow efficient communication between applications and networked equipment. The particular requirements within a Smart Home realisation are considered more thoroughly in references [A94a], [A94c], [A95], [A96a], [A96b], and particularly in [A97f].

4.2.2 Implications for Technical Designers

In view of the above, designers need to understand the nature of the problem they are attempting to solve. This requires a great deal of liaison at stages of functional specification, prototype evaluation, and user feedback. Often this process works best within the Service Delivery Centre itself, or at least in close consultation with it [A94b].

Designers need to consider the problem more globally. The alternative input or output mechanism must be useable in different situations, by people with different capabilities and expectations. At the same time, equipment manufacturers cannot afford the luxury of designing every device in a "one off" manner; costs would be prohibitive. The device would not be affordable by the very people who are the target users.

Modern thinking encourages the adoption of the "design for all" principle. This suggests the designer consider alternative needs at design stage, incorporating alternative controls or displays where possible, and allowing for the interconnection of the device with other more specialised equipment where not. This should be achieved through the use of well supported commercial standards. Interfaces should be adaptable, offering more, or less, complex displays and screens; perhaps using artificial intelligence in the programming to allow the interface modify itself and find the most appropriate level.

4.2.3 Implications for Clinicians

Professional clinical staff must adjust their current method of assessing the needs of disabled clients. It is essential the assessments be carried out by a multi-disciplinary team, willing to view the client's requirements holistically, and willing to modify their recommendations (if necessary) to allow the same goals to be achieved using technology that fits with the overall objectives. Instead of simply recommending an existing "off the shelf" device to meet one compartmentalised need, they must be able to describe the requirements of the assistive device to other team members or designers, charged with the task of realising the complete integrated system.

Good assistive technology does not happen by accident. The designer must be able to get necessary data and feedback during the design and manufacturing process. Clinicians must accept this as an integral part of their duties, resisting the temptation to lock themselves away within their own professional communities. They are not to regard technical liaison as something they do if there is time available. On the contrary, it is an essential process, and time must be made available for it.

The one overriding consideration of both technical and para-medical staff must be the needs of the client. This gives rise to an overall concept called "the Person Centred Continuum of Support" which will be examined in more detail later.

4.3 Use of Commercially Available Computers

4.3.1 Benefits of the Economies of Scale

Dedicated devices for disabled people are expensive. Relatively simple devices can cost between £4000 and £8000. This puts the device outside the reach of many disabled individuals, who represent a high proportion of those in the community below the poverty threshold. The reason for this high price, in an area where it can be little afforded, lies in the small numbers of devices sold compared to the development cost necessary.

A change of strategy is required. Instead of developing new devices, maximum use should be made of those already available. An example of this can be demonstrated by comparing the price of a dedicated interpersonal communication aid such as the "Liberator" system, with that of other, PC based systems such as "E-Z Keys". The later is simply a PC program that will run on any PC compatible machine. Even if the user employs a notebook computer, which tends to be the most expensive, the overall solution costs less. In addition, the later solution leaves the designer with a platform upon which other applications can be easily mounted.

The cost reduction lies in the fact that PC compatible systems are sold into the general market, as opposed to the limited market of disabled people. This represents an economy of scale. It compares with the situation 25 years ago when colour television sets began to appear on the market. At that time typical cost per set would be £350 – little different from the current price today. The difference lies again in the economies of scale. Many more TV's are sold today then 25 years ago. Consequently, taking inflation into account, the real cost per set has fallen.

The same thinking must be applied within the area of assistive technology for disabled people. We do not wish to increase the numbers of people with a disability, so we should look to the commonly sold platforms and then base assistive technology products around them. In this way, the economies of scale are brought to bear upon the provision of A.T. to disabled people in the most effective way.

As a further advantage, it should be remembered that disabled people are still people. They need computers for exactly the same reasons as everyone else. If their assistive technology tool is based on a PC platform, they have that computer and can employ it in many other ways. Their A.T. tool becomes their gateway to environmental control, education, work and leisure.

4.3.2 Ease of Maintenance

At some time, all machines can malfunction. Computer users are constantly reminded that they should keep backup copies of their work because, eventually, all computers will fail.

Because of this fact, obtaining service for common computers is relatively easy. This is not the case for dedicated, compartmentalised A.T. equipment, which may have to be returned to the main distributor for repair or adjustment. If the equipment is based on a commonly understood computer platform, however, it can be repaired locally and easily. The same diagnostic tools available to the users of PC systems can be employed with these slightly specialised devices.

In later Chapters, stress will be placed upon the need for local support provision. Many faults that prevent disabled people using their equipment are simple in nature. If the equipment is PC based, the same skills available to fault find a PC can be immediately brought to bear on a malfunctioning A.T. device. This fact became apparent during the development of the Technical Division of CRC. In addition to direct client assessment, the Division was required to provide I.T. support for the whole organisation. Training and courses provided to general support staff were soon shown to be directly applicable to the training of people as A.T. supporters. [A97e].

Future plans include building into the A.T. device, the capability of linking with the National Support Centre to allow for remote diagnostics and modifications.

4.3.3 Common Platforms for Integrated Technologies

If technologies are to be truly integrated, they must be designed to operate on a common computer platform. As explained previously, a PC based computer, for example, can accommodate a number of separate applications to cover needs in the areas of communication, environmental control, education, work and leisure. The applications must be designed to reside on this common platform, and to co-exist with other, separate programs.

In addition to running on a common platform, programs must follow accepted guidelines so that the interface environment can be unified, and keys have the same meaning no matter where the user may be within the overall application.

If the common platform approach is adopted, the disabled user can move their A.T. from one machine to another as technology develops. Currently, many users are migrating to the new hand held computers, which use an operating system very similar to that of larger machines.

4.4 Analysis of Needs to be Controlled by Computer

This approach can best be summarised by the following two diagrams:

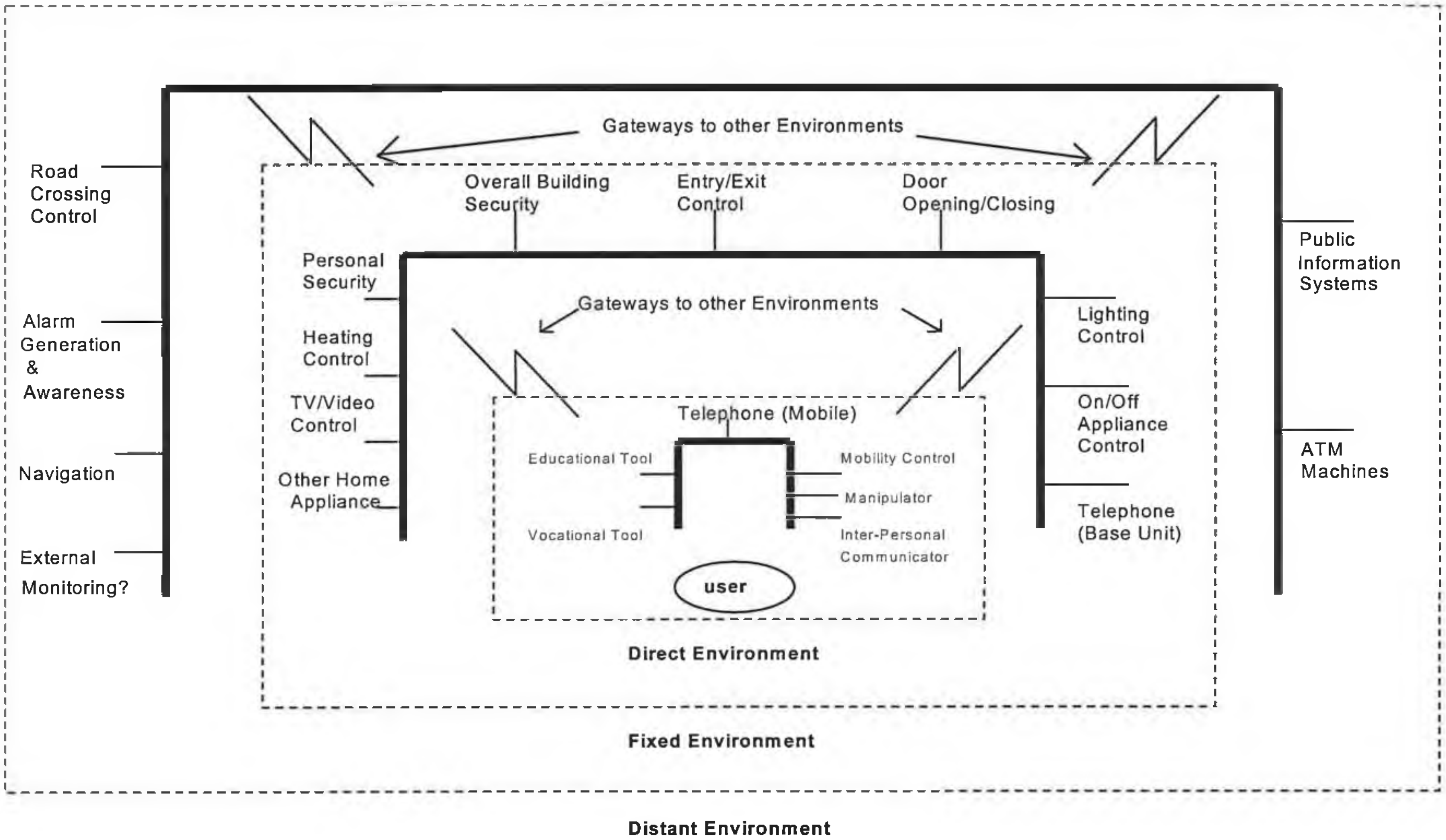


Figure 4.4-1 Typical User Environments

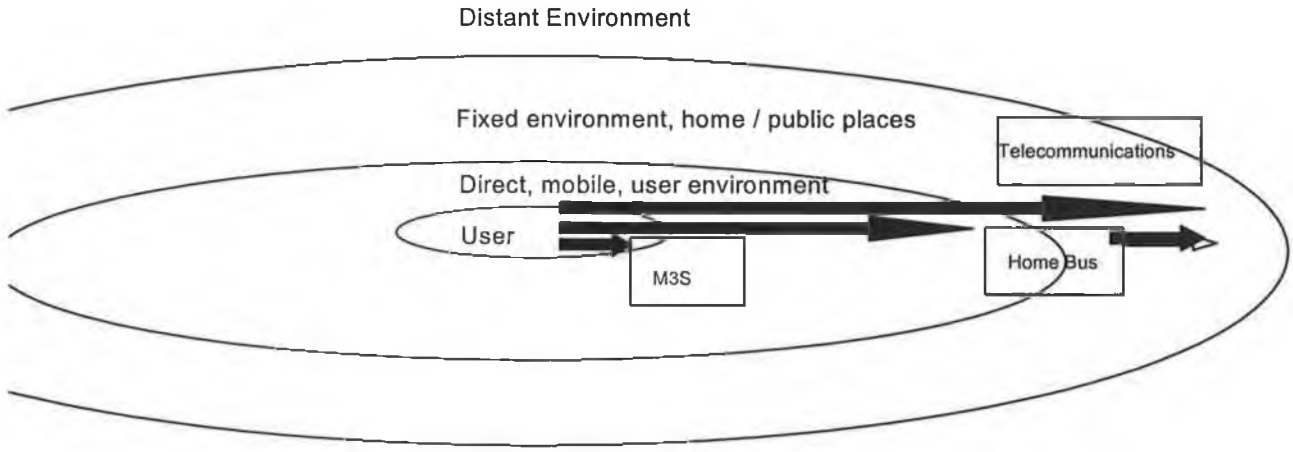


Figure 4.4-2 Gateways between User Environments

The disabled person is portrayed as being at the centre of a three-tiered world of control functions. Within each of these separate environments, attempts are made to establish a common platform for equipment, allowing for easy construction of an overall system following assessment. As well as allowing for a logical development of the system, tools are required to allow clinical staff to move from a plan of needs on paper to a real system. Such tools are partly available, some having been developed at CRC.

In an ideal world, the user's needs are assessed, then the integrated system is realised from "off the shelf" components designed to interface with each other through agreed protocols. In others words a communication bus is required. Establishing a standard of this type is not easy and requires considerable support from equipment designers. Market pressures can often determine the eventual de-facto standard, so consideration of the current support picture is important to allow for a clearer view of where the general industry is likely to be in this regard, in the near future.

CRC have carried out an examination of the degree of acceptance currently in place for bus systems proposed for the inner two environments. A summary of a recent analysis is contained in Chapter six, and in more detail in Ref. [A97f]

4.4.1 The Direct Environment

The Direct Environment is the term chosen to represent all devices and systems within the immediate vicinity of the user. This would include control of their mobility, inter-personal communication, telecommunication, manipulative control, and the use of a computer as a working or learning tool.

In practice, this is likely to include computer technology designed to provide the user with an artificial voice, control of complex wheelchair functions, access to a telephone and the ability to operate a robotic manipulator if necessary. All these functions were implemented on a pilot basis as part of the work of the M3S project [CEC93a], the SPRINT – IMMEDIATE project [CEC97a], and the MECCS project [CEC94b]. It is anticipated that work at CRC in developing this idea further, will continue through a new transnational activity called ICAN (Integrated Control of All Needs) anticipated to begin in 1998 and run for a minimum of 30 months.

The MECCS project (Modular Environmental Control and Communications) constructed a mobile platform incorporating a cordless telephone and infrared device controller. The platform used a specially produced and evaluated interface, running under Microsoft Windows 3.11. The platform contained a radio transmitter and receiver that allowed commands to be carried beyond the users immediate location when necessary. This last process of bridging between environments is inevitable, and is shown in the diagram as a "gateway".

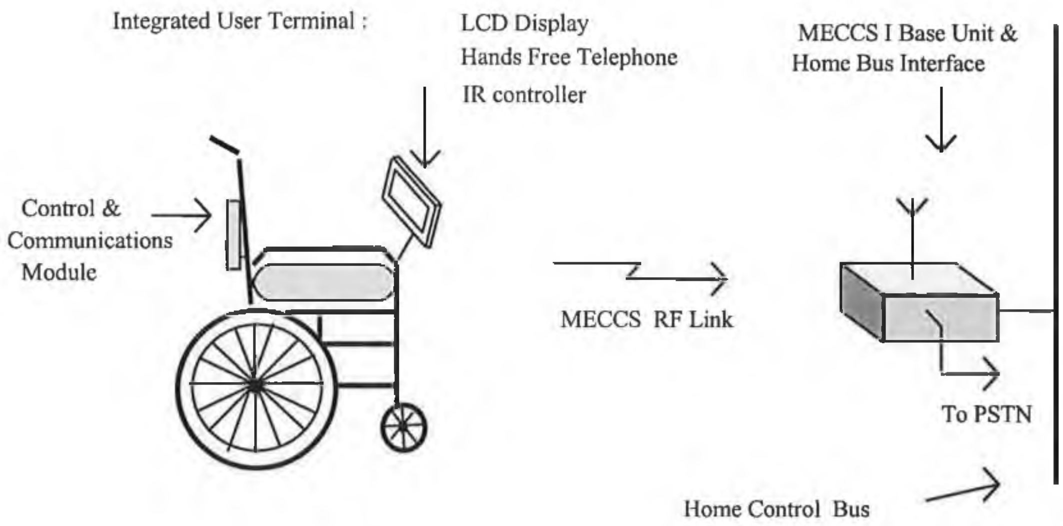


Figure 4.4-3 The MECCS System

The M3S project comprised 13 partners from across Europe. Since the object was to try to establish a wheelchair bus standard, it was felt that a large number of transnational partners could best accomplish this. The M3S Bus, and other similar wheelchair bus "standards" will be explained in Chapter five. The project was operated under the European Union TIDE initiative, which addresses a wide range of technical development needs for disabled people. The work of the M3S consortium, along with new partners, was continued in the SPRINT – IMMEDIATE project. In this case, the emphasis was on dissemination of ideas, and evaluation of prototype platforms. This project finished in February 1997.

4.4.2 The Fixed Environment

The Fixed Environment is the term applied to represent functions within the user's living or working space, but not mounted upon their wheelchairs. Obviously, someone with reduced mobility or communication, by virtue of a physical handicap, would stand to benefit more from systems allowing home automation than would many others.

The journey from one room to another is a great obstacle to a person with a disability. Equally, in other Countries, due to severe weather conditions, there is a greater need to ensure disabled people can live independently due to the difficulties experienced by carers in visiting them.

The following diagram shows a model system adopted for the Finnish ASHoRED project, [CEC93b] which set out to produce guidelines and a prototype model for an Adaptable Smarter Home.

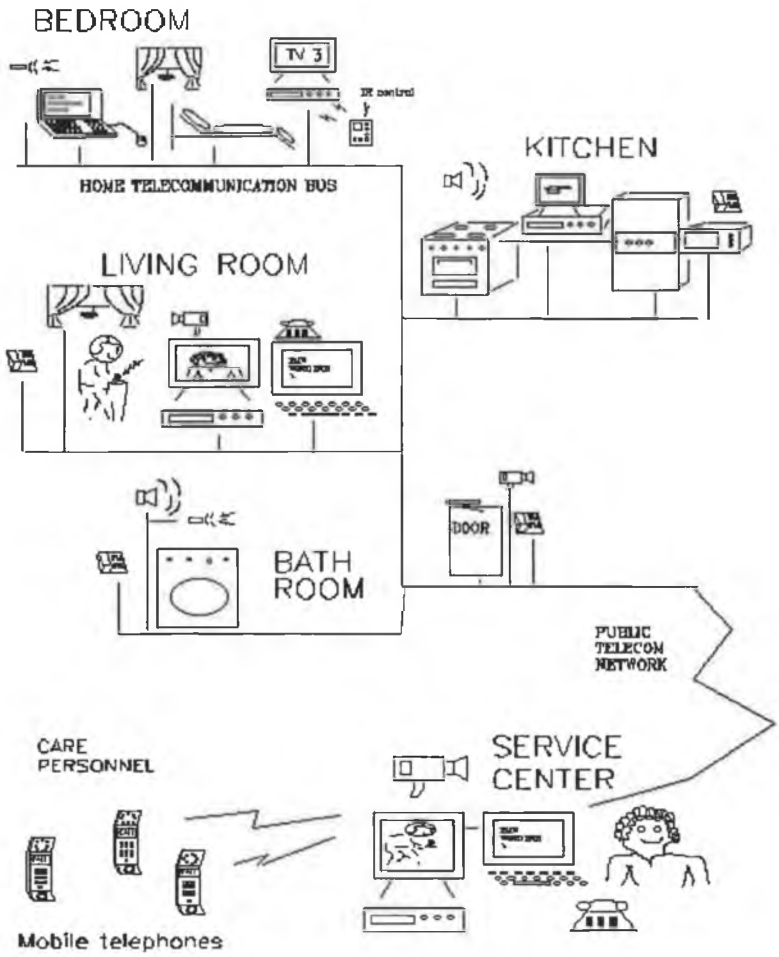


Figure 4.4-4 ASHoRED Model of a Smart Home.

Whilst reference is continually made to Smarter homes, the same idea can be extended to a disabled person's place of work or learning. It can be seen that control of devices within the Fixed Environment depends greatly upon the use of a Fieldbus or Home automation bus. Chapter six and Ref. [A97f] examine the current state of implementation and development of such systems within Europe, and considers the suitability of different systems for application within the rehabilitation area.

Chapter six will also consider home bus systems in more detail and will examine the issues surrounding their adoption by disabled users and those working on their behalf.

4.4.3 The Distant Environment

The Distant Environment is the least well defined of the three. It implies the adoption of a common interface standard for much of the I.T. equipment finding its way into the modern High Street. Since these systems are so diverse, including such things as Automatic Teller Machines, Public Information Terminals, and the awareness of public alarms, the total co-ordination of the technical standards employed is a massive, International task.

At this time, no sincere attempts have been made to produce such a public interface "standard". This remains a task for the future, and one that can only realistically be accomplished with International will and approval.

In a future ideal, situation, a disabled person would be able to move about their local community and interface with a variety of equipment. They would, for example, be able to pull up to an Automatic Teller Machine (ATM) and communicate with it through their own, individual assistive technology device. The medium of communication, or Gateway, has not been defined. An infrared link would be one possibility, as would a localised radio communication system. Whilst an infrared solution may present problems in its use outdoors, it remains a possibility, and is under consideration by bodies such as the Trace Center, in Wisconsin, USA, as part of their proposed Universal Auxiliary Interface Protocol [T96]. The second option – a radio link, could be implemented separately, or be realised through existing public radio systems such as the GSM network. The later option, gives the user an extra capability to extend their "gateway" to the Fixed Environment a considerable distance away from their homes or workplaces.

4.5 Integrated Technology Assessment

4.5.1 The Holistic Approach

Addressing isolated, compartmentalised needs, in an assessment leads to a short sighted, short term, poor value for money solution for the client. In addition, a proliferation of differing technologies is more than the average user can cope with. The assessment must call on the true multi-disciplinary skills of the team, to collaborate in achieving a solution that maximises equipment capability and flexibility, whilst minimising complexity, cost, and the shear volume of bits and pieces needed on the wheelchair.

The team is required to examine, with the client and their helpers, the full range of problems experienced in going about the activities of daily living, and to examine what the client is trying to achieve in life, with a view toward examining where help can be provided. Equipment can often double in its uses. A computer, for example, can be a communication tool, a working/learning platform and a mechanism to control devices within the user's environment. The latter use can lead to a much greater level of personal independence with consequent cost reductions in terms of care provision.

The Commission for the Status of People with Disabilities, set up by the Irish Government's Department of Equality and Law Reform, adopts and endorses this approach. They continually refer to the need for efficient and comprehensive assessments, leading to better service delivery from the disabled person's point of view, all services provided, going to form "A Person Centred Continuum of Support" shown below:

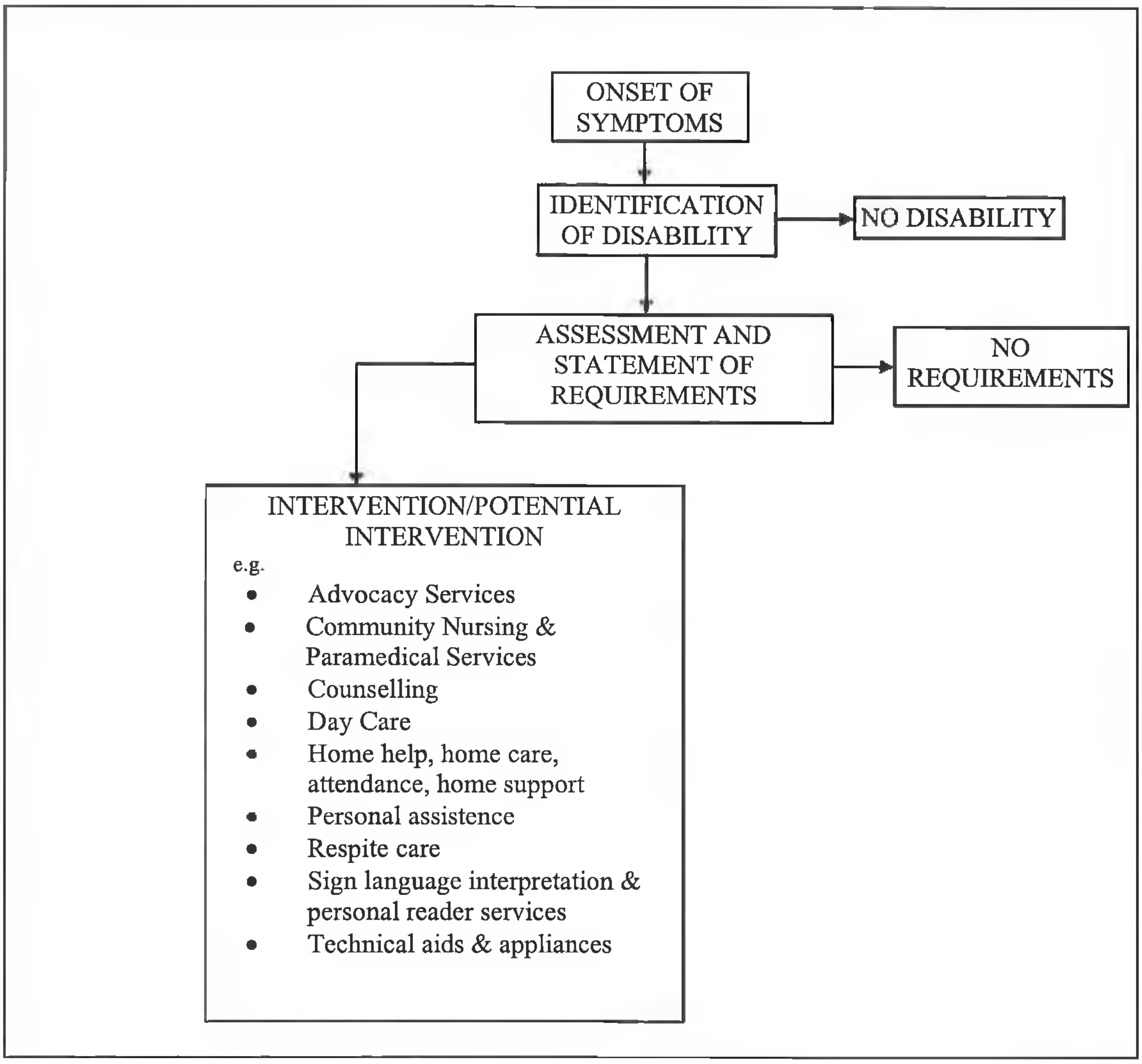


Figure 4.5-1 A Person Centred Continuum of Support

(Commission for the Status of People with Disabilities

Department of Equality and Law Reform 1995)

4.5.2 The Multi Disciplinary Assessment Team

An assessment team should be of an optimum size. Too large and the whole process becomes cumbersome and unwieldy. A large team will also have the effect of unnerving the client and giving rise to atypical behaviour during the assessment. The team must however include the essential disciplines. The whole purpose is to carry out a holistic assessment of the clients, examining and considering as many of their needs as possible. There must obviously be a happy medium.

Experience at CRC has shown that the core team should consist of an Occupational Therapist, a Speech and Language Therapist and a Technician. On occasions, others are drawn into the assessment to give specialised information, as the client's needs become apparent. Examples of these extra skills could include a Special Educational Advisor, someone with special technical skills, a client's family member or friend, a regional carer (if available), or Vocational Assessment specialists.

The important aptitude required by all team members is the ability and willingness to co-operate with each other in achieving the client's goals. Rather than requiring a leader, they need a facilitator.

4.5.3 Collection of Data Prior to Assessment

Collection of relevant data prior to assessment is important. This is particularly so in the case of a client referred to the specialist Service Centre from some outside agency. In this case, there is unlikely to be any previous knowledge of the client by existing team members. In addition to obtaining relevant assessment reports, it is desirable to focus the client's mind by requesting that specific questions be addressed, by asking for a questionnaire to be completed. The practice of the CRC assessment team is to also encourage the client to be accompanied by a carer. This could be a close friend, a family member of some other, locally identified supporter. This helps to put the client at ease, but also provides them with an alternative interpretation of what is said after the assessment, in the event there is some uncertainty in the client's mind.

If the "referral" is of an internal nature, i.e. from another traditional service area within the same organisation as the Service Centre, the above process can be shortened, but should then include the traditional Therapist with knowledge of the client, into the A.T. assessment team.

4.5.4 Provision of Loan Equipment

There are two main occasions when it is particularly useful to have a library of equipment available for loan purposes.

The first is when there is likely to be some change in the client's condition within a relatively short period. This could be due to a changing disability, or at worst, a terminal condition. Some A.T. equipment is very expensive, and it would not be reasonable to ask a funding organisation to provide such finance for short-term use.

The second occasion is when there is some doubt as to the correct device for the client even after the assessment process. A loan library allows things to be tried and evaluated, thereby reducing the probability of an inappropriate, and expensive recommendation being made.

CRC have began the process of developing such an A.T. loan library. This was initiated with assistance from the Irish National Lottery organisation, and is updated and modified from CRC funds.

4.5.5 Review Procedures

Ideally the process of client review should be continuos but for practical reasons, and lack of resources, this is not possible. Reviews are more easily conducted if the client lives near the Service Centre. In the case of an organisation providing a National service to a dispersed population, as is the case in Ireland, provision must be made to review client progress (or lack of it) in conjunction with local support agencies, or by conducting regular outreach workshop sessions. CRC are pursuing both these courses of action. The first, in normal day to day activities, and the second by a series of new initiatives such as the new APHRODITE project [CRC97b] which began in January 1998. This project will be described in more detail in later Chapters.

4.5.6 Measurement of Outcome Success

When reviewing a client's progress, it is normal to have certain outcome criteria against which an assessment can be made. Little work has been carried out Internationally, to determine an appropriate measurement method - something that reflects the relatively recent development of the whole application area.

It is necessary to establish what the desired outcomes are, then to develop an effective method for comparing these objectives with the real situation. The question must be asked, "what is success?" The answer is likely to be different depending who answers the question. For example, the equipment funder might regard cost as most important whereas the client would not. They are likely to see achievement of personal goals as of paramount importance.

Chapter eight will go into more detail concerning experiences at CRC, and in other organisations with which they have been associated.

4.6 Robotic Systems

4.6.1 Background to Robotic Applications

Robots have been considered for applications in Rehabilitation Engineering, and as A.T. systems for many years. The main application areas would focus on the design of systems to assist disabled people with manipulative tasks and with mobility problems. This later application, is realised using a wheelchair with sensors to form an overall "Intelligent Wheelchair", capable of detecting things in its immediate environment, and modifying its path if necessary. Whilst the objective of providing a disabled person with a tool for manipulation, for example, is helpful, several practical problems have manifested themselves.

The first problem, was the state of the technology itself. Robots still generate the general perception that they are futuristic tools. Therefore, very few A.T. equipment providers have even considered the idea of applying them in this way. Whilst there may be some truth in this assumption, it was also the case that artificial speech output systems were once classified in the same way – now they are better, cheaper and relatively commonplace than they ever were before. The A.T. service provider must be prepared to look into the future a little; consider current trends and be prepared to maximise advantages as they present themselves.

Robotic systems are expensive. They will stay that way until the technology develops a little further, the software and interfaces are improved, and some economy of scale is achieved.

CRC and others, have considered the use of robotic manipulator systems for the last four years. During their association with the partners of the M3S project [CEC93a], the FOCUS project [CEC96a], and their partnership in the IMMEDIATE project [CEC97a], CRC have participated in evaluation trials, user interface development and the general interfacing of a robotic manipulator to the proposed wheelchair bus (M3S); which is the methodology, this thesis advocates for implementation of the Direct Environment.

4.6.2 The MANUS Manipulator

The majority of work carried out by CRC, centres on the MANUS manipulator, manufactured by Exact Dynamics in the Netherlands.

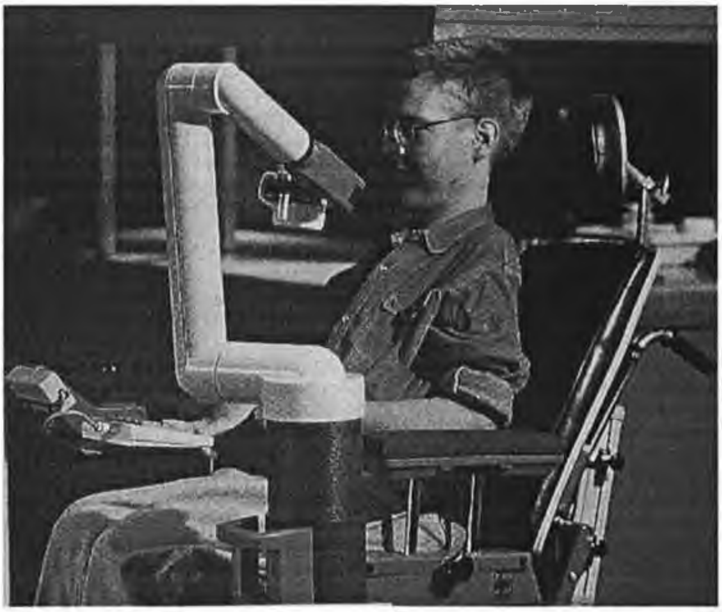


Figure 4.6-1 The MANUS Manipulator

Manus was a collaborative Dutch project started in 1984 and Centred at the Institute for Rehabilitation Research (IRV). Manus built on the conclusions of an earlier project called Spartacus. It did this by specifying and developing a wheelchair-mounted manipulator. The original Manus manipulator consisted of a 5 degree of freedom arm mounted on a rotating and telescoping base unit which could be attached to a variety of electric wheelchairs. Current versions have a reach of approximately 850-mm and can lift 1.5 kg at full extent. The use of slip couplings and a firmware watchdog increase the safety of this manipulator. Manus has been extensively evaluated within rehabilitation centres over several years. The Manus arm was used within the TIDE M3S project to demonstrate the functionality of a proposed wheelchair-based bus standard.

4.6.3 Other European Activity in Rehabilitation Robotics

In addition to the development activities referred to previously, many other groups within Europe have worked in this area. The inter-relationship of project activity may be pictured as follows:

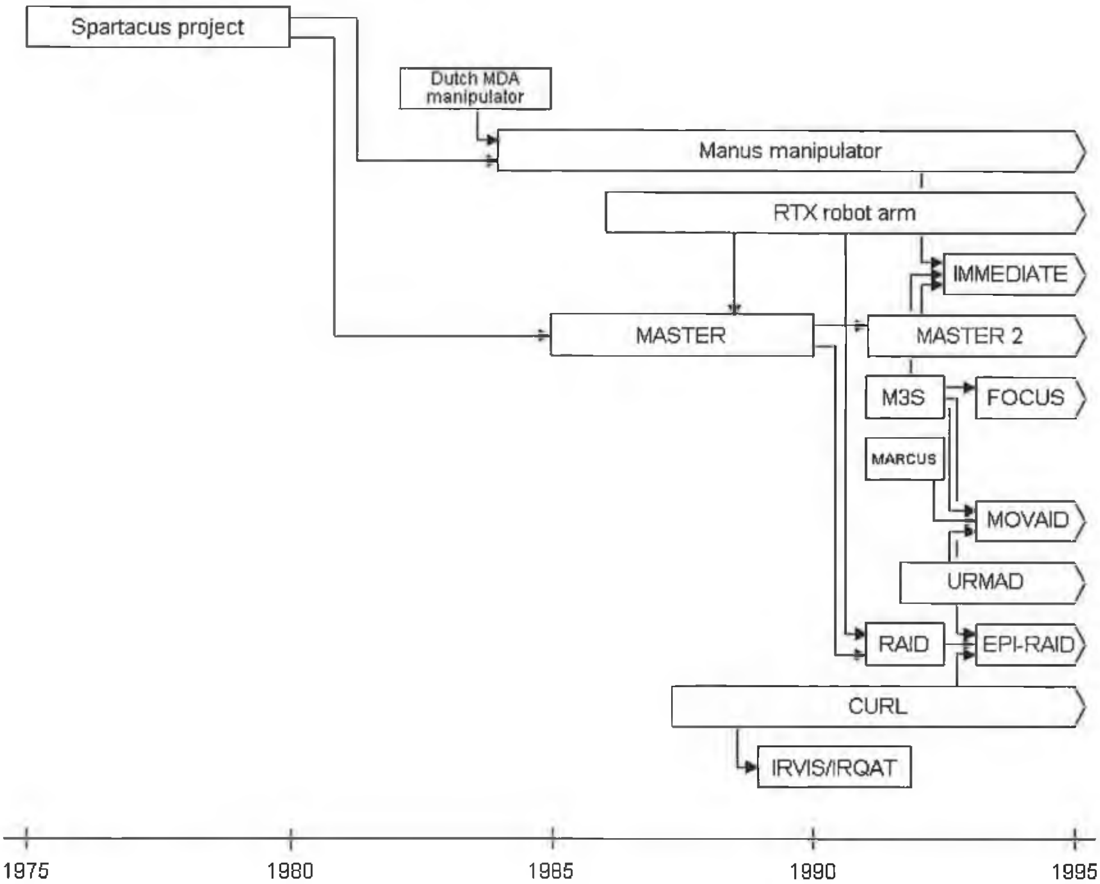


Figure 4.6-2 The Relationship between European Rehabilitation Robotic Projects

A convenient starting point was the pioneering work in France on the Spartacus project and concurrent work in Germany on a workstation for office-based tasks. These projects were summarised at an international conference on manipulators for physically disabled people, held in Rocquencourt, France, in 1978.

4.6.4 Market Availability of Other Products

There are some systems, which are already on the market or have an established place in rehabilitation programmes. The eating aid robot, Handy 1, has been successfully developed and marketed as a dedicated application of robot technology. The smart wheelchair programme at the University of Edinburgh CALL Centre has established the feasibility of intelligent wheelchairs as rehabilitation equipment.

4.6.5 Future Developments

There are two general factors, which are likely to influence the future development and exploitation of Rehabilitation Robotics technology. These are not unique to development within Europe, but are discussed here in the European context:

- Demographic and social change, and the associated move towards increased employment opportunities for people with disabilities
- Increased use of control and communications technology in the home and the evolution of smart house technology

The availability of funds to provide disabled people with workplace support will have a considerable influence on the future prospects of vocational robotic workstations such as RAID and those developed by HADAR in Sweden. A growing awareness of the potential capabilities of many people with physical disabilities may lead to improvements in the funding procedures for assistive equipment and open increased opportunity of employment. These changes will carry with them the need for employers to invest in facilities for training and employing disabled workers. Another factor, is the increasing awareness of the need, (influenced by legislation), to provide wider access to computer-based tasks within an office environment by the widespread inclusion of hooks allowing special-purpose access methods to be used in generic programming systems.

Despite the employment opportunities opened in this way, the market for this form of workstation is not large. The robot assistant will therefore remain an expensive solution to the problems of picking and placing books, paper and other objects in the workplace. The scope for other forms of robotic assistance is equally limited. Nevertheless, the experience of the Swedish training Centre, HADAR, shows that disabled people, with individually adapted work-aid devices and support, are a resource and an asset in themselves for the labour market.

Experiences with the Manus robot arm, show that it provides a significant improvement in a user's ability to perform everyday functions more independently. While it seems unlikely that there will be mass-production of domestic or light industrial interactive robotic assistive devices for general-purpose use by disabled people, the increasing awareness of the possibilities of both manipulators and autonomous vehicles is likely to open new opportunities for domestic applications of robotics.

The technical changes, linked to smart house technology, which are slowly beginning to make their presence felt in the domestic appliance market, will have considerable benefit in the field of assistive technology in the activities of daily life. Also, and with wider benefit, the smart house concepts should mean that more mass-production standard domestic appliances will either be accessible to people with disabilities or, as in computer technology, contain hooks making them accessible via additional interface devices. The evolving M3S specification will be of considerable importance in this field if it can provide a low-cost and standard means of giving wheelchair users a link into smart house systems.

Bearing in mind the limitations discussed earlier in this section, it seems likely that progress in robotic assistive technology in the immediate future will continue to rest with a modest number of small-scale developments. However, much has been achieved to date and current developments indicate promising possibilities for the future.

5 THE DIRECT ENVIRONMENT

5.1 Overview

As part of the methodology proposed in this thesis, and previous publications, the term "Direct Environment" is used to include functions within the immediate vicinity of a disabled user. If the client were normally in a wheelchair, the Direct Environment would include devices mounted onto that chair, going wherever that person goes. The Direct Environment is also the most "central" environment within the three-environment model proposed in Chapter four.

The work carried out as part of the MECCS project [CEC94b] referred to earlier, adopted this philosophy, albeit in a less structured manner. MECCS made provision for a "gateway" between the Direct Environment and the Fixed Environment using a high frequency radio link. A second option would have been to have used infrared linking - which was the norm at that time - but the Consortium choose to explore the use of emerging radio techniques and standards. Radio was considered by many to be less secure and more difficult to obtain type approval for in Europe. The MECCS consortium - led by CRC - took the decision that this situation had substantially changed over the preceding three years and that pending developments such as the emerging Digital European Cordless Telephone standard DECT, would address the problem of European wide type approval. This was because it was, from the outset, a pan European standard.

Radio systems offered the advantage of increased, out of line of sight, links. Infrared systems were not as reliable out of buildings, and so could not be developed for use as gateways to the Distant Environment in the future. It was accepted at the beginning of the project that the radio method used, was not a perfect solution, as it required two radio channels: one for data and one for cordless telephony. It did, however, form a useful transition mechanism whilst DECT was still under development.

DECT is now a reality. It is offered as an option in many commercial products. It is a safer, longer-range system, with the built-in capability to combine data and speech signals into one channel. In addition, there are many design similarities between DECT and GSM - the system now employed for pan European mobile telephony. The MECCS system laid the groundwork for a future methodology that could encompass the gateways needed to the Distant Environment.

It is now proposed to pursue this work in a development action called "ICAN" (Integrated Control of All Needs" scheduled to begin in May 1998. [CEC98a].

5.2 Example Devices Included in Direct Environment

The diagram in Chapter four showed the Direct Environment in the following way:

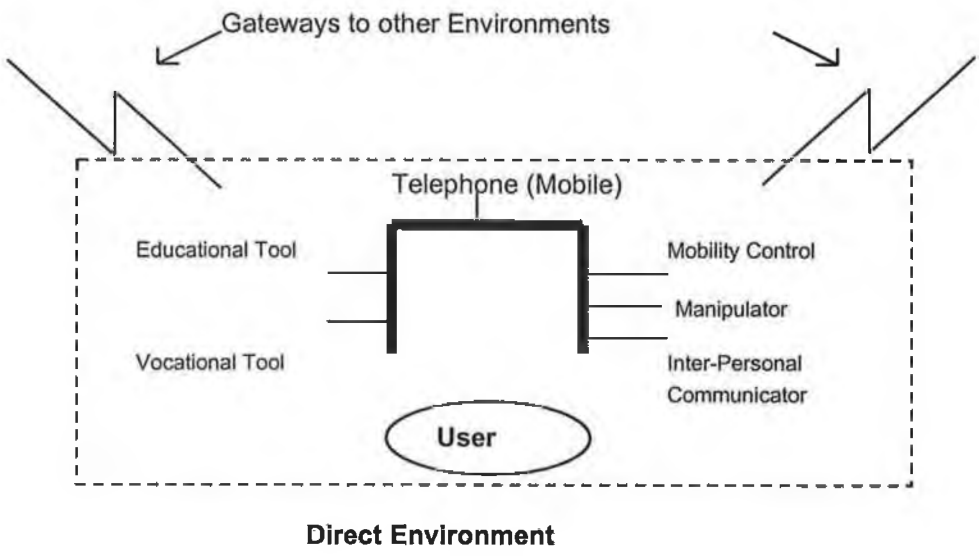


Figure 5.2-1 The Direct Environment

From subsequent discussion, it can be seen that the items referenced in the above diagram can be identified as:

Description	Detail
Inter-Personal Communicator	A device with either artificial speech output, or one designed as a writing aid employing word predication software
Manipulator	A robot based personal assistive system. Implemented to-date with the Manus Robotic arm
Mobility Control	A mechanism allowing control of a user's wheelchair
Telephone	A cordless telephone handset linked to a base station. Ideally operating on the new DECT standard
Educational Tool	A computer allowing the user to run special software to assist in access to the curriculum
Vocational Tool	A computer customised to meet the needs of an employment task
Gateways	Either radio or infrared devices, allowing the user freedom of movement within their home, working or learning environment

Figure 5.2-2 Examples of Items in the Direct Environment

The above list is not intended to be exhaustive. As needs become apparent, their place in the three-environment model should be considered, and an appropriate interface constructed. Ideally, as the idea gains acceptance, manufacturers would include these interfaces as standards, or as easily added options.

5.3 Wheelchair Bus Systems

The need addressed by each device above has been outlined in Chapter three. The main method of implementing them, however, has traditionally been in a non-integrated way:

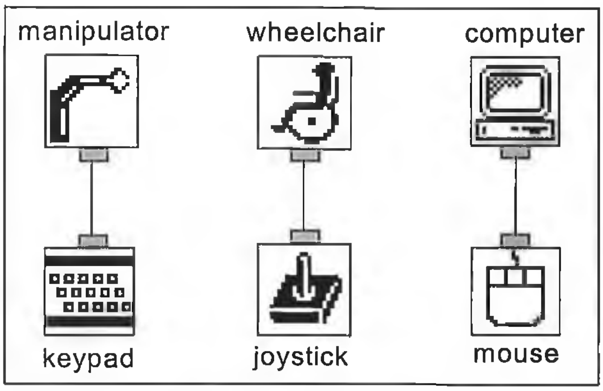


Figure 5.3-1 Non-Integrated Control Implementation

Chapter four explained the need for all such devices to be brought into an integrated system. It also presented the three-environment model for the realisation of an overall integrated system. What remains to be examined in detail, is how such an approach can be implemented practically by clinicians and equipment designers.

If a person's abilities deteriorate, then it might be necessary to add an additional assistive device (e.g. a robot-arm). This would be placed on his or her wheelchair. In current circumstances, this would mean that an extra control panel must be placed next to the existing one, for driving-motors. Considering the fact that possibly more devices may have to be placed on the chair as time goes on, it can be seen that it is better to include all control panels in one unit. This is very hard to do if different manufacturers make the devices, because they often employ different communication protocols.

When a client presents for a multi-disciplinary assessment, decisions are made as to his or her specific requirements. All these devices must now be integrated and enabled to communicate with each other. The approach recommended to carry out this task is to use an appropriate communication Bus

The idea is little different from that employed within a computer. The various devices are allowed to communicate with each other though the use of common protocols. When the idea is extended to a larger, more external system, the Bus specification must include extra details, such as connector sizes, cables etc. The notion of applying this methodology to a complete wheelchair mounted system, is new, and has only recently been developed.

5.4 The M3S Wheelchair Bus

M3S stands for **Multiple Master Multiple** Slave and is a proposed standard interface for technical aids for disabled people. An International consortium under the EU TIDE initiative [CEC93a] originally developed the M3S bus standard. It allows devices from different manufacturers to be linked within the same system.

The standard may be pictured as follows:

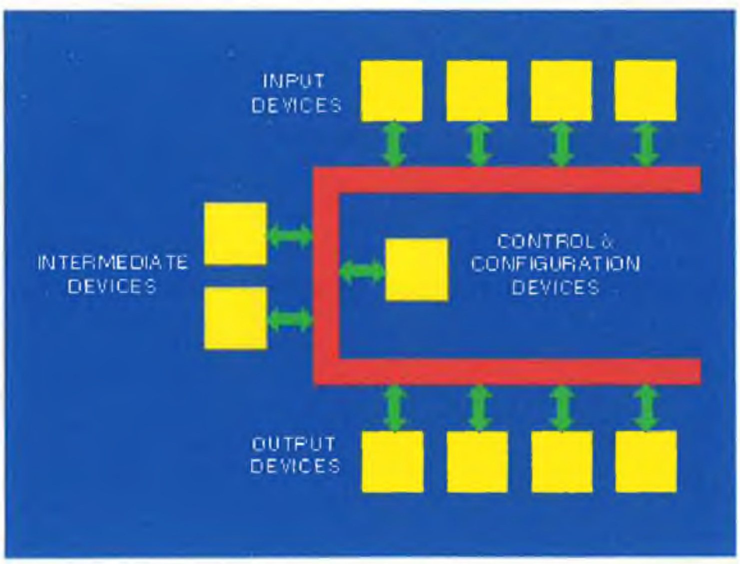


Figure 5.4-1 Pictorial Representation of Devices on an M3S Bus

The digital communication between devices in an M3S system is based on the two-line Controller Area Network, (CAN) Bus. This communication standard was originally developed for automotive applications and was chosen as the most suitable Bus system for M3S for the following reasons: -

- Deterministic method of data exchange
- Error detection and re-transmission facilities
- Availability of semiconductor devices

With this system, developed by various European Companies and Institutions, it is possible to add a variety of input (joystick, keypad) and output devices (motors, robot-arm, communicator) without any difficulty. This is possible in the M3S-system, because all devices contain their own specific information. For example, a joystick does not have to know the characteristics of a wheelchair. It just sends a standard message to the wheelchair. An interface at the side of the wheelchair then adapts the messages to usable signals for the motors. The M3S-system is very "transparent" and presents an open-interface to products from different manufacturers.

People with different disabilities not only need different assistive devices on their wheelchairs, but also need different setting configurations. The user can make small changes to the configuration during day to day usage. The set-up would typically be developed in the following way:

- Initial configuration by a system configuration specialist.
- Start up configuration by a helper, relative or therapist
- Maintenance configuration by a technician.

After start-up, the system uses the settings as determined during the previous configuration. After this initialisation, the user is able to convey their wishes to the system via the input device, with which, it is possible to scroll through menus on a display. The intricacy of these menus, and the time scale between different tasks, is adapted to suit the disability of the impaired user.

5.4.1 How the M3S Bus works

Information on the CAN bus is exchanged in messages. All other devices connected to it receive a message transmitted on the bus. Each message starts with an arbitration field, which is used to determine the message with the highest priority. After arbitration, the winning message continues with a length indication of the number of data bytes; followed by the data bytes themselves; and finally a fifteen-bit cyclic redundancy check number for error detection. All devices, which have successfully received the message, will simultaneously transmit an acknowledgement at the end of the message. Devices that noted an error immediately transmit a special sequence of bits that automatically force re-transmission.

As stated, M3S is an application layer sitting on top of the CAN protocol. This CAN protocol itself, only specifies how messages are to be transmitted and received. The application gives meaning to these messages. M3S completely specifies how each message is to be used to communicate information between devices.

In addition to the normal, two-line CAN communication channel, the M3S bus is enhanced with the addition of four extra lines. Two of these are used to distribute power and two are used for safety. The safety lines are called the Dead Man Switch line (DMS), and the Key Switch Line (KSL). They make it possible to stop any safety critical action or to switch off the system from any location. The M3S specification, which is now available as an open standard, is the result of several years of protocol definition and evaluation by an international consortium of engineers. Further information is available from reference [O96a].

As previously stated, when powering up the system an initialisation procedure starts. This consists of two parts: (a) powering up of all devices and (b) identifying all devices in the system. It makes it possible for the bus controller to automatically detect the set-up of the system and adapt to it. The M3S phases of operation may be more fully described as follows:

5.4.2 M3S Phases of Operation

The following descriptions and details are taken from the M3S Architecture specification.

5.4.2.1 Initialisation

The initialisation phase begins when the key line is activated. Each device is allowed a fixed amount of time to perform some power-up actions, which are necessary to take part in a process, called the *Serial Number Arbitration Protocol* (SNAP). After this, each device finishes remaining initialisation actions before it is ready to participate in normal operations.

The purpose of the SNAP process is two fold. First it is used to identify all devices in a system, and secondly it is used to give each device a unique handle, called a device number. The SNAP mechanism eliminates the need for hardware jumpers, dipswitches or harness resistors and therefore makes it easier to install devices in a system. Together with an auto configuration mechanism, it can offer true *Plug and Play* (PnP) possibilities.

Every device has a unique 64-bit SNAP ID number that differentiates one device from another. This ID number contains a manufacturer ID, a serial number and an additional category number. On power up all devices are placed in an inactive state. They arbitrate for the bus and the device with the smallest ID number wins. Because all ID numbers are unique it is guaranteed that only a single device is *isolated* on the bus at a time. The arbitration is carried out in a byte-oriented sequence, so a single arbitration cycle takes eight steps. After a device has won arbitration, all other devices drop off. The first arbitration cycle is used to find a master to control the SNAP mechanism; this device is called the arbiter. The arbiter will assign itself the first free handle, so, typically, it gets device number zero. In following cycles, the arbiter will repeatedly assign the next free device number to the devices that win arbitration cycles. Once a device has been assigned a device number, it no longer participates in the arbitration mechanism and arbitration of devices with higher ID numbers can proceed.

The power-up actions and the SNAP mechanism take place after activation of the key line. However three kinds of activation are possible: - (a) the normal activation of the key on switch, (b) *hot insertion* of a device or (c) when a remote bus link becomes active. Depending on these conditions, a device has to differentiate between a system with or without an existing arbiter. Therefore, each device starts the SNAP mechanism by issuing a request for an arbiter. If an arbiter is available it should respond within a certain time-span and start a new arbitration cycle; otherwise the device can start an initial arbitration cycle by itself.

The first arbitration cycle together with the arbiter response is also used to distinguish M3S compliant and M3S aware systems. When, during the initial arbitration cycle, a M3S compliant arbiter is found, the system should behave as a M3S compliant system. However, when a M3S aware arbiter is found, the system should behave as a M3S aware system. In the case that no arbiter is found at all, all devices in the system should stay inactive

An arbiter can assign 64 device numbers, but when it has run out of available device numbers, the arbiter assigns a void device number to all remaining devices. This limit of 64 device numbers restricts the number of concurrently active devices in a M3S system to 64. However, by using a *warm system reset* procedure it is possible to assign device numbers to a new set of devices in a M3S system.

To speed up the SNAP mechanism in M3S systems, the CCF arbiter can also directly assign device numbers to devices based on information stored in an existing system configuration.

5.4.2.2 Configuration

Configuration is basically changing the contents of the system by adjusting the system set-up and replacing or adding devices to the M3S bus. Because the M3S system is modular and open, its contents can be modified easily to adapt to the needs of a disabled user, with changing needs.

In order to ensure a safe system, the configurer has to adjust or create the right relationships between the different devices. The facilitator, in co-operation with the impaired user, has to personalise the system. The user has to be able to adjust basic settings that influence the interaction with the system. Alterations on the system set-up will be limited for each user group.

Because of user differences, the configuration might be divided into user specific sections, not concerning its users with too much information. Each group of users has to receive enough information to execute his configuration accurately. Several levels of configuration can be distinguished:

- Initial configuration
- Maintenance configuration
- Start up configuration
- Reality configuration.

The initial configuration is specially targeted to the system configurer and requires the highest level of understanding of the capabilities of the system. The maintenance configuration is intended for maintenance technicians, who are required to give support to systems with technical problems. The start up configuration makes it possible for the facilitator to personalise the system to the wishes of the impaired user. The reality configuration offers the impaired user the possibility of making small changes in the system set-up during day to day usage.

These levels of configuration are defined in such a way that users of higher levels are also allowed to perform lower level actions. Therefore the system configurers can have access to all levels of configuration, while maintenance technicians cannot access specific parts of the initial configuration, but can also actions related to the start up or reality configurations. The facilitator can carry out actions on the start up and reality configuration, but changes to the other configuration types are not possible. The impaired user can only execute actions related to the reality configuration.

When a certain user needs access to a higher configuration level, they should have special instruction. This training should explain the necessary responsibilities related to this new type of configuration and thereby raise the user level to a higher degree.

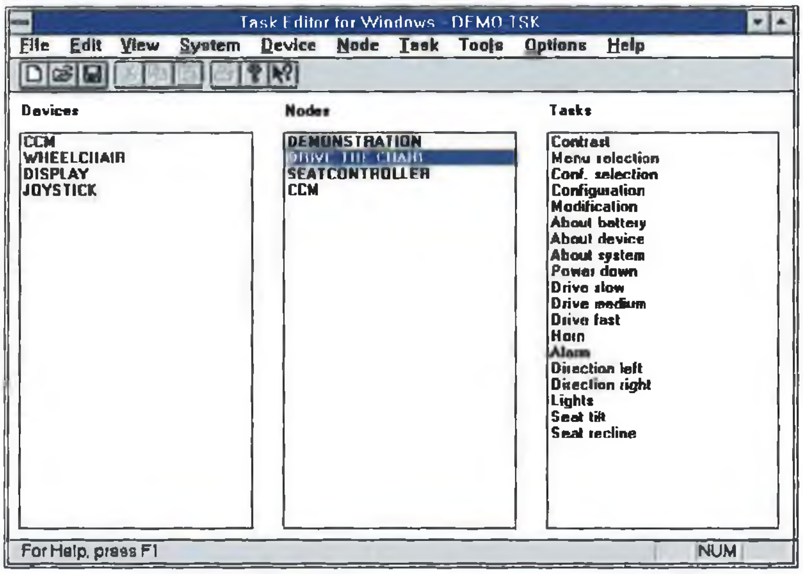


Figure 5.4-2 Screen dump: system set-up

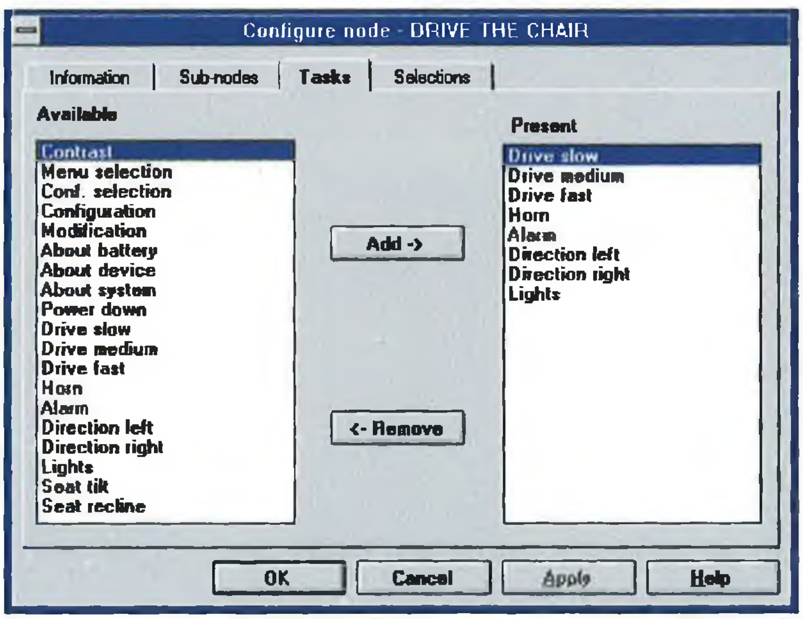


Figure 5.4-3 Screen dump: adding menu items

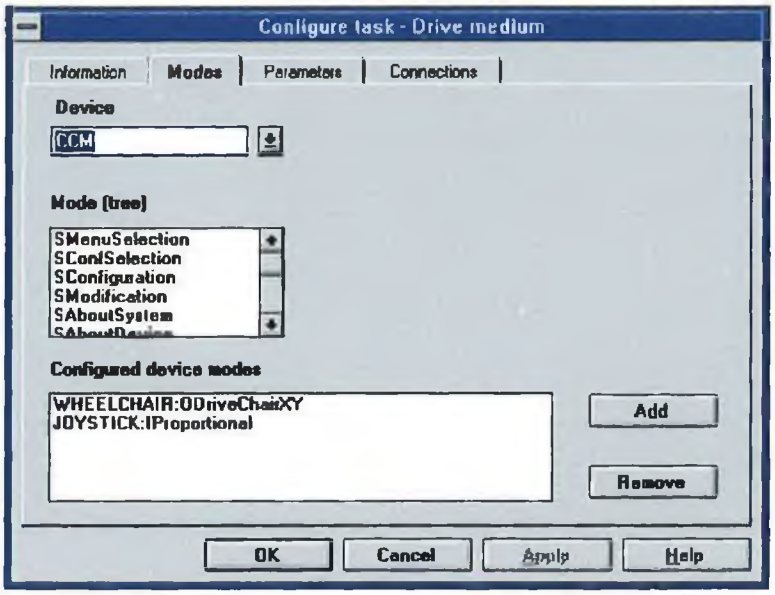


Figure 5.4-4 Screen dump: defining tasks

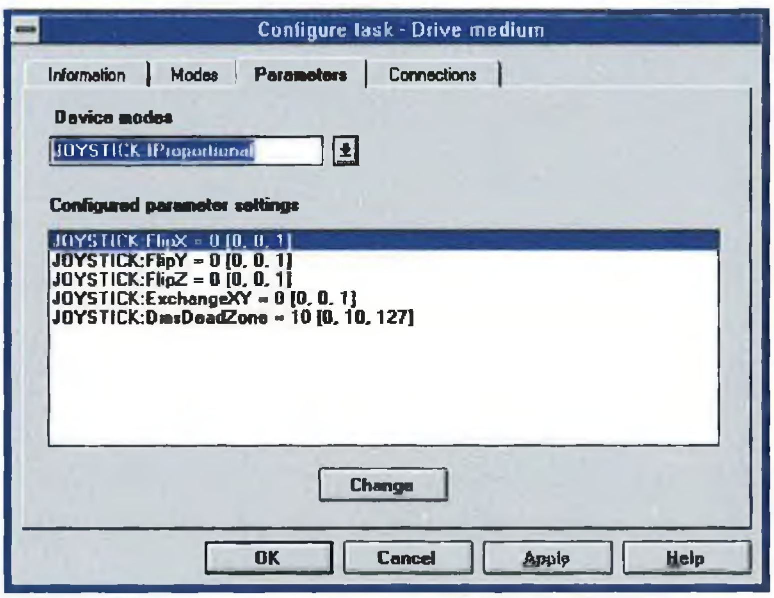


Figure 5.4-5 Screen dump: changing parameters

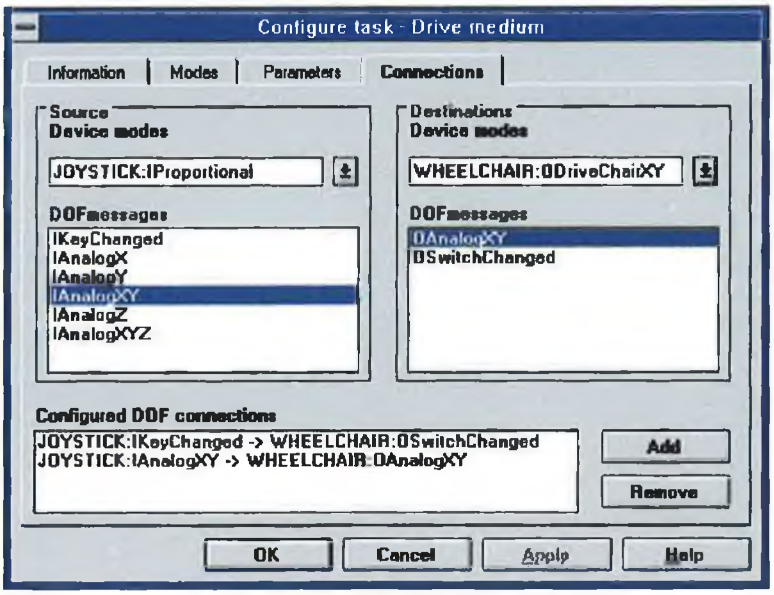


Figure 5.4-6 Screen dump: linking devices

5.4.2.3 Selection

Selection is the way in which a user is allowed to start a new kind of operation or task. To carry out selection, the system, and in particular the CCM, should have some knowledge as to what can be chosen.

The man-machine interface is heavily involved in the selection process. Many of these interface aspects are not specified, to leave particular implementations open. However, some items will be obligatory while others are optional.

After start up of the system, the user will enter into an environment with the possibility of directly accessing several tasks. Only important and frequently used tasks will be a part of this environment. Other, less frequently used, tasks may require more access actions. This applies especially to more sophisticated systems which have multi level accessibility.

Because the M3S system is modular and open, the method of selecting several tasks can be changed from an impaired user's point of view during operation. For this purpose, M3S defines a hierarchical and logical organisation of the different tasks the system can perform based on a tree structure. This structure has the possibility to group related and frequently used, tasks to nodes. As well as the relation of a node to a set of tasks, a node can also refer to other nodes, so called sub-nodes. The tree structure is depicted in the next figure.

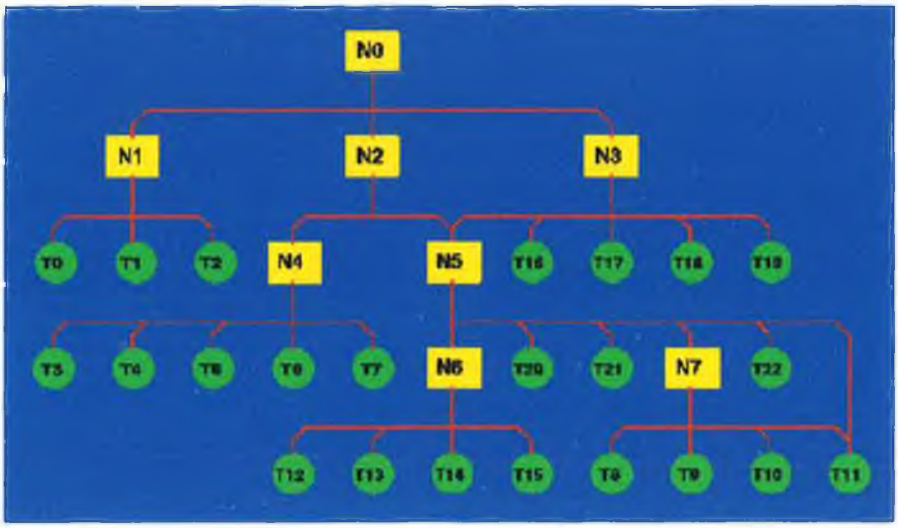


Figure 5.4-7 Hierarchical Tree Structure of M3S Tasks

The node with number zero is always the root of the tree; all other node and task numbers can be allocated freely. Node 0 has three sub-nodes (N1, N2, N3). Node 1 only has tasks (T0, T1, T2), node 2 only has sub-nodes (N4, N5) and node 3 has both sub-nodes (N5) and tasks (T16, T17, T17, T18, T19). Sub-nodes and tasks can be referred to from different nodes (N5 from N2 and N3, T11 from N5 and N7). The ordering of sub-nodes and tasks in a node is free and can be optimised to the wishes of the user to facilitate navigation in the tree.

The user must be able to navigate in the tree, from a node to a sub-node, to other levels in the hierarchy or between different tasks and finally to select the required task. However, the ideal selection mechanism would be direct switching between tasks instead of a selection - operation - selection sequence through the tree. The switching between the tasks will require some changing of modes on the devices, but it is important that this process be transparent to the user.

The selection mechanism also defines two additional items:

- Initial node
- Initial task

After power on a configured system would normally start from the root node of the tree. However if an initial node is defined, the selection mechanism starts from there. Further, if an initial task is defined, the normal selection mechanism is not started, and instead the system automatically launches the specified task.

Whenever a task is ended the selection mechanism can be automatically activated (explicit selection), but it is also possible to automatically start another task (implicit selection). This will give the user a sense of direct access, while the technical implementation is based on an automating of the above-mentioned sequence.

Based on the previous analyses, different selection mechanisms are possible in M3S:

- Single task tree
- Implicit task selection
- Explicit task selection
- Key line take over

In a single task tree, the configured system only contains one task definition. Therefore, it is obvious that this task is the default task to start and no selection is necessary.

Implicit task selection is suited for systems with very few tasks, but can also be used as a tree accelerator function in more complex situations. In both cases, there can be some daisy chaining of tasks, where the action of leaving one task, will automatically launch next one. The relation between user actions and the launch of a new task is implementation defined.

The configurer must be careful that the system has some way of showing the user which task is active. This can be carried out on a feedback device, or in very simple systems, by a simple indicator on a device, which shows if it is operated.

Explicit task selection is perhaps the most general case of selection. The mechanism is in fact a task of its own, which typically involves an input-device, a feedback device and the CCM. It shows a menu containing the items at the actual tree level and the user is then able to select one of the proposed items. When the user has made his choice, the CCM will leave the selection task and launch required option. The relation between the selection tasks and the tree structure is implementation defined.

The system configurer can create a set of selection tasks using different kinds of feedback or input devices. The feedback devices can be chosen to optimise the way menu items are presented to the user, for example by means of icons, text, voice, etc. The same principle holds for the input devices in the way they are used to select one of the menu items.

The key-on switch can also be used to select based on a key line take over mechanism. When a certain task is active and the user activates a new key on switch, the CCM detects this situation and ends the current task. The system can then automatically start a new task based on the information of the number of the device now holding the key switch. The relation between the previous or new task, the device holding the key switch, and the tree structure is implementation defined. This offers the system configurer the possibility of organising the system in such a way that the key-on switch mechanism can be used by an attendant to take over control, in case of an emergency or by the user to switch to a different kind of input device.

5.4.2.4 Operation

The prime actions during operation are related to the execution of a task. A task is a system wide mode in which one or more devices perform actions initiated by the user. Both configuration and the explicit task selection are in fact specific appearances of such tasks.

Just as in configuration and selection, the man-machine interface is extremely important and can be freely configured to suit the needs of the impaired user.

5.4.2.5 Termination

In the termination phase, a device is allowed an undefined but limited amount of time to perform some power down actions. These actions should always put the device in a well-defined and more-or-less safe position, which is not likely to harm the user or their environment. After this, the device enters an idle state, which can only be left by a new activation of the KEY line. The termination phase can be initiated by various actions; the primary difference lies in whether the KEY line is active or is switched off.

If the KEY line is still active when the termination phase is entered, this is because of the safety monitor of a non-recoverable error somewhere in the device or system. It is recommended to give user feedback that this condition occurred, possibly with an indication as to the source of the error (in the device itself or elsewhere in the system). Because the system is no longer guaranteed to work, the feedback should be completely local.

If the KEY line is not active when the termination phase is entered, there are three possible reasons. The impaired user can select a "power down" task, which shuts down the system in a controlled way. Alternatively, the user or someone else in the direct neighbourhood of the system can activate the "key off" switch, either to stop the system normally or to stop because of some kind of emergency condition.

Lastly, the KEY line can be deactivated on a remote part of the system, because the link between the local and remote bus was broken or unreliable.

5.5 The M3S Configuration Utility

The main purpose of the configuration utility is to allow a clinician to customise the system for the user. The utility was first developed at CRC [CEC97a], and was further modified and refined following this, to include modifications made in version 2.0 of the M3S system. This later work was carried out at CRC, in conjunction with TNO, the main developers of the M3S system in the Netherlands. The utility is designed to be user-friendly and graphic.

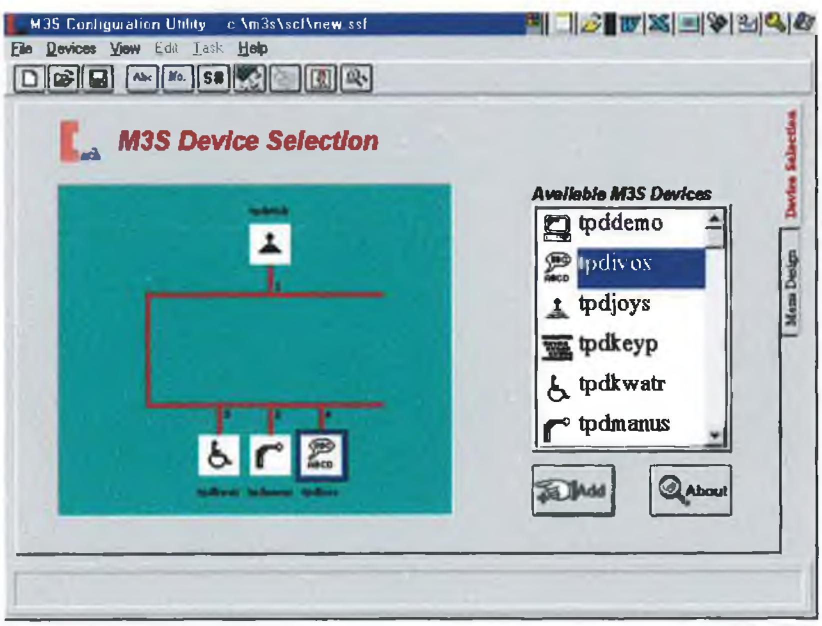


Figure 5.5-1 Typical M3S Configuration Tool Screen

The main purpose is to create a system configuration file. This file is then downloaded to the Control and Configuration Module (CCM) which uses it to initialise and maintain an M3S system. It contains information about every task that the system can perform and how these tasks are to be presented to the user.

Creating a system configuration file is carried out under the following headings:

- Device Selection - How to select devices which will be in the M3S system.
- Defining the Initial Task - Selecting the task that will be activated at switch on.
- Creating a Menu of Tasks - For systems with more than one task it is necessary to present to the user a menu of tasks from which to choose.
- Adding Functions - How to add device functions to a menu.
- Setting Parameters - Tweaking the system parameters to optimise performance.
- Creating Safety equations - Coupling the safety events of one device to the safety restrictions on another.
- Editing system messages - Editing the message texts which devices send to the display.
- User Levels - Setting the user level of the system, the menus and the tasks.

5.6 Plug and Play

As the M3S specification moved from version one to version two, a number of changes were introduced. These included alterations to the plugs and sockets and also to the software. One significant change was the introduction of an element of "Plug and Play". The detection of the system set-up during initialisation, and the ability of the system to perform an automatic configuration, made such usage of an M3S system possible.

Whilst enhancing the system considerably - especially from the point of view of the clinicians and practical implementers, the newly introduced "Plug and Play" capability did not totally remove the need for technical intervention, and did not allow for final tuning of the configuration to meet the user's needs. To meet this last requirement, the system configuration tool, originally designed and written at

CRC, was upgraded as part of a new exercise, to version two compatibility. Future plans include implementing the complete CCM block in software, allowing the configuration tool to become part of the system itself.

5.7 Device Availability and Market Acceptance

From initial design stage, the M3S system has been an open specification. Developer packs are freely available from the dissemination office in the Netherlands, and most, if not all, of the material required by new, third party developers is available for downloading over the Internet. Regular courses are conducted for developers and clinicians, and all actions considered for the future are aimed at encouraging Companies producing new products to make them M3S compatible. In some cases, where the Consortium have identified important areas where interfaces are required, these will be produced by the group. An example of the later approach, is contained within the workplan of the new ICAN project [CEC98a] which contains a specific task for CRC to produce an interface between M3S and the UK based DX controlled, wheelchair system.

The original M3S was developed as part of a TIDE project action [CEC93a]. This project had thirteen International partners: the large consortium was deliberately chosen to encourage the spread of knowledge throughout Europe. Many of the original partners continued together into a new action under the EU SPRINT program [CEC97a] called IMMEDIATE. This was extended at a later stage to include representative partners from Ireland, the UK and Sweden. CRC led the activities for Ireland and the UK conducting two seminars, one in the UK and one in Ireland. All Countries that took part in the IMMEDIATE project developed a M3S wheelchair platform, based upon a wheelchair in common use within their Country.

Many of the interested partners are now scheduled to begin the new ICAN action in May 1998, aimed at further enhancing third party support capability; at reducing configuration complexity; and at incorporating emerging devices into the system. Examples of the work planned, include the production of a number of interfaces for M3S to existing systems and the application of palm held computers as controllers. This later action continues the methodology, of allowing the system to form part of the Integrated, three-environment model, whilst allowing overall size and cost to be reduced.

At present, M3S compatible devices are available from Companies such as Permobil in Sweden (wheelchairs and control mechanisms), FST in Switzerland (environmental control systems, and alternative input mechanisms), VTT in Finland (obstacle avoidance systems for wheelchairs) and TNO/TPD in the Netherlands (CCM modules, keypads, joysticks, scanboards etc.).

In accordance with the proposed methodology, and to provide a more complete range of applications, work has been carried out at CRC to produce an interface and control software pack to allow a disabled user play and compose music on a standard, MIDI interface, electronic keyboard. The Swedish Company Permobil will distribute this later prototype, as a commercial product.

6 THE FIXED ENVIRONMENT

6.1 Overview of the Fixed Environment

In Chapter Four the Fixed Environment was defined as the following:

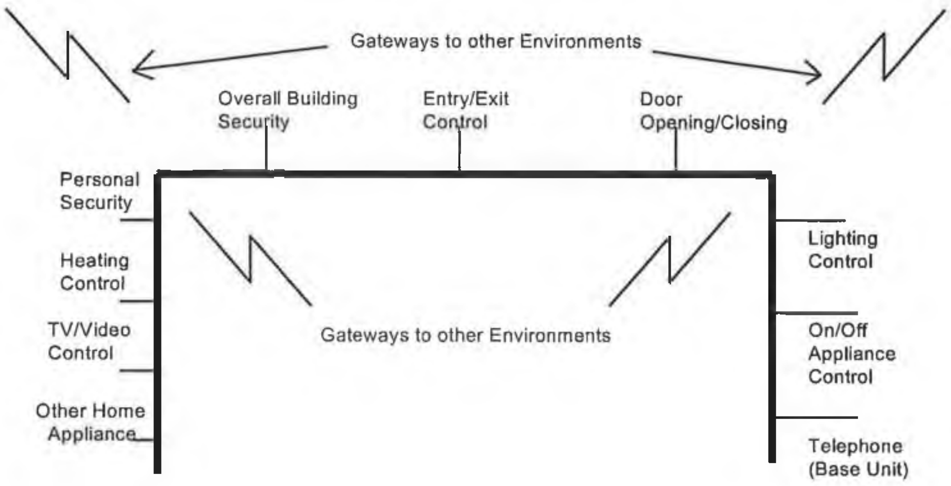


Figure 6.1-1 The Fixed Environment

The Environment is intended to include functions and operations found within a normal living or working area. The methodology of this thesis proposes that this be realised by adopting the idea of an Intelligent Home or Smart House

6.2 Smart Housing

6.2.1 What is a Smart House>

A home or working environment, which includes the technology to allow for devices and systems to be controlled automatically, may be termed a Smart House. The degree to which this control is exercised is variable, being a function of the cost, the person's own wishes, and the type of building into which the technology is to be installed. Homes which can automatically adjust the temperature, the level of security and permit efficient communications to the outside world, are of obvious benefit to all, providing they do not go too far and affect the freedom of choice of the person living within them.

A Smart House can be used to help people with physical and/or mental handicaps; those with mental illness; blind or deaf people, or those who are elderly. The electronics industry is developing Home Systems technology to serve a broad public. This will contribute to the comfort of modern living, but both handicapped and elderly people can benefit from this technology.

6.2.2 How Can a Smart House Help?

Within a traditional home environment, automation can assist a person to control a device in another part of the house, inquire into the state of something e.g. Is the electric blanket on or off? Is the front door open or closed? It can facilitate communications and enhance both personal and building security. In other situations, the controller can suggest appropriate actions, e.g. Should you not turn down the cooker? Why not close the front door? Etc. People who have short-term memory problems such as those with head injuries or those with Alzheimer's disease may find this feature appropriate.

To a person suffering from a significant level of physical handicap, the average staircase can present a formidable obstacle. If technology can reduce the number of times that obstacle must be surmounted, so much the better. Communication technologies can be used to keep people in touch with carers and loved ones, as well as providing the means to reduce the number of journeys to the shops or bank to coincide with the person's wishes. Even apparently simple tasks such as changing the channel of the television can be difficult if movements or hand dexterity are impaired.

The technology employed to automate the home can be applied to other needs. For example, a computer can be an educational or vocational tool as well as the system controller. The advances in communications technology can allow the person work at home, linked to an employer, or receive training/education from a distant source without leaving home. In addition, people with other special technical needs, can integrate these into the overall system and reduce both cost and apparent complexity. An example could be the inclusion of special inter-personal communication systems, such as those used by people with hearing or speech impairments, into the overall system, utilising one interface for all purposes.

6.2.3 How Can the System be Implemented?

Smart Homes can best be realised by using a central data highway within the area to be controlled. The "highway" is termed a Fieldbus or Control Bus, and it can be implemented using a variety of transmission media such as cable, infrared or radio. An analysis of current Fieldbus systems, and the issues surrounding transmission media is contained in Ref. [A97f]. The final choice is made depending on factors such as necessary speed of data transmission, building design, whether the installation is into a new or existing building and, of course, cost.

Each device, or system to be controlled, requires an interface to the Bus. Some systems simply allow for on/off commands to be transmitted. Others are designed to allow more complex control and hence require more complex interfaces. When designing the Bus, these factors must be considered, as well as the ease with which the Bus will permit the user access the Gateways discussed previously.

Gateways between the different environments are as yet poorly defined.

6.2.4 The User Interface

The user interface is the single component in such systems, upon which everything else will be judged. If the interface is confusing and badly designed, the system will be thought of in that way. Indeed, to make such systems appear simple is an extremely complex thing to do. It is, nonetheless, a very important thing to do.

Whilst the implementing technologies may be, at heart, similar, the interface must be appropriate to the special needs of the user. A person with mental impairment may require a less complex screen, presenting him or her with limited, and simpler choices at one time. The use of a greater number of menus may be necessary, as may be the use of alternative indicators such as pictures or icons. Such a person, in common with those having head injury problems, may benefit from systems, which make certain choices for them or suggest actions. Artificial Intelligence is often employed in these cases.

The User Interface should be consistent with all the applications the user may employ from time to time. Hence, the "look and feel" of the system should be the same whether they are accessing their environmental control system, their communicator, their telephone, their local ATM machine etc.

Such a requirement presents a great challenge to the Interface designer; requiring the involvement of various clinicians, engineers and of course, the users themselves. An appropriate development process may be as follows:

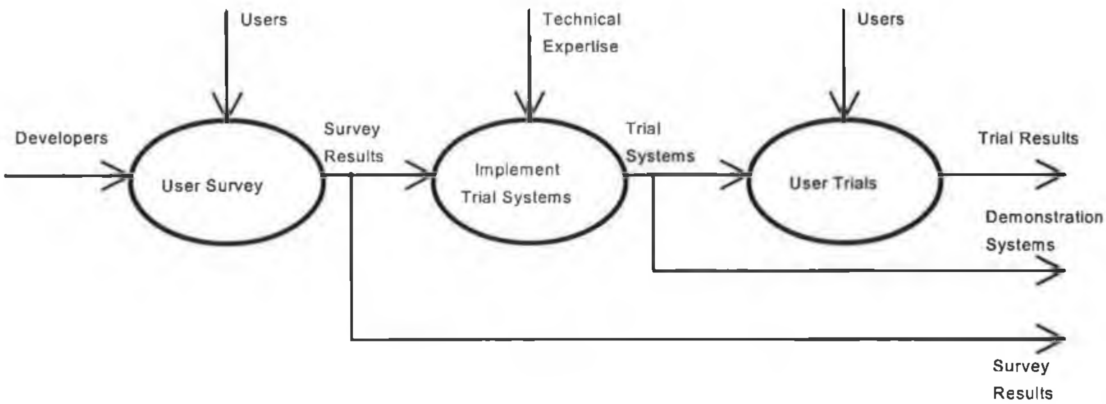


Figure 6.2-1 User Interface Development Process

6.3 Home Control, or Fieldbus Systems

6.3.1 Traditional Systems

In a traditional electrical installation, each sensor is connected directly to one or more actuators. A sensor is a command initiator such as a switch, brightness sensor, or a thermometer. An actuator is a command receiver such as la light, a window blind, or a heating system.

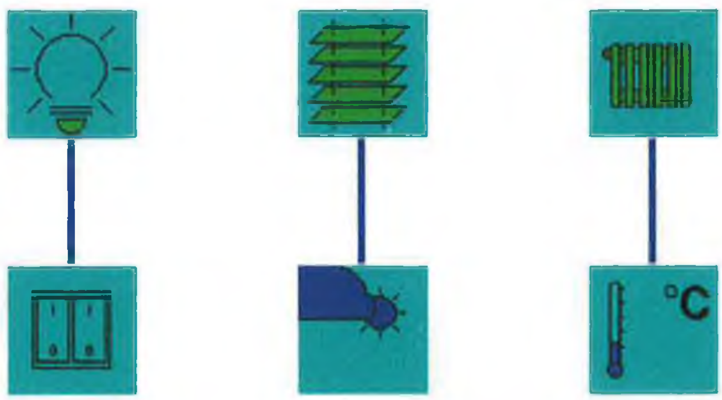


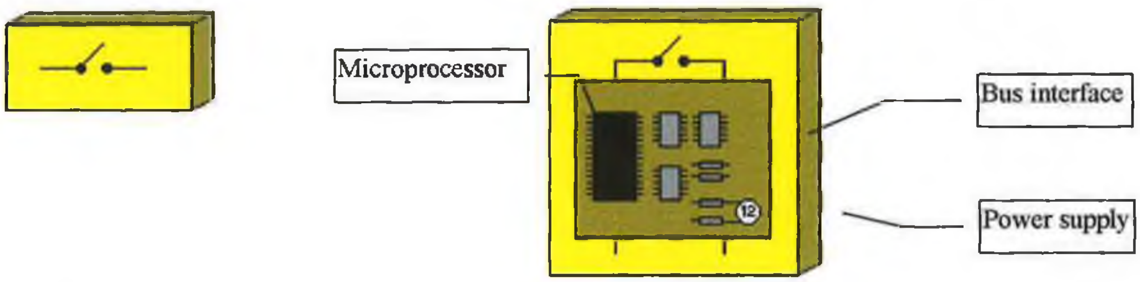
Figure 6.3-1 A Traditional Electrical Installation

An installation of this type has the following disadvantages: -

- No intelligence can be applied
- Wiring is costly and permanent
- Command receivers cannot be accessed by other command initiators
- Diagnostics on devices must be conducted locally

6.3.2 Distributed Intelligence

In a Fieldbus system, all command receivers and initiators are given intelligence in the form of a microprocessor and all are connected to the mains power supply. Where the Fieldbus is not implemented on the power line, the devices are also connected to the field medium.



simple point intelligent point

Figure 6.3-2 Simple and Intelligent Controllers

6.3.3 Topology

In a Fieldbus system, all devices are wired in a line, star, tree or loop topology.

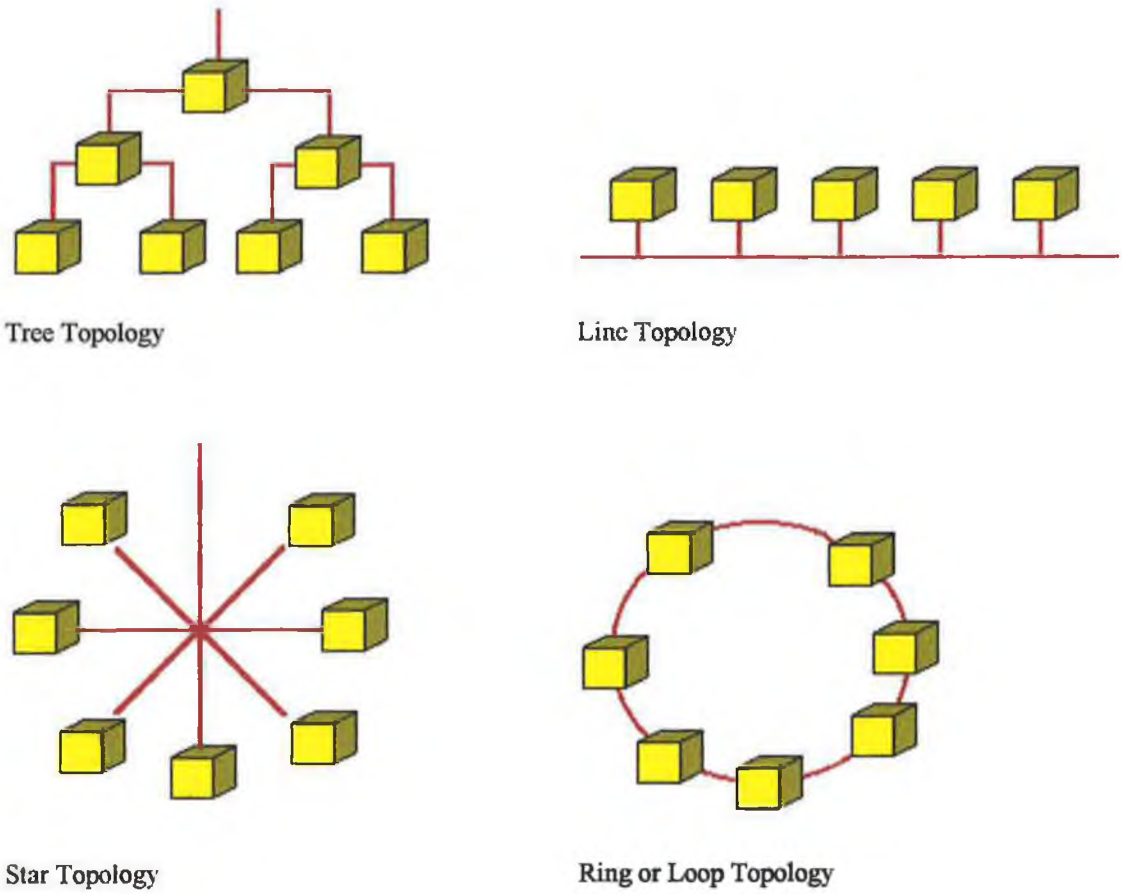


Figure 6.3-3 Fieldbus Topologies

6.3.4 Device Communication

As can be seen, there is no discrete wiring between command initiators and receivers. This connection is implemented in software when the system is installed. For example, a light switch is instructed to communicate with a light or a set of lights. A brightness sensor is instructed to communicate with a window blind etc.

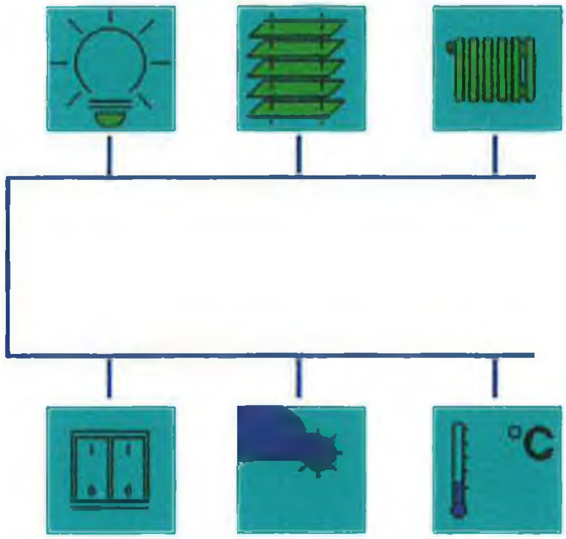


Figure 6.3-4 Interconnection of Actuators and End-Effectors

Some of the possibilities that this intelligence provides are: -

- Lighting and heating can be timed to come on and off at specific times
- A single light switch can control many lights with no additional wiring
- The installation can be easily expanded by adding another line, ring, star or tree
- Every device in an installation can be checked for correct operation from a single point
- The installation is flexible and can be reconfigured at any time
- The command receivers can be accessed externally through an appropriate bus interface

This last point is the most interesting from the point of view of rehabilitation technology. Given the appropriate interface a person with a disability can completely control their environment from one location. Some systems allow for infrared and radio control opening the possibly of environmental control from a powered wheelchair or simple hand-held controller.

6.3.4.1 Transmission

In a Fieldbus system devices communicate with one another digitally over the transmission medium. There are several different transmission media types including: -

- Twisted Pair
- Power Line
- Coaxial Cable
- Infrared
- Radio Frequency

The rate of transmission depends upon the medium and the sophistication of the transceiver. The information transmitted on the bus is described, in terms of messages, of which each is divided into the following generalised fields: -

Source Address	Destination Address	Data	Error Check

Figure 6.3-5 Composition of a Typical Fieldbus Message

Each device is identified by its Fieldbus address. In general, a message will contain the source address and the destination address. Together they identify which device transmitted the message and which device is to receive the message. After the address fields, comes the data communicated from one device to another. This field varies in length depending on the type of information and can mean anything from "*Activate Lights*" to "*Retrieve Diagnostic Data*".

6.3.4.2 Data Protocol

The exact data format depends upon the protocol being used, however all Fieldbus protocols use what is called a Carrier Sense Multiple Access (CMSA) method of communication. CMSA allows devices to send and receive on the same transmission medium by actively monitoring that medium. When a device wishing to transmit senses that no other device is transmitting on the medium, it takes control of the medium and sends its data. If another device wishes to transmit during this time, it must wait until the medium is free again.

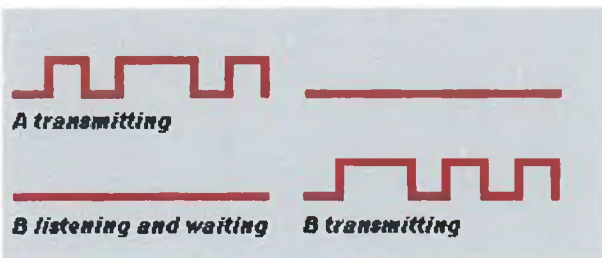


Figure 6.3-6 Typical Message Timing on a Fieldbus

Some protocols implement collision avoidance techniques (CMSA/CA). With this protocol, the transceivers not only sense the transmission medium for a free slot, but also monitor the data as it is being transmitted. If a transceiver detects that what it has just transmitted differs from what it sees on the transmission medium it then knows that a collision has occurred and it withdraws from the Bus until another free slot is available.

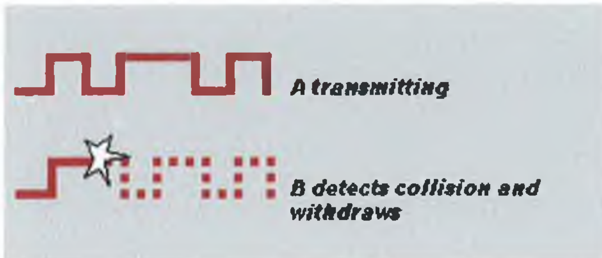


Figure 6.3-7 Message Timing under Collision Conditions

Some protocols implement an arbitration mechanism, which allows the remaining device to complete transmitting its message.

6.3.4.3 Configuration

Configuration of a Fieldbus system is the method by which an installer couples a command initiator to one or more command receivers. For simple systems such as BatiBUS and X10, configuration is achieved by setting hardware thumb wheel switches to identical address numbers. For complex systems such as LonWorks and EIB, configuration is achieved using a PC connected to the bus and a graphical interface through which devices are set to communicate with one another. One such interface allows a configurer to enter the electrical points on architectural drawings using the mouse, group, and assign lights to switches.

6.4 Fieldbus Systems for Rehabilitation Applications

An analysis of the most common Fieldbus systems in use at present has been carried out by Allen and Dillon [A97f]. This study looked at the following:

Origins	The origins of the bus system. Who initiated its development? Whether it is commercially lead, whether it is available as an open standard.
Technology	The type of technology employed. The type of transmission medium and topology, a protocol description, and the method of system configuration.
Usage	What type of building the bus system is most suited too, where it is currently in use and its market penetration.
Suitability for Rehabilitation	For what reasons the bus system is or is not suitable for exploitation in the rehabilitation field.

Figure 6.4-1 Comparison Parameters used in Allen, Dillon Fieldbus Report

In addition, it examined current standardisation efforts, and any moves to converge the systems into a more commonly accepted standard. It also looked at the most appropriate systems to fit with the three-environment model proposed by this thesis.

Overall, two bus systems stood out as being most suitable for use in the type of rehabilitation applications of interest. These were the BatiBUS and EIB systems.

6.4.1 BatiBUS

6.4.1.1 BatiBUS Origins

LANDIS & GYR, MERLIN GERIN, AIRLEC and EDF first developed BatiBUS. These four firms founded the BatiBUS Club International (BCI) in 1989 in order to promote the BatiBUS system. Today the BatiBUS association has over 80 partners engaged in the fields of energy control, security, access control, lighting etc. The aim of the association is to encourage a single European standard, an open, independent and multi-application standard developed within the framework of European alliances.

They achieve this aim by: -

- Promoting BatiBUS through publications and participation in exhibitions
- Informing members on all aspects of the BatiBUS system
- Distributing technical specifications, test procedures, standardisation work etc.
- Encouraging exchanges between BatiBUS members
- Preparing and monitoring standardisation work

Members of the Association can: -

- Independently develop and market BatiBUS compliant products
- Use the patent covering the BatiBUS transmission system
- Have access to technical specifications
- Use the BatiBUS trademark and logo

The symbol of the club is the BatiBUS logo. Manufacturers conforming to the standard, use the logo as evidence of compatibility.

6.4.1.2 BatiBUS Standardisation Effort

BatiBUS is an open protocol and has been accepted in France as a standard for building control systems. The French standard is described as NFC 46620 and lays down regulations for the physical layer, data link layer, application layer, and network management requirements.

The BatiBUS standard has also been submitted to CENELEC (European Electronics Standard Committee) and ISO (International Standards Organisation) for approval.

6.4.1.3 BatiBUS Bus Line

The BatiBUS is a twisted-pair, which is laid parallel to the mains power supply network. Any telephone wire pair or twisted electric cable may be used, shielded or not. The Bus Line interconnects all sensors and actuators in a building control system such as heating, air conditioning, lighting and closure functions. Under the BatiBUS protocol a maximum 7680 devices can be connected to the bus at any one time.

6.4.1.4 BatiBUS Topology

The installer can freely determine the topology of the BatiBUS. The wiring can be implemented in a line, star, tree or loop formation.

The following table describes the maximum lengths applied to the bus given the cross-sectional area of the conducting lines. The distance (D) is the maximum distance between the central unit and the farthest point. The length (L) is the total network length.

Section mm	D m	L m
0.75	250	1900
1.5	500	2500
2.5	600	2500

Figure 6.4-2 BatiBUS Media Criteria

6.4.1.5 BatiBUS Transmission

Devices on the bus communicate with one another at a rate of 4800 bits per second. No impedance matching is required. Information transmitted on the bus is described in terms of frames. Each of which is subdivided into the following fields: -

- Message type field
- Destination/emitter type fields
- Destination/emitter address fields
- Data field
- Check field

The destination/emitter type field describes the type of device transmitting the frame and the device type that is to receive the frame. Examples of different types of devices are temperature sensors, lights, binary command (switches) etc.

The destination/emitter address field describes the physical address of the transmitting device and the physical address of the device to receive the frame.

The data field contains the data of the frame. A maximum of 25 bytes can be transmitted in one frame.

The Check field provides for error free communication.

To transmit a frame on the bus, it is split up into 8 bit characters and transmitted as 1 start bit, the 8 data bits, a parity bit and a stop bit.

The BatiBUS communication is described as a CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) protocol. In order to ensure orderly communication on the bus an arbitration type mechanism is employed, which only allows one device to complete its transmission frame at any one time.

6.4.1.6 BatiBUS Power Provision

BatiBUS aims to simplify installation by providing power on the twisted pair. The power is intended for low power devices drawing not more than 3mA, the total power available being 150mA at 15V. In the event of supplying power to a device via the Bus there must be at least one power supply device on the Bus.

6.4.1.7 BatiBUS Configuration

Every module of the installation is identified by a BatiBUS address. In a simple system the address can be set on the device either by drum wheels, dipswitches or keyboards with displays. For example if an ON/OFF command initiator is required, such as a push-button, to communicate with an ON/OFF command receiver, such as a light, all that is necessary is to set the BatiBUS address on each device to the same number. For more complex systems control can be programmed from a central command module. For the example quoted above, the push-button and the light are given different addresses. The central command module, on receipt of a message from the push-button will forward it to the light. The advantage of this is that the system can be configured via software tools and reconfigured at any time. The push-button can be set to operate different lights or different sets of lights at different times. If an ambient light sensor is added to the bus, the central command module could be configured to turn off all lights during daytime.

From documentation available it would appear that this potential of BatiBUS has not yet been fully implemented. Most commercially available devices employ the “drum wheel” method of configuration.

6.4.1.8 BatiBUS Usage

BatiBUS is particularly suited to small and medium tertiary buildings including homes, schools, hotels and small office blocks. It has found commercial success in mainland Europe, particularly in France and has quoted a figure of approximately 500,000 points in over 5000 sites.

6.4.1.9 Suitability of BatiBUS for Rehabilitation Purposes

BatiBUS is very suited to exploitation in the rehabilitation field for the following reasons: -

- Availability of low cost commercial products
- Technology is open to third parties for exploitation
- Development kits are available
- BatiBUS/infrared gateway is available
- Interface to M3S has been developed by the IRV in Holland

The one major drawback of BatiBUS is that it is confined to the twisted pair media. This means that if an existing building is to receive BatiBUS products, a twisted pair network must be installed.

6.4.2 European Installation Bus (EIB Bus)

6.4.2.1 EIB Origins

Founded in 1990 by 15 firms the European Installation Bus Association is now an association of almost 100 electrical installation firms who have joined together for the purpose of developing a common standard for installation Fieldbus systems. Their objective for a uniform building management system throughout Europe is achieved by: -

- Laying down technical directives for systems and products
- Devising quality rules
- Drawing up test procedures
- Making system know-how available to members, subsidiaries and licensees
- Engaging test institutes to perform quality inspections
- Granting third parties who pass tests the use of the "EIB" mark
- Taking an active part in standardisation

The symbol of the association is the "EIB" mark. Manufacturers conforming to the standard use the logo as evidence of compatibility.

6.4.2.2 EIB Standardisation Effort

In November 1991 a draft standard was submitted to the European Electronical Standards Committee (CENELEC) for processing and is proceeding to a European standard (EN) or pre-standard (ENV). In July 1992 the German Electrotechnical Engineering Commission (DKE) passed the EIB system as a provisional standard which was published as DIN V VDE 0829. In France the EIB system has been published as an "Experimental Standard".

6.4.2.3 EIB Bus Line

The EIB Installation bus is a twisted-pair that is laid parallel to the mains power supply network. The Bus Line interconnects all sensors and actuators of an installation together. Sensors are command initiators such as switches and pushbuttons. Other types of sensors include temperature sensors, brightness sensors etc. Actuators are command receivers such as lights, blinds, heating, door openers etc.

On each Bus Line up to 64 devices can be operated. Up to 12 such Bus Lines can be joined together with a Line Coupler to form one Bus Area. Up to 15 such Bus Areas can in turn be connected by means of an Area Coupler.

6.4.2.4 EIB Topology

The topology if the EIB bus can be freely determined by the installer. The wiring can be implemented alongside the main electrical supply in a line, star or tree formation.

The following conditions must be adhered to: -

- Overall length of a bus line: 1000m
- Maximum distance between 2 bus devices: 700m
- 64 devices per Bus Line
- 12 Bus Lines per Area. Bus Lines coupled together with Line Couplers.
- Maximum of 15 Areas. Areas coupled together with Area Couplers.

6.4.2.5 EIB Transmission

Devices on the bus communicate with one another at a rate of 9600 bits per second. No impedance matching is required. Information transmitted on the bus is described in terms of telegrams. Each telegram is subdivided into the following fields: -

- Control field
- Address field
- Data field
- Check field

The data in the control and check fields provide for error free communication. The data in the address field specifies which area, which bus line, and which device the telegram is addressed to. In order to ensure orderly communication on the bus an arbitration mechanism is employed that allows only one device to communicate on the bus at any one time.

6.4.2.6 EIB Power Provision

The installation bus is driven with low voltage (DC 24V) and in this way is separated from the heavy current system. There must be at least one power supply per Bus Line.

6.4.2.7 EIB Configuration

Configuration of the bus system is achieved using the EIB Tool Software developed by the EIBA. The location and physical address of each bus device is entered in the architectural drawings. When an installation is complete a serial interface from a personal computer configures the EIB system.

6.4.2.8 EIB Usage

The EIB Installation bus is ideal for any building, be it an office block, utility building, hotel, school or detached house. It has found commercial success in mainland Europe, particularly in Germany and has quoted a figure of approximately 10 to 15 thousand installations.

6.4.2.9 Suitability of EIB for Rehabilitation Purposes

EIB bus is very suited to exploitation in the rehab field for the following reasons: -

- Availability of commercial products
- Technology is open to third parties for exploitation
- Development kits are available
- Established network of training centres
- Interface to M3S has been developed by FST in Switzerland

The one major drawback of the EIB Bus is that the technology has so far only been applied in great measure to the twisted pair medium. This implies that if an existing home is to receive an EIB bus a certain amount of re-wiring will need to take place. However, the technology can be applied to other media and products, and specifications do exist for Infrared and Power Line media. The EIBA is also carrying out development for the coaxial cable, optical fibre and radio frequency mediums.

6.4.3 Existing Interfaces to Wheelchair Bus Systems

Interfaces to Rehabilitation Systems		
Home Bus	Wheelchair Bus	Source
BatiBUS	M3S	TNO-TPD, IRV
EIB	M3S	FST

Figure 6.4-3 Existing Interfaces to Wheelchair Bus Systems

6.5 Conclusion

Fieldbus systems potentially offer disabled people complete control over their environment. Through an appropriate interface a user can access all the functions of their home or workplace. Further, if these systems become common place for electrical installations, a disabled person will have little or no expense in adapting their home. A newly wired building will come “ready-made” for environmental control.

A disabled person’s access to a Fieldbus system will be through a Fieldbus interface. The following types are possible: -

- Simple scanning program on a dedicated piece of hardware
- Infrared Control box
- A voice activation unit
- Software running on a PC
- Access from an integrated wheelchair display (DX or M3S)

The only Fieldbus used in the rehabilitation field to any great extent is the X10 system. It can be operated from an infrared control. While X10 is cost effective and simple to install it provides limited functionality and sits on top of the existing mains system as opposed to being part of it. As for the other systems, no commercial interfaces are available at present, but the previously mentioned interfaces from an M3S wheelchair bus system have been designed.

6.5.1 Standards

Presently the six HBES (home and building electronic systems) outlined in this report are in commercial competition with each other. Within the next five years there will be various standardisation committees completing their work and declaring protocols ready and suitable for implementation. Leading vendors will come forward supporting one or more protocols. This will lead to a consolidation that should result in: -

- The development of more standard compliant devices, at lower cost.
- Vendors joining to produce integrated systems that provide greater functionality than individual systems
- Rapid advancement of engineering tools to allow integration
- The entrance into the market of new organisations specialising in system integration for disabled users

Within five to ten years, the "family" of standards will be further consolidated and replaced by one or two dominant standards that will be the basis for true wide-spread "plug and play" operation for simple applications. Already there are initiatives to form such dominant standards. In the USA, the CEBus Industry Council has put forward a HPNP (Home Plug and Play) specification that can operate on top of CEBus and LonWorks. In Europe the European home systems association is actively encouraging a merger of EHS bus, EIB bus and BatiBUS.

6.5.2 Convergence

The European Home System Association Bus (EHSA) initiative in particular is called "Convergence". It aims bring together the best of three systems taking into account the existing products on the market without having to start from scratch. Convergence will occur on four levels: -

- Technical convergence (hardware)
- Protocol convergence (software)
- Management convergence (network installation)
- Marketing convergence (common strategies)

The EHSA Bus is not, however, likely to be a major market force in this area. The end result of their "convergence" initiative is likely to be a working agreement between the larger standards; in particular, the BatiBUS and EIB standards previously referred to.

6.5.3 For the Person with a disability

The investment in Fieldbus systems is coming from the World's major electrical companies. If they are successful, and succeed in penetrating the market the result will have a direct positive effect on the lives of people with disabilities. Rehabilitation companies will exploit the emerging technology and make available low cost environmental control systems. These systems will be truly integrated with a buildings electrical system and will provide much greater functionality than the "add-on" systems that are currently available.

7 THE DISTANT ENVIRONMENT

7.1 Overview

The Distant Environment, as defined in Chapter Four, includes the following functions and operations:

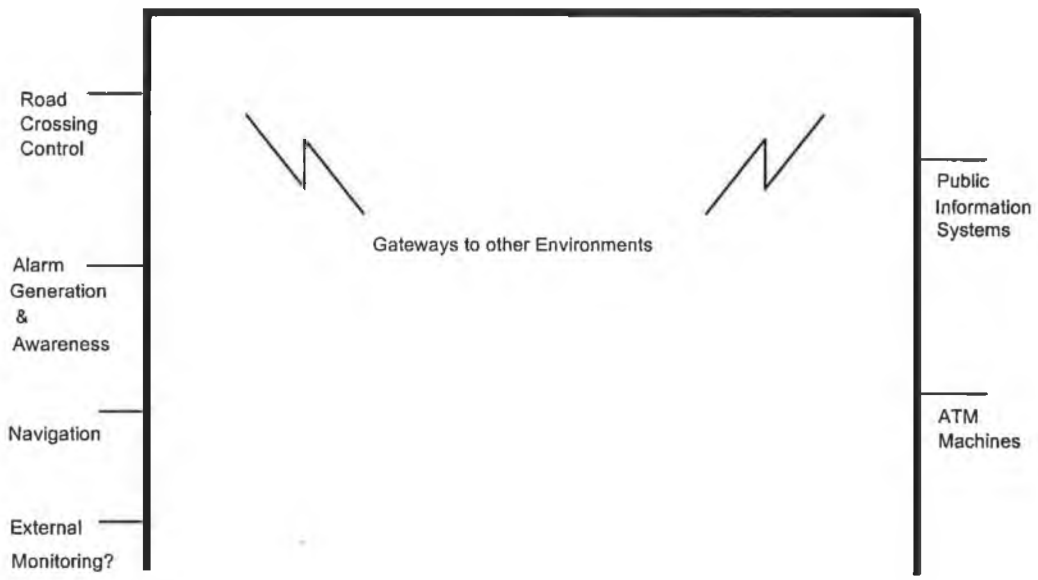


Figure 7.1-1 The Distant Environment

The items listed are not intended to be exhaustive, and will undoubtedly vary as the public information technology environment develops. The essential idea, however, remains the same. Disabled people should be able to use public I.T. equipment as others do. This should be either through existing interfaces and technologies, that are designed to accommodate their needs, or by the provision of interface channels within public equipment, that will allow for simple interconnection between the device and the disabled person's customised assistive technology.

The methodology proposes the development of a common communication protocol or "Bus"; allowing third party equipment developers to produce a range of assistive devices, following the integrated approach, which incorporate a gateway allowing for interface to the Distant Environment.

Unlike the previous two environments described, the Distant Environment is much less well defined. Indeed, it is questionable whether it has been defined at all. There is a need for a considerable amount of work in this area, but efforts must involve or be linked with, European standardisation bodies since any such Bus would have to be accepted by a wide range of equipment manufacturers.

7.2 The Existing Situation

The existing situation in regard to the Distant Environment is poor, piecemeal and, in many respects, totally non-existent. For example, Automatic Teller Machines (ATM's) have no alternative input output mechanisms available and have no agreed user interface methodology that allows a person with a disabilities move from one to another with any ease. Such an approach, however, is not beyond the bounds of technical expertise. It has not proven to be too much of a problem to network machines from different Banks; nor has it been difficult to introduce European wide systems that recognise a user's Country of origin and present an interface and options appropriate to their cultural needs.

If the above facilities are possible with relatively little effort, why not consider a situation in which an ATM identifies a user as having special needs. This identification could be carried out by interpreting special data on their Bank cards or Smart Cards, or by recognising the person and their needs, from specialised assistive technology devices they are using, as they approach the machine.

It would be unreasonable to single out Bank cash machines for all the attention. Disabled people also require access to the ever-increasing number of public information terminals that are appearing. They need to be able to operate simple road crossing controls; be made aware of public alarms or safety announcements; be able to shop and browse as others do. In some cases, there may be an argument for allowing the person's geographic position and medical condition to be monitored on a continual basis. This later issue raises ethical questions, unless it is done with the user's full, informed, consent.

The questions and aspirations mentioned above, cross a number of boundaries, the least of these are the geographical ones. The question of access to ATM machines, for example, requires an in-depth examination and agreement upon protocols by many different bodies, one of the most important details being the whole question of security.

7.3 Current Relevant Work

Very little is being done to achieve the above goals at present. Mainly because there is little perceived need for such work, however, with an increasing average age of European citizen, the question will have to be approached soon. Small efforts have been made, such as the production of a wrist worn, vibrating, alarm system for people with hearing difficulties and the option of larger text on screen with some public information terminals.

The above work is only scratching the surface of the problem. The methodology of this thesis proposes that the whole question of interfacing to public equipment be approached in the same way as it has with the inner two environments. In other words, co-ordination is required, together with appropriate gateways to the other functions. This thesis will not present an exact solution - merely identify the problem, mention known work being carried out at present and will suggest possible avenues that others may pursue, to achieve the overall objective of producing a totally integrated solution that meets the complete needs of disabled people.

7.3.1 The Universal Auxiliary Interface Protocol (UAIP)

In 1996, [T96] the Trace Center, at the University of Wisconsin, USA, produced a draft working paper proposing an Universal Auxiliary Interface Protocol (UAIP). This protocol was intended to cover more than just public equipment interfaces, but did highlight the above mentioned problems and started work on a protocol definition. The standard proposed did not explicitly exclude any interface transmission media, but focussed heavily on the use of infrared technologies. Much of the reason for this may have lain with the state-of-the art in remote technologies at that time, and also that the protocol was intended to be used with existing infrared operated equipment. To find application in the Distant Environment, however, other considerations should be highlighted.

Firstly, infrared systems do not always perform well in situations where receiver and transmitter are not clearly within line of sight. Within homes or workplaces this problem can be overcome using repeaters that receive infrared signals, convert them to another form such as radio or electrical mains borne signals, then reverse the process near the device to be controlled. Such an arrangement may be difficult to implement in a Distant Environment scenario.

Secondly, infrared signals do not operate reliably out of buildings. The higher ambient light levels can cause poor operation, or zero operation, depending upon the circumstances.

Thirdly, whilst for many years infrared systems have provided a low cost solution to the question of remote linking, radio standards have evolved to the point where cost difference is no longer a significant factor.

Despite its apparent shortcomings for direct application as a Distant Environment control mechanism, the UAIP does identify many of the desirable features that would be required. This would include, for example, the need for public equipment to be in a continual state of readiness to detect a person with special equipment approaching, and to adapt itself readily and quickly to link with their equipment. This process is somewhat similar to the method used by IrDA when a mobile device is brought within range of a desktop machine, or the localised radio system employed by some Museums and Art Galleries that allows a visitor approach an exhibit, to listen to the particular information about that item on a portable headset.

7.4 What is Required?

As previously stated, the required solution must fit within the integrated philosophy, and the three-environment model. It must be an internationally accepted solution or standard. Whether that standard is arrived at by committee, or becomes established as a de-facto model through market forces, is not important. What is of significance is that there be such as standard.

7.4.1 Possible Alternative Solutions

The Universal Auxiliary Interface Protocol (UAIP) mentioned previously may be one possible way forward. Its shortcomings in terms of the methodology proposed in this thesis have been identified; however, these may be overcome in various ways.

The preferred solution would be to look to using existing, easily available transmission media such as the GSM telephone network, and to build the required standards and protocols on top of such a system. This approach opens up other possibilities, such as: -

- Using existing, cheap GSM equipment as a general interface with few range or line of sight limitations.
- The possibility of having gateways that are much longer range than is currently possible. For example, if a disabled user is out in public, they can be made aware someone has rung their doorbell, they can speak to the caller and allow them enter, if appropriate. The caller need never know the person is not at home. Similarly, the user can operate devices at home whilst actually being some considerable distance away.
- The bandwidth and range of the GSM network would allow for transmission of medical monitoring data in a fully transparent way.

- A GSM based system can allow a user's movements to be monitored (if that is desirable) either by using the network itself as a locator, or by combining it with a different form of location system such as the Global Positioning System (GPS). BT Laboratories in the UK have produced such a device on a pilot basis.

8 RESULTS AND ANALYSIS OF TRIALS

8.1 Analysis of Central Remedial Clinic Experiences

8.1.1 CTS Client Profiles

In 1997, the Central Remedial Clinic commissioned a specific client survey to be conducted by the Lansdowne Market Research Company. Representative samples were selected from clients seen by the various Departments and services within the organisation for qualitative analysis. Additionally, a quantitative survey was conducted over a much larger sample.

Clients previously seen by the technical assessment service (Client Technical Services Unit, CTS) were asked the following simple question.

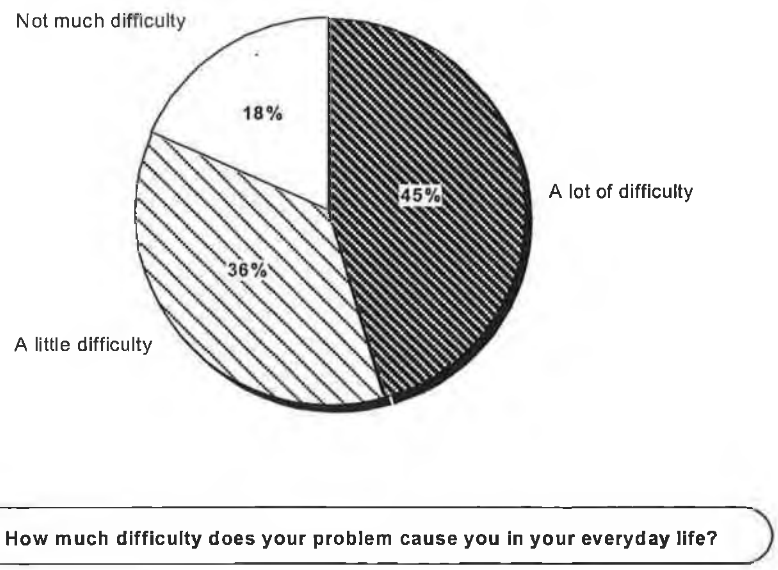


Figure 8.1-1 Extract from Client Survey Conducted by Lansdowne Market Research - 1997

It is likely that the responses underrate the extent of difficulty experienced, as it has been observed by the assessment team, that clients tend to over estimate their own ability to cope with their disabilities, when communicating with others. Nevertheless, some 78% expressed a degree of difficulty for which they were seeking a technical or other solution.

The difficulties can be further broken down within the same survey.

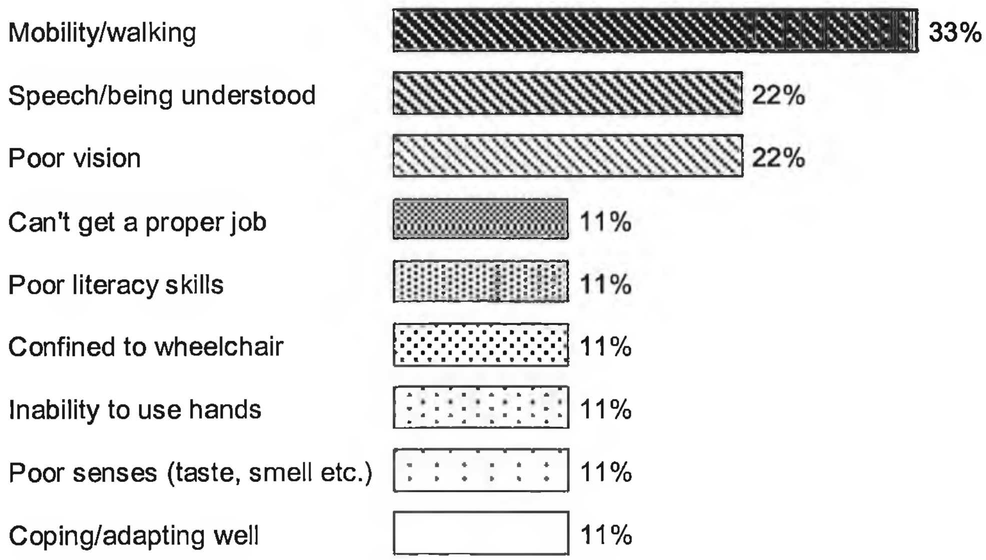


Figure 8.1-2 Nature of Difficulties (Lansdowne Survey)

CTS Clients' profiles were as follows:

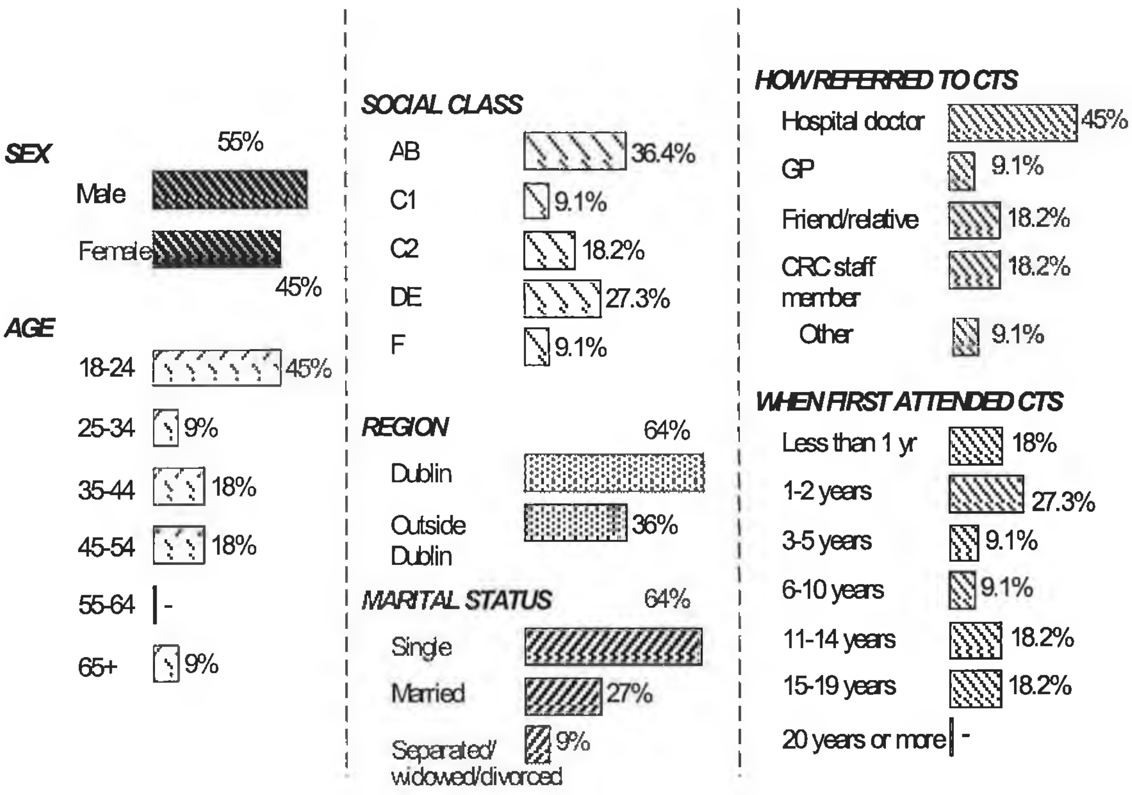


Figure 8.1-3 CTS Client Profiles (Lansdowne Survey)

The methodology proposes that clients be assessed holistically by a multi-disciplinary team and that integrated solutions to their problems be sought wherever possible. It also proposes that the service and continuing support be delivered as close to the client's home as possible. This later point was emphasised by clients in response to questions in the Lansdowne survey for the full range of CRC services, including CTS.

It was noted that regional support was rated No: 1 among existing CTS users, as the thing they most wished to see improved.

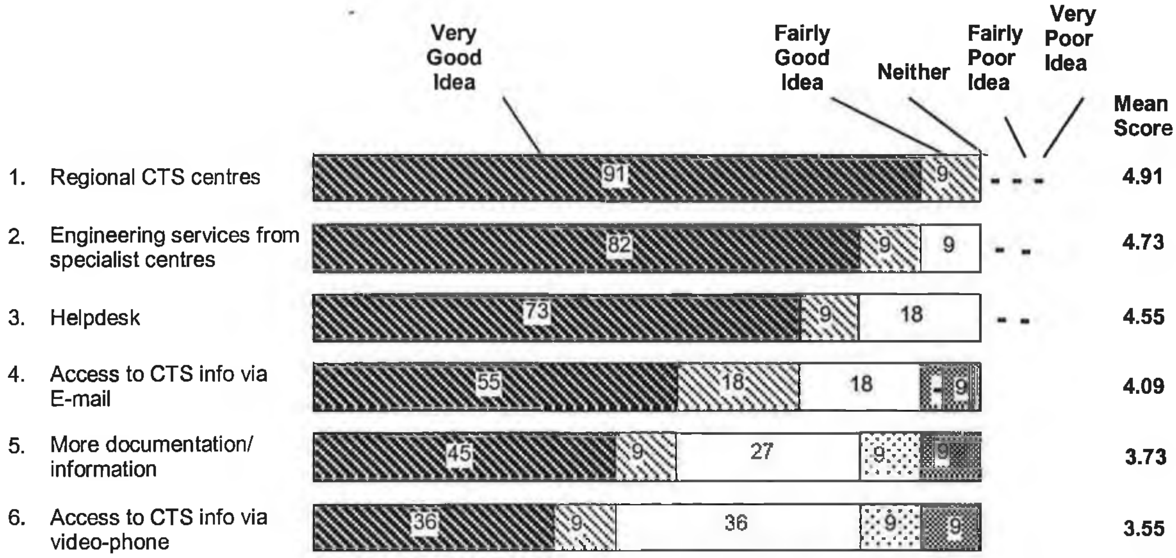


Figure 8.1-4 New Ideas for CTS (Lansdowne Survey)

Whilst the CRC considers itself a National service delivery organisation, it is nonetheless, Dublin based. Some services are available to limited degree, across the Country. Unfortunately, this cannot be said for technical assessments, as the resources have not been available to set up regional service centres.

As a consequence of this later point, CTS, more than most services, has seen clients from all over Ireland. The following table gives a breakdown of the geographic spread of clients seen during 1997.

8.1.2 Number of Referrals (1997)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	**Totals**	**Waiting List**
Carlow													**0**	0
Cavan		1					1						**2**	2
Clare		1											**1**	0
Cork									2	1			**3**	3
Donegal						1				1			**2**	1
Dublin	4	3	2	5	6	5	5	6	8	5	9	5	**63**	30
Galway			3	1	2			2	1				**9**	12
Kerry													**0**	2
Kildare					1	1		1	2		1	1	**7**	1
Kilkenny						1							**1**	1
Leitrim		1		1									**2**	1
Limerick		1		1	1								**3**	1
Laois													**0**	1
Longford	1					1							**2**	1
Louth							1						**1**	4
Mayo													**0**	1
Meath			1									1	**2**	1
Monaghan													**0**	0
Offaly					1						2		**3**	1
Roscommon		1									1		**2**	2
Sligo	1			1	1								**3**	1
Tipperary	1		1	1	1								**4**	3
Waterford	2	1											**3**	0
Westmeath									1		1		**2**	5
Wexford					1								**1**	3
Wicklow						1	1						**2**	3
Totals	**9**	**9**	**7**	**10**	**14**	**10**	**8**	**9**	**14**	**7**	**14**	**7**	**118**	**80**

Figure 8.1-5 Geographic Breakdown of CTS Clients seen in 1997 plus Waiting List

8.1.3 Reasons for Referral

The methodology proposed implies that clients are often referred for several reasons; hence the need to consider their needs holistically in a multi-disciplinary assessment process. This fact was observed in the pattern of referrals to CRC technical assessment service over the last few years. In particular, careful monitoring over the last 6 months of 1997 shows a breakdown as in the following diagram.

The abbreviations should be interpreted as:

AAC	Alternative or Augmentative Communication
Access	Access to Personal Computers
EC	Environmental Control or Smart Home systems
Education	Access to special educational technology or assistive technology to access conventional services
Employment	Access to specific job capabilities
Internet	Access to specialised Internet resources
Powered Mobility	Control of powered wheelchairs by non-standard controls
Software	Access to specific software packages

Primary Req.		Secondary Req.		Tertiary Req.	
Unclear	3				
AAC	**12**				
		Access	3		
		Education	1		
				EC	1
Access	**15**				
		Internet	1		
		Education	2		
				AAC	1
EC	**6**				
		Access	2		
		AAC	2		
Education	**20**				
		Access	3		
Powered Mobility	**2**				
Software	**1**				
		AAC	1		
Employment	**1**				

(Total = 60)

Figure 8.1-6 CTS Referrals between 1st July and 31st December 1997

8.1.4 Reaction of Clinicians

Given the previously described geographic spread of clients referred to CRC for technical assessment, the diversity of reasons for referral and the lack of overall resources; it was somewhat inevitable that the clinicians involved in assessments were compelled from an early stage, to rationalise the number of visits a client was required to make by conducting the most comprehensive assessments possible. As time passed, and comparisons were formed between the service provided by CRC and that common in other Countries, it was discovered that CRC clients were being provided for more efficiently, and were expressing better overall satisfaction with the service. Now, the idea of integrating technologies and conducting holistic assessments is being taken up by other States, often as part of collaborative actions linked to the work of the author. Examples of these in The Netherlands and in Finland are outlined later.

Clinical staff who have involved themselves in the CRC technical assessment process, have unanimously expressed their support for the approach. The largest hurdle having been to get professional clinical staff to take on the idea of true multi-disciplinary assessments which involves medical, para-medical and engineering disciplines. By virtue of their compartmentalised training and experiences prior to this work, it often requires a considerable mindset adjustment to establish true multi-disciplinary assessment teams. CRC are pursuing a number of actions to assist in this, including the current APHRODITE project [CRC97b]. They have spearheaded the development of a Certificate Program in Assistive Technology in conjunction with University College Dublin. It is hoped that this programme and others, will help provide true appreciation for the multi-disciplinary nature of the work, among both under and post graduate clinicians.

Figure 8.1-7 Model of Educational Areas

The figure shows the type of approach being taken. It identifies certain basic "core" areas of knowledge for people involved in assistive technology service provision. As time moves on, modules will be identified and produced, to fill the various areas of the diagram, being applicable to different potential professional staff, depending upon their backgrounds. The various components or modules must be designed with Trans-national acceptance in mind, albeit with elements of "localisation" at certain delivery points.

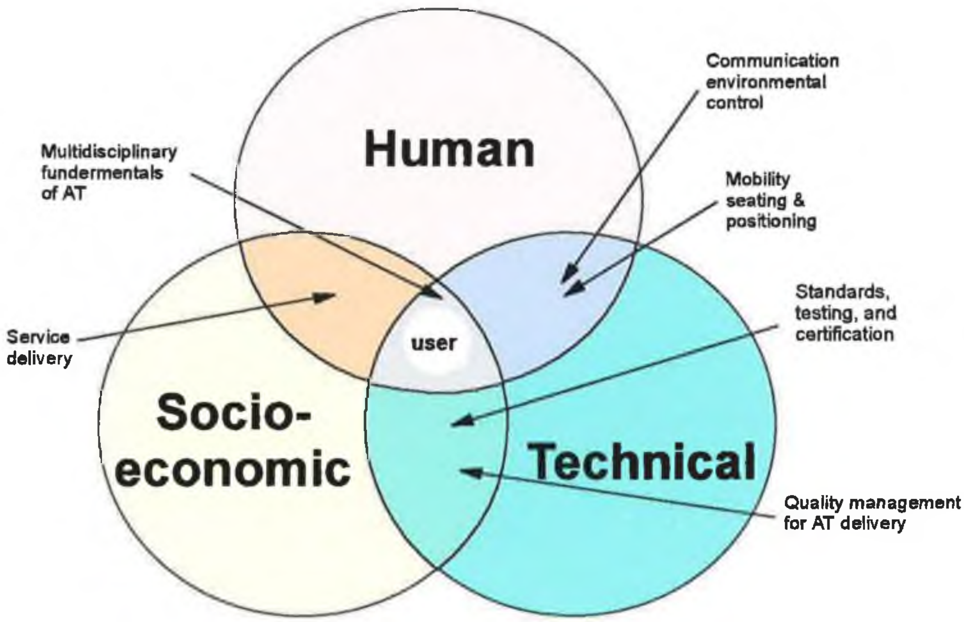


Figure 8.1-8 Some examples of AT courses

Gradually the complete picture can be developed and maintained. [A98b].

The experience of clinicians gained during the European TEST project [CRC97a] gives a clear acceptance of the philosophy and methodology proposed. The resources to implement the approach are, however, not fully in place. The report from the Commission for the Status of People with Disabilities [CSPD96a] does strongly recommend this approach. Since the report is forming the base for up-coming legislation, there is good reason to suppose that the approach is moving closer to reality.

8.1.5 TEST Project Experiences

The TEST [CRC97a] project had three strands. Two of these related directly to this work.

The first, involved establishing a network of trainers or supporters at key regional sites around Ireland, charged with the task of providing support to assistive technology users closer to their homes or workplaces, in turn linking with the CRC as and when required. Initially, community therapists and other workers were identified as filling the role of supporters and a series of training workshops were held around the Country to train them, and to introduce the CRC technical assessment team who would be their back-up.

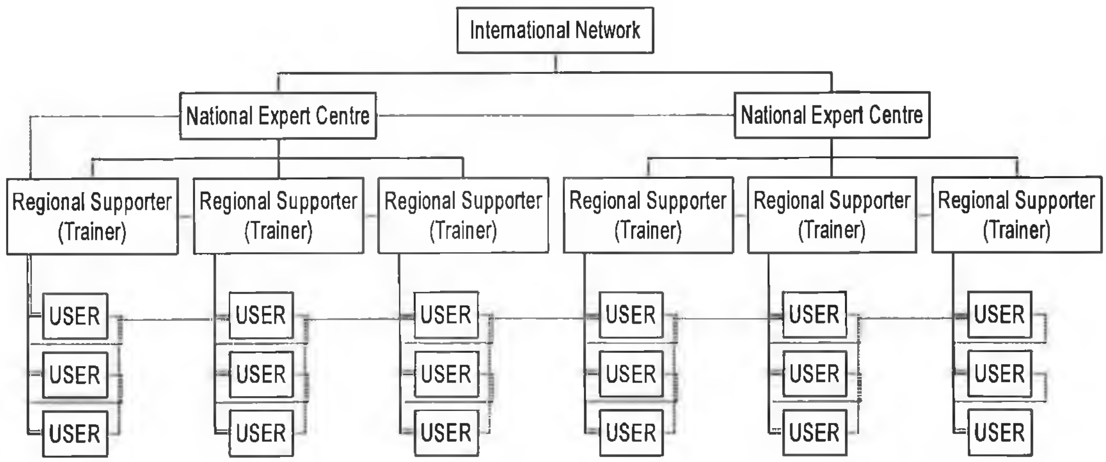


Figure 8.1-9 Support Structure

The diagram shows the support structure required. It allows for communication at all levels

The second relevant strand involved forming a Trans-national consortium to start work on the design, production and validation of suitable course module material that would be used for future graduate, and in-service training.

The results were mixed. Efforts within the first strand above yielded little, due to the already high workload of the existing community therapists. They simply could not afford the time to train in A.T. systems, nor could they afford the relatively high level of time required to adequately support a disabled A.T. user. The activity served to gauge interest - which was very high - but to then disappoint many users because of failure to implement the planned system.

Strand two activities were more successful, and resulted in the production of five course modules. These were:

I. General Introduction/Training Theory & Philosophy
II. Knowledge of Disability Needs Analysis
III. Basic Introduction to Assistive Technology
IV. Assessment for Assistive Technology
V. Ergonomics and Workplace Adaptation

Whilst these modules were produced to high standard, no readily available vehicle existed to allow for them to be put into practice.

The staff actively involved in the TEST project felt that many useful lessons had been leaned. It was important that the momentum be maintained to correct mistaken assumptions.

8.1.6 The APHRODITE Project

A perfect opportunity to build on the work of the TEST project presented itself when CRC were successful in securing further European support for these activities, late in 1997. A further action called APHRODITE (**A** **P**artnership to **H**arness **R**esource **O**pportunities & **D**istribute **I**nformation **T**echnology **E**xpertise) was approved, allowing for an additional two years work in the area.

The lessons learned during the TEST project, were addressed in the following ways:

a) The CRC formed an alliance with an organisation involved extensively in delivering services to disabled people at regional level. This body is called the Center for Independent Living, and has plans to have a point of presence in all 26 Irish Counties within the next 2 -3 years. They currently have some 16 - 18 outlets. CIL undertook to provide and support Training Liaison Officers (TLO's) to fill the role previously envisaged for community para-medial staff.

b) Partnerships were formed with the Center on Disabilities at the University of California, Northridge, and with University College, Dublin. The former had extensive experience in the development and delivery of training courses for people wishing to become support personnel. The work and modules produced, are American biased, and will require an element of "localisation" for Irish use: - a task CRC will perform. UCD accepted responsibility for securing validation for the material, and for delivering it, through a series of programmes. The first of these has begun, and will accept students in September 1998.

8.2 Integrated Technology Trials within Three-Environment Model

8.2.1 M3S Evaluations and Experiences

The SPRINT - IMMEDIATE [CEC97a] project focussed heavily on aspects of information dissemination and demonstration. As such, limited trials were conducted at CRC during the later stages, to establish user reaction to the principle of integrating technologies, and allowing single input and output mechanisms to perform a number of different roles.

The following plan was made to implement the evaluations: -

- To address user-friendliness of the system, in particular when the equipment configuration changes. The evaluators were the assistants, rehabilitation engineers and family accompanying the user, as well as the users themselves. The evaluation would encompass questions related to the understanding of the configuration program, the flexibility of the system, technical problems, and needs for standardisation.

- To perform comparisons, between the test system and the wheelchair that would otherwise be used. This involved driving in small passages, turning, driving indoors, driving outdoors, straight, etc. Training was required, before the user felt at ease with the new system.

The evaluations concentrated on three users and were organised in a number of sessions. The users concluded the following: -

- It is easy to understand how to operate the integrated system.
- The safety Dead Mans Switch, (DMS) worked 100%.
- It was difficult to use several devices at a time, e.g. it was hard to control environment devices whilst driving.
- The collision avoidance mechanism, called a Navigator, did not work satisfactorily.
- Results from tests comparing the users' own equipment show that the M3S system did not affect the functionality of each device.
- It is possible to use different end Effectors with the same input device.
- An annoying sound occurred when the footrest was raised with the joystick panel.
- A safe and reliable system.
- More technical aids are needed, to choose from in the future.
- Reduces "waiting-time" at the try-out for a new powered wheelchair
- Should work with the user interface on the input devices.

- Implantation of a M3S system demands more competence and education from the workers around the user and the user themselves.

Furthermore, therapists involved in the evaluations concluded the following: -

- Easy to exchange different input controls.
- The configuration program needs more work on the user interface and a better pedagogical touch. It should also have an option of a Macintosh computer interface.
- Receiving and sending information from/to the CCM was problematic.
- All the different equipment was totally M3S compatible, allowing communication between each device and the CCM.
- They were true plug & play devices on the M3S system.
- It's a simple and easy way to detect errors.
- The module oriented way of working saves of time.
- The Immediate project should not only spread the knowledge but also teach the workers how to operate it. Make them take a "driving-license" in operating, changing and adjusting the M3S system.
- The environment is also affected in a positive way through the use of a M3S system. Fewer wires were needed owing to the CAN based bus. It is easier to re-use technical aids attached to the wheelchair.
- The CCM consists of a processor that can communicate with a computer. Since computers are used so widely, it should be feasible to connect a modem allowing remote supporters monitor or re-configure, the wheelchair.

This work will be continued under the new European action ICAN (**I**ntegrated **C**ontrol of **A**ll **N**eeds) [CEC98a] due to begin May 1998.

8.2.2 MECCS Project Trials

The MECCS project was conducted by a smaller, less powerful consortium, at a time when many of the standards for both wheelchair and home bus systems did not exist.

The system was used in trials by one, relatively in-experienced user. To conduct the evaluation, a small living unit, close to CRC, was completely re-fitted with technical equipment. This included: -

- Door/Entry exit systems
- Curtain opening and closing mechanisms
- Internal door operation
- Control of a telephone
- Control of electrical devices
- Control of Infrared equipment

The evaluating user operated the system from a purpose built; PC based unit mounted on his wheelchair. This allowed control of all the above devices.

The system worked relatively well allowing for the state-of-the-art in technology at that time. Poor home control bus technologies did not permit the user to "question" the system to establish current states. In addition, the unavailability of DECT cordless telephone systems meant that two; radio channels were required for the voice and data information. The unavailability of DECT also meant that the resultant system would require modification in each Country of use, as no commonly accepted standards existed.

The feasibility of integrating technologies under computer control was nonetheless established. The terminal operated by the user, also served as a working tool for his use, and allowed him access to other leisure facilities.

8.3 International Trials Linked with this Work

Joint efforts have been underway for some years. In particular, collaboration between CRC and the IRV organisation in the Netherlands, and the National Association for Welfare and Health in Finland. The emerging strategy has been jointly published [A95]. The resources in the other two Countries did allow for more detailed trials.

8.3.1 Smart Home Trials in the Netherlands

At the IRV in Hoensbroek an experimental facility was developed starting with the adaptation of an existing home. The purpose of the project was to evaluate new equipment and to provide a basis for consultancy in the area of smart housing. The basic infrastructure present in this house contains the usual modifications to make it accessible (kitchen, bedroom, toilet, doors etc.) The home is equipped with a home bus system for control of functions. The control of these functions is integrated, and can be placed on a wheelchair using the M3S bus.

In the project above only one house was involved. Several feasibility projects are under consideration directed to groups of houses (either standing alone ore integrated in one building) aimed at the elderly. Most of these projects are directed to home management functions in general such as security, energy, and comfort. Some projects try to combine home-management functions with external services.

8.3.2 Smart Home Trials in Finland

In Finland, the concept of an adaptable smarter home is used. This is a home that is built or renovated in such a way that it is easy and cheap to adapt the home to the changing needs of the inhabitants. For disabled and elderly people, for example, this means that devices assisting the activities of daily living can be easily installed at a later stage.

Typical examples, would be the first 12 adaptable smarter homes constructed in Finland as part of the project ASHoRED (Adaptable Smarter Homes for Residents that are Elderly or Disabled) [CEC93b], These were built in the municipalities Kiihtelysvaara and Pyhäselkä and were put into use at the end of 1992. Some implementations in older buildings were also realised in Helsinki. The homes were built to comply with the disability requirements as well as the adaptability requirements. The devices were chosen, based on the real needs of the actual inhabitants. Connections were also built between the adaptable smarter homes and service centres, as well as to the carers.

The system normally includes the network, central unit and infrared remote control console, which allows for the control and monitoring of

- Door locks and door motors,
- Windows, lights
- Television, radio, and telephone.
- Security (fire, burglary, water etc.)

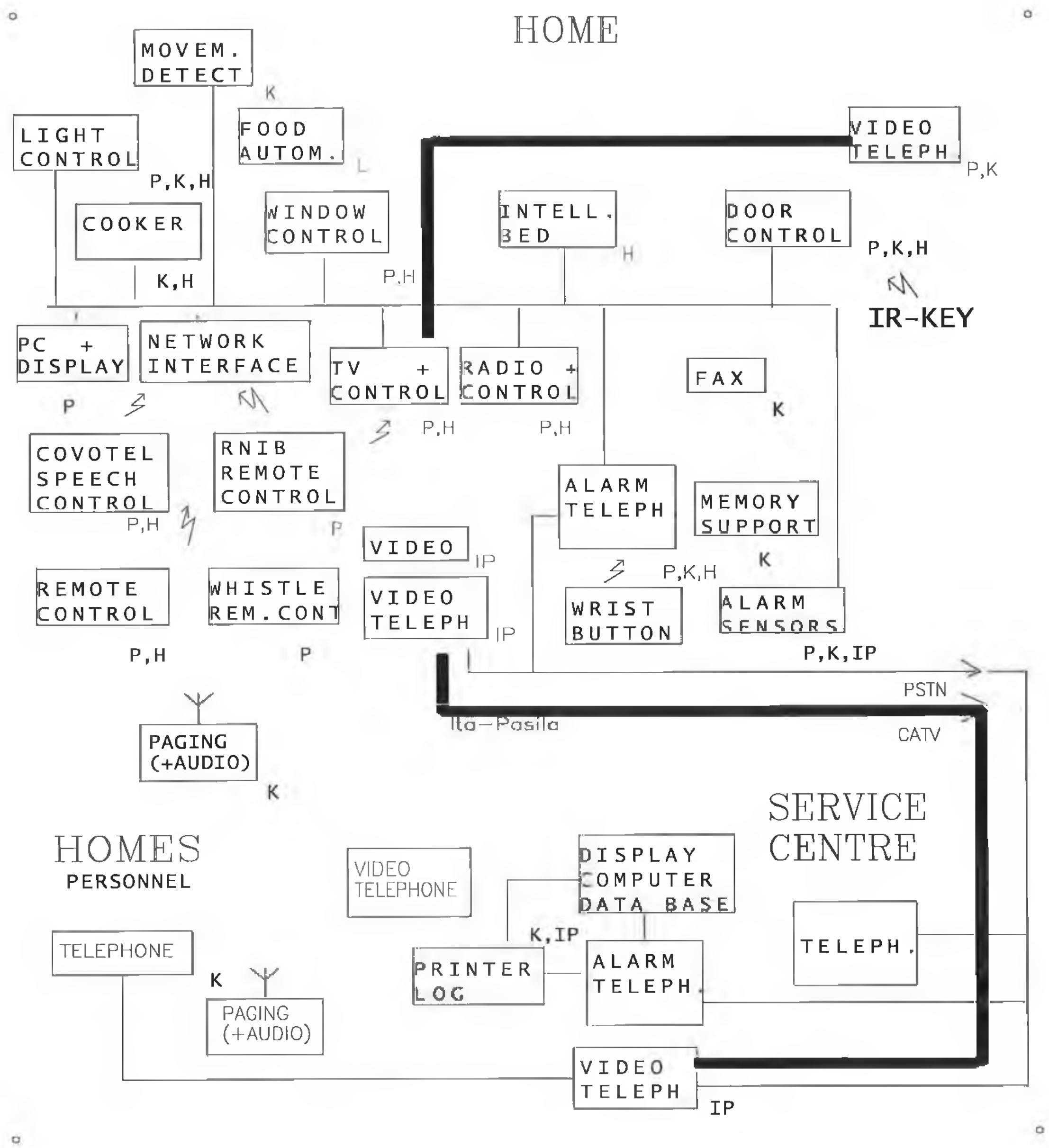


Figure 8.3-1 Devices in Smarter Homes Built in Finland 1993.

(Broad line = broad band connection)

A PC supports the communication. The client can use different auxiliary input devices for this purpose. An example of new devices used, is the local video-telephone system which allows the inhabitant talk to and see the person in the service centre or the person at the front door.

The elderly or disabled inhabitants in adaptable smarter homes require services such as alarms, home care, home health care, and teleshopping in order to cope with the activities of daily living. An alarm telephone system consists of service centre equipment including telephone, PC, display, printer for communication logging and a database with information about the clients. The communication to the service centre, automatically activates many other systems when the client initiates the alarm by pressing the appropriate button on the telephone or by pressing the wrist worn alarm button. Information about the calling client is automatically shown on the display when the alarm is received at the service centre. The alarm can also be activated in a passive way by the network.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Summary

This thesis sets outs a methodology to greatly improve the lives of disabled people by correctly and efficiently applying computer systems to help them cope with their difficulties. The actual equipment employed by these end users, is often collectively referred to as "Assistive Technology" (A.T.), however an analysis of the actual techniques and implementation methods used, quickly shows that the equipment is primarily based around a computer system. Sometimes the application sits on top of an existing "off the shelf" item; other times apparently dedicated systems are developed based on single board computers, imbedded into special enclosures with alternative access or interface capabilities. The essential fact remains; the objective is achieved by applying computer hardware and software.

The integrated technology methodology has proved effective in the limited trial situation, represented by the experiences of the Client Technical Services Unit of the Central Remedial Clinic, Dublin. In addition, the three-environment model has been adopted in other European Countries, and is being considered by others. The methodology has been deemed worthy of further support by the European Commission, the Irish Government and the CRC. More importantly, it has received a favourable response from the user's themselves.

9.2 Recommendations

Because of the power and versatility of modern day machines, one computer is capable of coping with a number of different needs. This potential has not been fully realised because the needs have not been globally assessed in an open-minded, person centred way. To rectify this problem, the following approach is suggested: -

- The power of modern computer systems must be recognised and employed to produce an integrated assistive device.

- The assessment process must be muti-disciplinary and person centred. It must work with the user to holistically decide on an appropriate system for that person.
- The approach to finding the best technical solution should be based on addressing functional needs. This works most efficiently, when engineering problem solving techniques are employed. This implies a move away from the current medical model approach.
- Realisation of an integrated solution should consider the full range of emerging technologies and identified needs to allow the user take part in the fullest range of daily living activities.
- The requirements of a user should be considered within a "three-environment" model. Each environment is inter-connected by gateways, but within each of these, the best available techniques should be employed to produce an integrated, adaptable system.
- The needs of the user will change. This will occur as their lives alter, or as new techniques become feasible. Consequently, all systems will require periodic re-consideration and review. The three-environment approach allows for these changing needs to be quickly satisfied.
- The problems experienced by disabled people, often affect members of the "normal" population, especially elderly persons. Identifying and addressing these problems can often have a beneficial spin off effect in helping others.
- Consideration of special needs at design stage often results in a better product at little additional cost. Such an approach makes market sense, as it brings the product within the consideration of many additional potential customers.
- Service delivery systems should aim at having a point of presence in major population centres.

9.3 Topics Requiring Further Work

9.3.1 User Interfaces

Access to the many different assistive technology systems is dependent for its success upon the provision of good, well designed, user interfaces. The integrated technology methodology relies heavily for its acceptance, on the users and their supporters being able to readily understand how to achieve an objective.

As suggested previously, the user interface is crucial, and is worthy of considerably more effort that it has received to-date. Ideally, the interface should be capable of adapting to the abilities of the user and the situation in which they find themselves. It should, for example, be capable of adjusting its own complexity to suit the users response rates averaged over a period of time. An interface with built in intelligence, could be realised using artificial intelligence programming tools. The work should be conducted in a situation where it can be easily field tested with typical users.

9.3.2 Measurement of A.T. Effectiveness

Virtually no tools exist to allow clinicians and users gain an objective assessment of the effectiveness of one system over another. Such a tool would be of tremendous value to clinicians, and would permit the introduction of A.T. "benchmarks" that would allow easy comparison of one system with another.

9.3.3 Wheelchair Bus Improvements

The wheelchair bus environment, using the M3S Bus promoted in this methodology, requires much additional work. The topics identified, are as follows: -

- Improve M3S to Device interface procedure
- Develop better M3S to Smart Home (Fieldbus) interfaces and gateways
- Develop a greater number of third party device interfaces that can attach to the Bus

In addition, there are many devices peripheral to the wheelchair bus, that could be extremely useful for disabled people if additional time and effort where to be devoted the their refinement. These include: -

- Production of an effective collision avoidance mechanism
- Refinement of the Manus (or similar) robotic arm to reduce weight, improve flexibility and improve user interface

9.3.4 Commercial Fieldbus Systems

Most Fieldbus systems are intended for industrial applications. Those that address control of building functions, are focussed at the high, commercial end of the market. Despite this, home applications, and in particular applications by disabled people, have been identified by the promoting Companies, as application areas to be pursued in the future.

For such systems to be successful, they require third-party endorsement and adoption. Specifically, the manufacturers of domestic equipment - a very cost competitive market - must start producing equipment with Fieldbus interface ability or capability. Before this is likely to happen, the same manufacturers will need to see a greater "standardisation" or convergence of the systems being offered. It is simply too expensive and complex to try and cover every option available at present.

The economies of scale are needed. This requires that such control systems find acceptance among the greater population, or that the market of disabled and elderly people expands to such an extent that production becomes viable.

Any work that makes Fieldbus technology more attractive to the general populace, will have the side effect of reducing cost. This will make the technology more achievable for disabled people. Studies are needed to examine the changing situation, specify convergence mechanisms, and produce third party interfaces.

9.3.5 Control of Public Systems

The distant environment does not currently exist. It is a concept that would be desirable, and which would fit in with the proposed three-environment model. To realise the idea will require agreement among the planners of public infrastructures, and among the Companies producing equipment, to provide an acceptable interface to their equipment, that can be utilised by disabled people.

The task of establishing this "standard" or "public information Bus" is large, requiring International co-operation and legislation at European level. Since it would involve interfacing to very sensitive equipment, such as Bank cash machines, security would be extremely important. These difficulties are not, however, insurmountable. Further work focussed on the specifications required, would speed the day when public authorities would see such a "Bus" as a realistic proposition.

9.3.6 Provision of Appropriate Information

Information is useless unless it is relevant and appropriate to the needs of the intended recipient. An in-depth examination and analysis of users needs is required. An initial attempt has been made by CRC and others, as part of an EU action called "TURTLE" which focussed on the provision of appropriate transport information, intended to be made available at bus stops, at public information terminals and via television Teletext. Similar consideration is required to consider the needs of disabled and elderly people in other aspects of their lives.

9.3.7 Overall System Design

Whilst average life expectancy has continued to rise in recent years and there has been a considerable improvement in provision of resources to disabled people, there has been little or no change in the philosophies and practices taught to young designers. The emergence of a dedicated group called the European Institute for Design and Disability (EIDD) has gone some way toward addressing this imbalance.

Between the EIDD, disabled people and legislative bodies, a new idea has been promoted called "Design for All". It is a philosophy that declares - as a matter of principle - that good design should not only mean building-in the technical competence to accomplish a task, but should also recognise the real needs of all the potential users of devices or systems. The EIDD have produced a number of case studies to show that such an approach is not only altruistic, but that it also makes eminent commercial sense.

The following sections outline how this principle can be introduced into normal, widespread, practice by focussed special efforts.

9.3.7.1 Education of Designers

Several Universities and Colleges educating designers are introducing new modules, similar to the "Design for Ageing and Disability", course taught at Loughborough University in the UK. This module enables students to view the assistive technology market as a specialised one, emphasising the commercial nature of the designer's role.

This approach should make it easier to have the special needs of disabled or elderly people considered, and included at design stage. As always, however, there is a need to refine this material to fit with the particular, localised needs.

9.3.7.2 *Access Features as Standard*

Examples of this thinking, in the technology world itself, can be seen in the additional features built into new commercial software such as that distributed by Microsoft. Undoubtedly, the introduction of these new features is the result of a number of factors such as the consistent lobbying of the software producers, by organisations such as the Trace Center at the University of Wisconsin, the gradual introduction of design for all guidelines, and federal legislation such as the American's with Disabilities Act (ADA) in the USA.

The result is a set of easy to use tools to help users cope with audible, visual and dexterity impairments by simply switching on or off certain parameters built into the software. The work requires further effort to further enhance the adaptability of software, as well as the inclusion of the necessary "hooks" that will permit easy interconnection of conventional software and hardware, with the range of special systems that constitute Assistive Technology.

9.3.7.3 *Virtual Reality Design Tools*

Attempts have been made, such as those by Humpries and Allen [H94], to employ emerging computer systems in the design process itself. Virtual reality has been identified as particularly useful in this regard, as it allows the user go into a virtual world, design their own environment or access system, and pass the appropriate parameters to the designer.

This process requires further refinement.

9.3.8 Availability of Statistical Data

Statistics and analysis data is very poorly provided in the area of A.T. equipment provision. Indeed, such data is very poor in most areas of disability service provision.

A major improvement could be made if the current data was brought together and harmonised. Figures from other European States can be extrapolated to cover the Irish situation, in the absence of firm raw data.

Finally, the process by which such information is gathered requires examination. There may well be a need to produce specific data entry formats, and have them accepted and used by assistive technology assessment personnel.

9.4 Concluding Remarks

The methodology set out in this thesis represents an approach to helping disabled people that is badly required. At the same time it represents an area of computer applications that is relatively new and untapped. The following comments can be made in conclusion: -

- Assistive Technology (A.T.) is a relatively new area of computer applications, and one that can benefit greatly from the application of organised computer design techniques.
- Due to changing profile of Western European populations, which are giving rise to increased numbers of older people, coupled with the falling cost of technology, the application area is likely to become increasingly important as time goes by.
- The thesis opens up many areas of research that need to be addressed. It leaves many questions unanswered. If the area is to receive the attention it deserves, the research effort should be co-odinated as far as possible, and be collaborative with organisations that can directly represent the views of potential equipment users.
- There is a need to introduce a greater degree of professionalism into the area. This applies to the design and production of A.T. equipment, but also to the educational needs of the staff involved in applying the technology, both at a national and regional level.

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Keywords

Assistive Technology

Augmentative Communication

BatiBUS

Computer

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EIB

Enabling Technology

Environmental Control.

Handicap

Holistic Assessment

Home Bus Systems

Integrated Systems

Ireland

M3S

Rehabilitation Engineering

Smart House

Special Needs

Training of Trainers

Transdisciplinary Teams

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