

Palmtop Based System for Vocational Integration of Intellectually Disabled People: Preliminary Definition

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Resumo- O projecto VICAID (Vocational Integration through Computer Assistance for Intellectually Disabled People) insere-se no âmbito do programa TIDE (Technology Initiative for Disabled and Elderly People) e tem como objectivos desenvolver e avaliar um sistema baseado num palmtop para apoio a pessoas com deficiências intelectuais profundas na realização de tarefas complexas em locais de trabalho integrados. O desenvolvimento do sistema será baseado num modelo de referência, o qual deverá considerar o inter-relacionamento entre factores humanos e limitações e possibilidades técnicas. Esta comunicação apresenta e analisa um conjunto de requisitos que está a ser utilizado para a definição do modelo de referência.

Abstract- VICAID (Vocational Integration through Computer Assistance for Intellectually Disabled People) is a project within the TIDE programme (Technology Initiative for Disabled and Elderly People) that aims to develop and evaluate a palmtop based system to support people with severe intellectual disabilities to perform complex work routines in integrated work settings. The development of the system will be based in a reference model, which should consider the interrelationships between human factors and technical constraints and possibilities. This paper presents and analyses the set of requirements that is being used for the definition of the reference model.

I. INTRODUCTION

Severe learning disability is a common form of life-long disability frequently associated with long-term unemployment. In recent years, employment within the competitive job market has become a meaningful option with severe learning disabilities [1]. Supported employment has offered an effective approach to assist persons with disabilities to secure paying jobs and can be considered as new opportunities for a large and disadvantaged section of the community. In this supported employment model, the individual with a severe disability is first assisted to find a job in the competitive market and then accompanied to the job by a

work supervisor who provides direct individualised on-the-job training and support for the disabled worker.

The limited application of the supported employment model for persons with disabilities can be directly linked to two related phenomena: the first of these is the high initial costs of one to one work supervisor involvement while the second is the length of time for which work supervisor input is required, not only to initially teach the disabled person work routines, but also to maintain an acceptable level of performance over time.

One approach to the problem of maintaining consistent task performance has been to recruit the disabled person's fellow-workers to provide support to the disabled person. However, such interventions require greater-than-normal input from co-workers, focus mainly on limited target behaviours rather than on complex work routines, and are only effective if followed by intensive input from the work supervisor.

An alternative approach is the use of computer-aided programmes to facilitate occupational engagement in individuals with severe or profound disabilities [2]. Despite the effectiveness of these programmes one major drawback has been envisaged [3]: the lack of portability of complex equipment. However, the recent developments in consumer electronics have included the widespread availability of palmtop computer at relatively low prices. The VICAID (Vocational Integration through Computer Assistance for Intellectually Disabled People) is a project within the TIDE programme (Technology Initiative for Disabled and Elderly People) that aims to develop and evaluate a comprehensive system based around the use of palmtop microcomputers as prosthetic, teaching and support aids. This system will be used to support people with severe intellectual disabilities to perform complex work routines (tasks) in integrated work settings by providing a sequence of instructions as response to users keyed entries.

II. TECHNICAL APPROACH

The challenge of designing a system that should be at the same time light and small to be easily carried around,

simple enough to be operated by any impaired or non-impaired user, sufficiently robust to endure hard treatment by people with sensory or motor problems, easily expandable to accommodate different interaction devices, self-powered and autonomous for long periods of time, able to communicate or tele-communicate with other systems, powerful in terms of computation and with enough resources to support intelligent software capable of provide an adaptive prompting system is by no means a simple task that can be achieved by a simple engineering error and trial approach. A *Reference model* resulting from the merging and intersection of different requirements is a fundamental basic structure needed to perceive the best possible solution out of the ideal one as well as to design a feasible prototype in a pre-defined scheduled time. Therefore, the first aim of the engineering component of the project is to provide a common *Reference model* gathering all human factors and establishing their interrelationships with the technical constraints and possibilities. In order to do this we have structured our approach to the definition of that *Reference model* in the following three steps:

- Try to establish the major groups of requirements gathered according to their nature. The way this division is established must also imply that each of these groups of requirements may be examined and discussed separately from each other. By doing this we can envisage the different global solutions that could solve the problem when seen simply from that particular group of requirements.
- Perform a first independent analysis of each group of requirements, providing as a result the set of hardware and software prerequisites needed to answer those needs. This phase provides a first in-depth perception of the technical constraints and possibilities resulting from each requirement, its feasibility, and the level of its importance by comparing its practical need with the ease of implementation with current state of the art technology.
- Determine a *Reference model* by intercepting the different groups of requirements and their resulting hardware/software prerequisites. The interception volume will provide the guidelines for the best possible solution, eventually trimming the general ideal solution to a more simple but consistent and feasible one.

III. MAJOR GROUPS OF REQUIREMENTS

Following the approach just described, we have started by trying to identify those basic groups of requirements according to the specifications given above: they should be self-contained as much as possible, gather requirements that can be associated under a same common name and be as much orthogonal with each other as possible. This means that each group can be analysed independently from each other but that, in the end, at the

hardware and software support layer, there will be a common intersection volume able to supply an answer to most of each group's needs. As a result of this top-down approach, three major groups of requirements have been identified: *General requirements*, *User Interface requirements* and *Programmability requirements*.

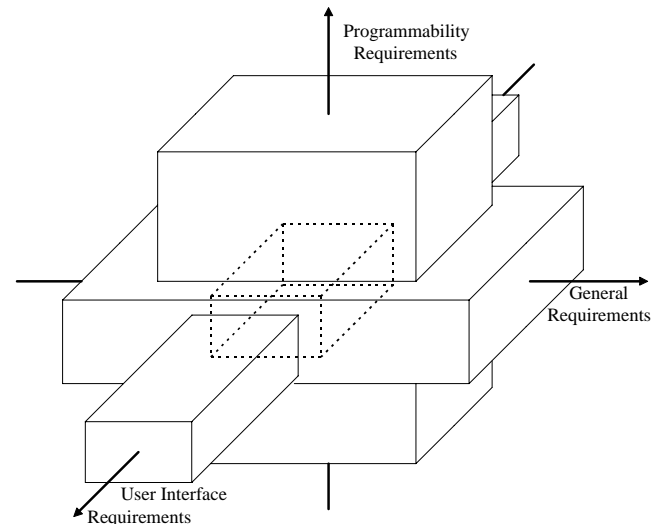


Fig. 1 - The *Reference model* definition approach.

The above described approach is depicted in Fig. 1, where each one of the requirement groups are identified as a volume centred on the origin of a three axis system. Each group, on the other hand, will grow according to one of the axis directions. Some requirements will stretch the corresponding volume away from the centre therefore reducing the intersection volume that will define the set of technical constraints of the project. By evaluating the importance and precedence of each requirement, and removing or redefining some of them, this intersection volume can be trimmed to the best compromise possible. A short description of these groups, and the current state of their structural analysis is further presented.

A. General Requirements

This first group of requirements results from previous knowledge of the problem, from the proposition of the project itself and, in general terms, from the common sense collected from the analysis of the typical constraints imposed by the virtual model of a mental impaired user working in an unidentified indoor environment. It was already clear from the project proposition that the equipment should be small and light to be easily carried around, easy to operate, self powered and robust. From the software point of view, the system should also have the capability to be adapted to new working situations, that is, it must be re-programmable and flexible enough in terms of processing power and architecture specifications to support software with different levels of complexity. The following set of requirements have therefore been systematised under this *General requirements* group,

followed by a discussion of the possible technical solutions to answer those needs:

- *Adaptability*; the system should be designed for people whose only severe impairment is cognitive. Nevertheless, it should also take into account that a substantial minority of these persons also have moderate to medium hearing losses, long or short sight that may not be properly corrected by glasses, and some problems with fine motor co-ordination. Provision for ease of adaptation to those particular cases must therefore be taken into consideration.
- *Small size (volume)*; this was a necessity from the start of the project, and the use of palmtop or alike computers has always been specified as a target objective. This requirement will naturally impose clear limitations to the integration of new, specific designed hardware, due to physical limitation of space, and will require a redesign of the traditional palmtop architecture.
- *Portability*; the equipment must be taken by the user as he/she moves around a non confined area. This also implies small size, but, most of all, it means that the equipment must not be heavy. This, again, imposes limitations in terms of inclusion of new features. We have also concluded that careful redesign of the equipment may compensate a small increase in weight by means of a more efficient way of handling it.
- *Autonomy*; the equipment must be fully operational at all times, that is, its power should not be turned on/off while moving around at the work site. Hence, solutions based on permanent attachment of the equipment to power outlets may not be considered. Ideally, the equipment should also be able to work uninterruptedly for at least eight hours (a full working day). Current state of the art palmtops support continuous work for over 60 hours. This will give us an overhead in terms of available power to integrate well designed, low power, devices.
- *Robustness*; careless treatment can most probably be expected by people with cognitive impairment. On the other hand, and at least in some cases, the environment itself may very well turn out to be hostile to the computer due to the nature of the work. Therefore, the equipment should be able to support mechanical impacts with no damage and possibly other aggressions such as liquid spill or dusty environments. The system should be strong enough to cope with a careless treatment and should present improved characteristics in aspects such as physical impact response, resistance and durability of movable parts.
- *Simplicity of operation*; being targeted at people with cognitive impairment, simplicity of use is naturally a fundamental requirement for the equipment. Furthermore, the system should not present all sorts of user's options, but a very easy user interface suitable for an interaction with a wide range of

different users. The simplest of the solutions will comprise a graphic display and some conceptual keyboard made from a small number of keys. This conceptual keyboard must take into account the lower level of recognition ability and manual precision of the potential users. On the other hand, and in order to increase its usefulness, the equipment must also be fully operational without requiring more than minor changes in the working environment

- *Expandability*; the need for interactive adaptation of software, both to different user needs and to different applications, may require different levels of hardware support, either at the CPU performance level and at the memory storage capabilities. The use of an IBM PC compatible platform has already been considered as the best approach, as this will ensure a higher degree of independence to technology obsolescence. This will also provide the simplest development path due to the large availability of low cost widely used PC compatible computers and components. The selected platform should also provide means to interface to other devices, either through serial or parallel ports, or through more powerful PCMCIA plug and play interface ports.
- *I/O devices*; A set of I/O devices independent from the standard PC compatible platform must be considered in order to enhance, complement or even substitute the hardware platform native ones by providing alternate forms of interaction both in the direction from the user to the system and in opposite direction. The aforementioned I/O devices, apart from their functional aspects, must provide an easy integration to the prototype at the hardware level.

B. User Interface Requirements

As previously stated, the potential users of computer assisted instruction and maintenance who suffers from intellectual disabilities will most probably have some kind of additional disabilities, such as some sort of physical or sensory impairments. Therefore, and due to the individualistic nature of the person involved, the design of the system should be broad enough to interact with a mixed variety of people. One should not, on the other hand, be tempted by the illusion that a universal system can be developed to answer all kinds of user needs and requirements. A well-balanced solution using a modular approach and capable of integrating different I/O devices and supporting adaptive software modules may therefore be the best approach to this question. This will imply, among other things, that an appropriately delimited target group of users should be defined, and their most significant characteristics, from the interaction point of view, be established. This specification work, as it deals with the technical integration, performed by engineering people, of the specific *User Interface requirements*, is only possible by means of a multidisciplinary team composed by engineers, psychologists, sociologists,

special education professionals and social careers. Therefore, a multidisciplinary team involving the different partners of the VICAID consortium has performed an assessment of the technical constraints, by evaluating practical options for the user/equipment interaction through the analysis of different possible technical solutions, both at hardware and software levels. As a result, several requirements were also defined for the input and output interface.

Regarding the input devices:

- There should be a total avoidance of any device that requires motor dexterity.
- The users will be allowed to interact with the system through a conceptual keyboard composed by a small number of physical keys (with a pre-defined meaning for each of them).
- The conceptual keyboard should require less manual precision and less recognition ability than a standard keyboard.
- Keys should be large and strong enough to support handling from heavy handed users.
- Both tactile and auditive feedback should be considered for the action upon the keys.
- The users must be able to provide the system feedback related with their own actions.

Regarding the output devices:

- The use of a colour display has been considered an important issue as a way of improving the capability of keeping the attention of at least some of the users.
- Sound, including voice music and audio signalling, either synthesised or recorded, should also be considered, as well as other forms of catching the user attention, such as flickering lights.
- As a consequence of the limited capacity of the user for self-decision making in situations of difficulty (when something unexpected happens or something goes wrong), the equipment must also contemplate some form of communication with the co-worker, so that he/she can be promptly notified, either automatically or by user initiative, of those critical situations.

C. Programmability Requirements

Programmability requirements emerge from two distinct needs. The first is the need to assure a modular software approach, able to be easily adapted, reviewed or updated. The second is the need to provide, at a higher level, the mechanisms that will allow the co-workers to develop the different prompt sequences, as well as to set the parameters and rules associated to each one of them. From the first of those needs, the following requirements emerge:

- Processing power must be enough to assure a response in real time to all predictable user actions. Otherwise, any delay may result in erratic behaviour of the user, due to its inability to understand why the machine does not react as he/she expects. This

requirement will have a great impact in the processor selection.

- Memory capacity must also be big enough to support all the software, and should not contribute as a bottleneck to the equipment development. This means that it should be either over-dimensioned during early project phases or the hardware platform should support memory expansion capabilities.
- Due to the resilient nature of PC based architecture, and wide availability of well-established development tools both at hardware and software level, the selection of a PC compatible infra-structure is also and clearly a requirement.

As to the second of the above referred needs, task programmability by the co-workers may very well need to be performed in a different kind of equipment. This is due to the fact that the palmtop, with its conceptual keyboard, will not provide the necessary resources to be easily used as a programming device. Therefore, task development software will be run in standard desktop PC computers, and downloaded afterwards to the palmtop. On the other hand, evaluation of both user and software performance will also imply that recorded data on task evolution will need to be transferred to a remote computer. Therefore, as a result from these questions, the palmtop based system should be able to support some form of communication with the outside world.

IV. INSTRUCTIONAL MODEL

As a mean of consolidating the main characteristics of the user interface, the above *User Interface requirements* were evaluated using a top-down approach by cross-correlating them with an *Instructional model* which is also under development [4]. The *Instructional model* defines the way the prompting sequences will be delivered to the user and how each one of the prompts will relate both to the undergoing task and to the user performance. This model includes the following basic elements:

- Instructions.
- Reinforcement.
- Instructional re-adjustment.
- Automatic prompting.
- Corrective feedback.

A. Instructions

The instructions are to be delivered to the user as a sequence of prompts. Typically each prompt, with its associated icon, will have a direct connection with a specific step of the task (e.g., "open the dishwasher door"). Prompt presentation will be made using a visual and, possibly, an auditory mode:

- Visual instructions will consist of simple pictorial images with colour elements.
- Auditory instructions will be in the form of verbal statements.

In terms of the user interaction, the user will only need a single step command to require the next instruction. This step will take one of two possible forms:

- The users will be expected to push a key to ask for the next instruction in the sequence.
- The user will be instructed to pick up some kind of small device associated with the task step he/she has completed, and to provide it afterwards to the palmtop.

B. Reinforcement

At pre-set intervals, requiring the next instruction would not show the next prompt of the job task but rather a prompt indicating that the user should contact a co-worker (the work supervisor or somebody else) to have a check on his/her work or to have reinforcement (a positive remark, a sticker or some other form of pleasant event).

When a reinforcement instruction occurs the system should:

- Present an image of the co-worker that the user should contact.
- Present complementary information such as flickering lights or sound pattern.
- Interact with the co-worker in order to inform him that a reinforcement action should take place. This interaction could be performed by either an auditory unit (through a sound pattern) or a communication link established by a radio transmitter.

C. Instructional Re-adjustment

Instructional re-adjustment aims to reduce the number of performance errors by re-organising the sequence of instructions. This results from the fact that some of the steps in the prompt sequence may be performed in one of several ways, as long as all the steps are completed. Lets take the example of figure 2. If, for some reason the user, after completing step 1, executes step 4 instead of step 2 as it should (Fig 2.a), the system may still be able to re-organise the sequence successfully by prompting steps 3 and 2 sequentially after step 4, as in fig 2.b.

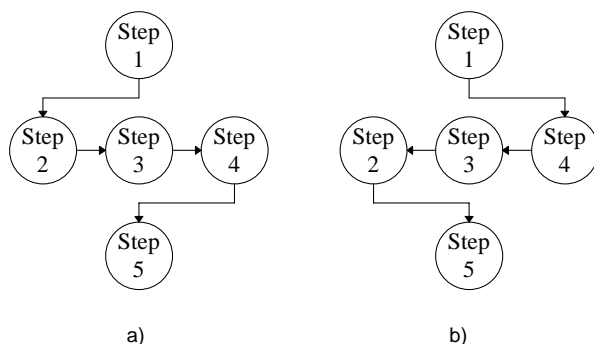


Fig. 2 - Instructional Re-adjustment.

a) Normal sequence. b) Re-organised sequence.

Steps shown in parallel can be re-organised in any order.

However, and to be aware of what have been done by the user, the system must keep track of his/her performance. This requires a dedicated mechanism that can be implemented either by using technology related with intelligent buildings or, in an ad-hoc way, by using sensors connected to the computer by some sort of radio link and differently coded for the various task steps. Both of these solutions are clearly complex and would not satisfy one of the general requirements of the system, which is to support disabled people on work settings with minor changes in the environment.

Being impossible to have a complete control of the users task performance, we should therefore consider different options where the users themselves provide the system with feedback related with their own actions. In this way the system will have a way to find out if the instruction sequence is correctly performed. In terms of user interaction this means that the user, after reading and performing the instruction, will inform the system of what he/she had done instead of asking for the next instruction. This is illustrated in the following sequence:

- The user reads the instruction from the system.
- The user performs the action.
- The user informs the system that the action has been performed.

We are aware that, by using this kind of mechanism, it is not possible to have non vulnerable communication between the user and the computer. Therefore, and to ensure the maximum success rate, special care should be taken while designing the user interface system. This system should provide not only the best possible communication, but also be very easy to learn by the user. To achieve these goals, and for the time being, the following three options have been considered:

- The user provides the computer with little self-identifiable chips related to the each one of the task steps. In this solution, providing the chip to the computer will be integrated as part of the user automatic response. The user, after performing an action, has to look for the chip related with that action. If the chip corresponds to the step that the computer has illustrated, the conclusion is that the user responded correctly. Thus the computer will proceed to the next instruction that may be a next step or a reinforcement instruction. If the chip does not correspond to the step that the computer has illustrated, the conclusion is that the user had produced an incorrect response. If such a response does not preclude the continuation of the task, the computer will provide the necessary reactions such as the re-organisation of the instruction sequence (instructional readjustment). This kind of solution requires a device connected to the palmtop able to receive and process the chips (chip reader).
- The user provides the computer with the same little self-identifiable chips but, in this case, only when instructed to do it by the prompt sequence. In this case the feedback related to the each one of the task

steps will be integrated as part of the task itself in the form of control points. This solution will simplify the practical constraints related to the strategic placement of the chips but reduces, on the other hand, the point by point control provided by the previous option with consequences at the instructional re-adjustment level.

- The user provides input to the system by selecting one out of two or three keys. It is clear, however, that a severely mental impaired user will not be able to tell the system, through variable and abstracts symbols, which activity he/she has done, as their ability to perform discrimination is highly reduced. This means that this mental model should be somehow simplified. One way of doing this is to consider that the selection will be done by means of comparison between different colours, shape or tactile characteristics associated with each one of the keys and one symbol that is drawn in the object that the user must manipulate to perform the action. In order to illustrate this let us consider the task "open the door". The user must follow several steps:
 - He/she reads from the system the action that he/she has to perform (to open the door).
 - He/she performs the action.
 - He/she finds which one of the three selection keys is associated with the symbol in the door by means of its colour, drawing, shape or tactile consistency.
 - He/she presses the appropriate key of the conceptual keyboard.

D. Corrective Feedback

The corrective feedback will alert the work supervisor whenever the user is not in the position to proceed in the task (he/she has made a mistake that can not be solved by instructional re-adjustment). This element can be implemented only if the system is aware of the users performance, which is a similar situation to the one described for the instructional re-adjustment.

The work supervisor can be alerted by the two following forms:

- The radio transmitter already introduced for the reinforcement, should also be considered to establish a communication link with the work supervisor for actions related with the corrective feedback.
- The auditory unity can be used to signal the situation (beep).

E. Automatic Prompting

The interval between two user requests (the period of time to perform a particular instruction) should not be smaller than a pre-set minimum execution time neither longer than a pre-set maximum execution time. Two different warnings should be therefore provided:

- If the interval between two user requests is smaller than a pre-set time for the particular instruction the system should not move to the next instruction but it should alert the co-worker (considering the short interval a sign of inappropriate performance).
- If the interval between two user requests exceed the maximum time allowed for that particular instruction, the system should alert the user and also the co-worker.

The first warning can be performed by using a radio transmitter, while the second one can be performed by using a radio transmitter together with the auditory unit (beep).

F. Consolidated View

Table I presents a summary of the intersection of the *Instructional model* with the *User Interface requirements* at the Input/Output devices level. Each one of these devices is evaluated in terms of need for each kind of *Instructional model* element. Its degree of importance will also be inferred in a later phase of the project to further enhance the proposed *Reference model*.

	Instructions	Reinforcement	Instruction Re-adjustment	Corrective Feedback	Automatic Prompting
Colour Display	•	•	•	•	•
Maximum number of symbols in the display	1	1	1	1	1
Next instruction key	•				
Selection keys			•	•	
Radio Transmitter		•		•	•
Beep				•	•
Sound patterns	•	•			
Flickering lights		•			•
Chip reader	•		•		

Table I - Consolidated view.

V. CONCLUSIONS

In this paper we have identified the technical approach for a definition of a *Reference model* that will support the development of a palmtop based system for vocational integration of intellectually disabled people. By using a volume intersection model and a systematic process analysis the major requirements of the system were identified. These requirements have been gathered into three different groups: *General requirements*, *User Interface requirements* and *Programmability requirements*. An independent analysis of the *User Interface requirements* group has been performed by cross-correlating them with an *Instructional model*, which is also under development.

Based on the presented work, several technical solutions were identified and are currently under discussion, which will lead to the implementation of a first prototype of the system. This prototype will be evaluated in a laboratory environment (University of Leiden) during the second trimester of the next year. The result of this evaluation will be used to trim both the prototype and the

Instructional model resulting in the final system, which will be introduced in real life situations both at Leicester (Work-Place of Leicester) and Lisbon (Faculdade de Motricidade Humana) during the year of 1997.

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