ITACTI

IST - 2001 - 32240

Smart Interactive Tactile Interface Effecting Graphical Display for the Visually Impaired

DELIVERABLE D7.4

Final Report

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Project Co-ordinator: De Montfort University

Partners: Smart Technology Group Limited (SMART)

Kaunas University of Technology (KUT)

Metec Ingenieur-AG Medizintechnik-Feinwerktechnik (METEC AG)

Associazione Nazionale Subvedenti (ANS)

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1.0 Project Overview

Contract IST-2001-32240 ITACTI was signed by the commission in July 2001. The starting date was set at 1st August 2001. Amendment No 1 to contract IST-2001-32240 ITACTI was effected as from 11th March 2002. Amendment No 2 to contract IST-2001-32240 ITACTI was effected from 6 July 2004. Amendment No2 provided for an extension of the duration of the project by 6 months thus effecting a project duration of 42 months moving the completion date of 31st January 2005.

1.1 Description of Consortium

Partner 1	De Montfort University[1]	(DMU)
Partner 2	Smart Technology Group Ltd[2]	(SMART)
Partner 3	Kaunas University of Technology	(KUT)
Partner 4	Metec Ingenieur-AG, Medizintechnik	(METEC)
Partner 5	Associazione Nazionale Subvendenti	(ANS)

Subcontractor	Royal National Institute for the Blind Vocational College, Loughborough[3]	(RNIB)
	ENEA[4], Italy	(ENEA)

[1] Coordinator
[2] Technical Coordinator
[3] Subcontractor to De Montfort University
[4] Subcontractor to ANS

1.2 Financial Arrangements

Monies have been expended as per the contract including amendments to contract as mentioned above. All queries from the Project Officer relating to cost claims were reconciled in every instance. In a similar manner all requests to the Project Officer for the virement of funds were accepted and agreed in every instance.

Indicative funding made available for the project amounted to €1,941,809.

1.3 Coordination

Coordination of the project has been undertaken by DMU. Subsequent to each review there has been acknowledgement of good management practice in the undertaking of the coordination. Scientific coordination was undertaken by SMART.

Fourteen Quarterly Management reports have been submitted to the Project Officer covering the period 1st August 2001 to 31st January 2005.

Ten meetings of the ITACTI Consortium have taken place commencing with the first in early September 2001 and culminating with the final meeting in January 2005-06-12
The Project Officer invited the ITACTI consortium to three review meetings, all held in Brussels. The third and final review meeting was held in March 2005 a few weeks after the official end date of the ITACTI project. An outcome of the final review was that further unfunded work on the ITACTI project was agreed

1.4 Background to Project

The members of the ITACTI consortium came together to develop a system, multimedia peripherals and innovative personal devices for blind and visually impaired, enabling such persons to use the IT recourses including accessing the Internet . The intended project was to be focussed on innovative aspects in the novel devices to be developed which would lead to a new type of array manipulator and tactile sensor and services allowing active internet use for the blind and visually impaired.

2.0 Objectives for ITACTI

- The needs of the visually impaired community with respect to improved access to information technology resources will be researched in detail. The results will be used to design a specification for the development of a new interactive tactile interface.
- A new interactive tactile interface will be developed using advances in the application of smart materials technology. It will be a large rectangular array of controllable dots which may be raised or lowered under the control of a personal computer (PC) with touch sensitive feedback.
- Control electronics and driver software will be developed and fully documented, such that it may be easily integrated into applications by third party software developers.
- To develop software to display information in a tactile form, and demonstrate how the clarity and utility of IT resources have been improved for the visually impaired.

2.1 Description of Work

An investigation of the information needs of the visually impaired and as to the shortcomings of existing technology was undertaken. Subsequent to the investigation a full device specification was developed that covered safety, quality, electromagnetic compatibility and cost targets. This specification was used to steer subsequent work packages towards maximising the benefits brought to end users by the developed technology.

Research was then conducted into the best route to the production of an actuator array suitable for use as a tactile display. Full assessment, in terms of ability to meet the defined specification, of three potential technologies was made.

An actuator was built using the chosen technology, based on electro-rheologic fluid (ERF). The developed device was relatively uncomplicated to manufacture. It was shown to be capable of providing a controllable array of ‘dots’ with interactive touch sensitive feedback.

Control systems and support software have been developed. The latter has provided image and information processing software in a form suitable for the tactile device. A functional set of software tools have been developed that facilitate control the tactile interface.

Integration of the array, control systems and support software into a system has been achieved. The system has been housed in an aesthetically pleasing and ergonomically functional enclosure. The development route to a fully functional device included the development of a single Braille line display which allowed many functional and operational requirements for the full device to be developed, tested and evaluated. A completed prototype has been delivered. The software tools have been used for web access and document display software has demonstrated certain of the uses for the developed device.

Design verification and evaluation have been undertaken by a small representative group of end users.

3.0 Approach

The technology to effect a large array device comprising of many thousands of Braille ‘dots’ is constrained only by cost per dot. Current technology for effecting a positive (‘dot’ raised) state of a Braille dot in a tactile display is based on piezo-electric actuators. Piezo–electric driven actuators are based on well established technology that produce reliable actuators that can operate effectively over many millions of cycles. The manufacturing process for the production of piezo-based actuators is now well established technology with few problems for the specialist manufacturers of such actuators.

There is a problem with piezo-actuators in that to build an equally spaced array, with the same spacing between ‘dots’ on the X-axis as the Y-axis, is technically most difficult as the piezo-actuator has a cross sectional area which will not allow ‘spacing’ along both axes that will permit a sensible, in standard Braille terms, distance between ‘dots’.

The main problem with piezo actuators is their cost per actuator, thus for arrays comprising many ‘dots’, a 128*64 array has 8192 ‘dots’ (if it was possible to build) , would be over €50,000.

Many attempts to develop usable technology that can effect the movement required for a positive ‘dot’ have been recorded in the technical press but before the ITACTI-project started no reliable, cost effective technology has been brought from the research laboratory to the marketplace.

Current Braille displays typically display one line of text at a time and a page is read by pressing buttons to navigate between lines or pages. Thus such devices are restricted to Braille text display only. In order to display tactile diagrams, a tactile printer can be used. Tactile diagrams cannot currently be output in real time. There has been reported recently a haptic device that offers a force feedback system to ease the use of graphical operating systems in place of a mouse.

Devices have been produced which operate in permanent contact with the skin. The VISIO system produced by ENEA has 400 servos that mechanically stimulate the skin in an analogous way. This system has shown that it is possible to represent simple graphics to the visually impaired. There is however a trade off between resolution and costs and at 2000-point resolution is currently the most optimum in terms of cost v benefit.

ITACTI set out to produce a tactile display with 128*64 (8192) ‘dots’ an order of magnitude improvement in resolution.

From the outset the technological approach was targeted towards the manufacture of an actuator array which used electro-rheological fluid (ERF). In this device a master actuator provides an increase in pressure in the fluid that is sufficient to generate the force that will cause individual pins, in an array, to rise from a negative state, ‘dot’ not discernable to the touch, to a positive state, ‘dot’ discernable to the touch. The generation of an increase in pressure in the ERF would without the ability to control the force acting on each individual pin cause all pins to rise. The control of pressure to an individual pin was therefore the second key goal of the approach.

In simple terms the approach employed the concept of ERF as an hydraulic medium and a control valve for each ‘dot’ in the array. A master cylinder generates a controlled pressure rise in the ERF. The ‘dots’ are small diameter plastic pins that can be raised and lowered through the change in pressure in the ERF and the state of the valve corresponding to each pin allows the pressure to be applied, or not applied, to a pin. The valve makes use of the properties of the ERF. When a voltage is applied to an ERF its viscosity increases and thus given sufficient voltage an ERF can effectively become frozen. When the ERF in a particular valve is charged with sufficient voltage it ‘freezes’ and thus the pressure on the pin is not sufficient to cause it to rise.

The ability to address a sufficient change in voltage to cause the ERF to freeze in each individual valve creates the situation where an individual pin (‘dot’) is either raised or lowered on each change in pressure of the ERF. The approach therefore delivers an ability to control each individual ‘dot’.

The approach adopted for the second challenge for the ITACTI project, to develop control electronics and driver software to operate an array device using a PC computer was to utilise known technology. Drive electronics for the array suitable for addressing (de-multiplexing) the signals and directing them to the correct pins was required, additionally there was a necessity to provide a suitable interface to communicate with the PC. The development of command protocol design was the approach such that representation of images, text and single pixel display commands could be output by the information interpretation software and received by the driver software. The driver software was to be designed to have the capability to interpret these commands and write data to the output ports of the computer as appropriate and also to receive input from the touch sensor. Simultaneous use of the developed array with other peripherals, such as a tactile printer, would be facilitated by the separation of driver and applications software and adherence to standard Windows programming conventions.

The third challenge was to present images in a tactile form. It was planned to develop a suite of software based around the TAWIS (Tactile Windows) screenreader for graphical Braille arrays developed by Metec. TAWIS which has many functions to drive Braille arrays with a command line interface was to be enhanced with new functionality. This would provide ITACTI with an ability to convert images in common graphics format to be suitable for tactile representation.

4.0 Project Results and Achievements

4.1 Scientific/Technological Quality and Innovation

ITACTI objectives are:

- *The needs of the visually impaired community with respect to improved access to information technology resources will be researched in detail. The results will be used to design a specification for the development of a new interactive tactile interface.*

This objective was fully achieved. An extensive survey of existing accessibility equipment and competing technology was undertaken. A prospective user survey was designed and user groups in two countries were surveyed for their opinions and responses were gained as to the developed specification. Standards relating to electrical safety and EMC requirements were identified such that manufacturability could be achieved so as to allow conformation with all standards and guidelines applicable within the EC. From the above work a specification for a device that will enhance accessibility of IT applications to the visually impaired was developed.

The specification defined a device that would possess many key innovative features to any device that was currently available in the marketplace.

The innovations include:

The indicative cost per ‘dot’, indicated that an array device could be developed that would be at an affordable cost to the user.
Development of an array with 128*64 individual actuators at a 2.5 mm pitch giving a total usable are of 320 * 160 mm
A maximum refresh rate, to refresh all 8192 ‘dots’, within 10 seconds with faster refresh by way of intelligent refresh for partial refresh.
Touch sensitive feedback at an individual Braille cell level (2*4 ‘dots’).

- *A new interactive tactile interface will be developed using advances in the application of smart materials technology. It will be a large rectangular array of controllable dots which may be raised or lowered under the control of a personal computer (PC) with touch sensitive feedback.*

This objective has been fully met. A large rectangular array of 128*64 controllable ‘dots’ that can be raised or lowed under the control of a PC has been developed. The developed interactive tactile interface is based upon advances in the application of a smart material, in this instance electro-rheological fluid. The development has resulted in an array that promises an affordable cost per ‘dot’ to a typical user.

Initially a 3*3 pre-prototype array was developed that enabled the design parameters, such as the required voltage level to effect sufficient loss of viscosity of the ERF in an individual valve, to be established. Additionally, process methodologies for the various components within an array were iteratively evolved to effect ease of manufacturability. The process to facilitate the metal coating of the inside of an array of small holes, each 1.8 mm diameter and 10mm length at 2.5 mm pitch, was developed. The pre-prototype development also allowed for suitable material specification for all element of the large array to be established with confidence. The performance of the chosen materials was tested in terms of functionality, resistance to ERF and serviceability over a simulated six million cycle lifetime of use. The material specification, and serviceable life, of the membrane between the ERF and the cylindrical pin was fundamental for pre-prototype success.

A second - pre-prototype 128*4 single Braille line array was designed, built and tested to gain further knowledge and practice of the operation of an array device based upon the use of ERF fluids. The 128*4 array also allowed for the electrical and electronic systems to be tested and further refined as required. A fully functional interface between the array and a PC allowed for Braille text to be displayed on the line array and for certain elements of the control software to be evaluated and modified where necessary.

A full 128*64 prototype array was manufactured based on the outcomes of the pre-prototype development and testing. Several major technological challenges were overcome to effect the realisation of a working array. Not least the significant improvement in the formulation and operation of ERF fluids in small cavities and at the required short on-off (cycle) times. The development of a new range of ERF fluids that have a capacity to work in small cavities at rapid cycle rates was the key factor for the success of the ITACTI project. The full prototype was electrically tested and fully interfaced so as to be under the control of a PC.

The innovations include:

The formulation of a new range of electro-rheological fluid in terms of operational performance in small cavities and with respect to cycle time.
Enhanced understanding of the control of an ERF with respect to the effect of time response on the fluid in short time cycle operation.
The use of the new knowledge concerning ERF fluids to effect a usable and functional large tactile array that is interfaced to a PC for control.
The development of a full 128*64 array for use as a tactile display device by blind and visually impaired persons.

- *Control electronics and driver software will be developed and fully documented, such that it may be easily integrated into applications by third party software developers.*

The electrical drive circuitry was developed based on the results of the 3*3 array development. This allowed a forecast of the required consumption of a 128*64 array to be deduced from measured experimental data. The power requirement to effect functional operation was shown to allow an operating voltage well within defined safety standards.

A one-chip solution was used as the interfacing technology as it afforded a compact, flexible and cost effective solution to handle the low-level protocol. Such a technology solution also provided sufficient power to control all identified functions. The selected interface controller was constructed on a purposed designed printed circuit board that provides flexibility for the current suite of functions and for the development of future functionality. A device driver has been developed that will work on existing and future Microsoft operating systems. The methodology chosen uses the Windows Driver Model and is independent of interface technology. Application specific code to handle the driver protocol has been developed. The developed driver protocol can handle all device communication necessary for the defined functionality.

An ‘Application Programmable Interface Developers Users Manual’ is available to allow third parties software suppliers to interface to the developed large array device.

The innovation includes:

A universal interface to the large array that is flexible and allows for ease of future development.

- *To develop software to display information in a tactile form, and demonstrate how the clarity and utility of IT resources have been improved for the visually impaired.*

A suite of software based around the TAWIS (Tactile Windows) screenreader for graphical Braille arrays developed by Metec’s Fiedrich Luthi has been utilised for use with the large array. TAWIS has many functions to drive Braille arrays by way of a command line interface and was enhanced with new functionality. This provides ITACTI with an ability to convert Window’s Graphical User Interface to a suitable tactile representation on the array. Standard graphics can be displayed, and several options of representations are available.

Testing and evaluation of pre-prototype ITACTI tablets has been undertaken. A composite evaluation plan has been developed to provide a benchmark for testing. A refined subset of the evaluation plan has been applied and testing and evaluation, in a controlled environment, undertaken by a number of screened 'users'. Evaluation has been carried out by expert evaluators including ITACTI consortia personnel allied to the intended user community and from the technical partners. Important information concerning the performance of pre-prototype ITACTI tablets has been gained from the testing and evaluation. A potential for further development has been demonstrated to exist and knowledge as to the required advances, so as to allow realisation of an operational 'consumer-user' tablet, has been established.

The ITACTI tablets subjected to testing and evaluation have demonstrated that its performance complies with the agreed specification.

- Braille text can be displayed in a state such that competent Braille readers can read the displayed text.
- When used to display graphics the device is able to display raster images using any number of the pins available.
- Graphics images generated by way of external PC based software can be displayed on the tablet.
- The maximum refresh speed is less than the pre-specified rate of 10 seconds.
- Users found the tablet to be a flexible graphical display comprising a large display that can accommodate both graphics and Braille and its realisation was judged to have exciting potential.
- Touch position accuracy has been shown to be equivalent to one finger width.

However there are still some technical problems that could not be fully solved within the project. The performance of the device will be vastly improved with further development of the ERF and finding more suitable components.

4.2 Community Added Value and Contribution to EU Policies

The ITACTI project addressed the fundamental problem of providing user-friendly, readily acceptable access to graphical operating systems and the application to the visually impaired user community. A PC compatible tactile interface peripheral device has been developed that engenders a greater state of inclusion for persons who are blind or with poor partial sight to the activities and benefits brought about by current information technology and the advances being made as Europe advances towards the Information Society.

Community Added Value occurred at several identifiable levels.

1. The further harvesting of technological development that emanates from a previous successful EU funded project.
2. Inclusion of scientists and engineers from a then candidate member state in the project consortium.
3. Harnessing of knowledge developed and residing in the former Eastern block to effect a wider European benefit.
4. The forging of a consortium on a European scale that not only has technological and entrepreneurial capabilities but also is representative of the pan-European visually impaired community, and thus has available the experience and understanding of the problems experienced by this sector of the population from several member states.

5. The realisation of a tactile interface peripheral for blind persons has placed Europe in the position as leader in the supply of PC compatible peripheral aids for the visually impaired.

With respect to the first three points above, the foundation of the of the technology being harnessed to push forward the technological breakthrough required to effect the tactile interface peripheral stems from the successful Copernicus project Smart Piezo-electric Multi-degree of Freedom Actuators (SPA). Three consortium members of that project were partners in the ITACTI project, one of these being from the now member state, Lithuania. All three have exploiting the results emanating from SPA. There was also added value though the harvesting of technological expertise and knowledge that stemmed from the former Soviet Union.

In relation to the fourth point then the diversity of the various national approaches towards training and education, and the generating mechanisms behind inclusion of blind persons into the wider society within the member states, presented a situation that required a pan-European approach where the various national nuances were be fed into the consideration and experience pots as the research programme progressed. Further, and of primary importance, was that the concept of a tactile interface peripheral for blind persons required a project on a European scale in order to represent the full scope of required technology, users and suppliers across several industries. The European-wide expertise of the project consortium was essential to generate results applicable at a European level.

The project consortium with members from Italy, Germany, the UK and Lithuania were well balanced and highly qualified to undertake the tasks at hand. There was good representation of end users: associations for the blind, including a vocational college for blind persons, research expertise within university based research institutes and industry, combined with participation of industrial partners that had both expertise in the design, manufacture and marketing of Braille devices, and a good track record of exploiting the outcomes of previous research projects. Further added value has come by way of technology transfer from the research institutes to the industrial partners

There are various national and international standards relating to Braille and other representations of the alphabet, such as the Moon system, which allow visually impaired persons access to the written word. There are evolving standards at the national level as how to divide multiple software layers. However, there are currently no standards as to the representation of a graphical display in a tactile manner. There is work in the area of tactile graphics that uses edge detection algorithms. The realisation of the Tactile Interface Peripheral has promoted a move towards defining the functionality of the developed processing algorithms such that all Tactile Interface Peripherals will display the same tactile image of the graphic in question. Thus, an opportunity has arisen Europe to take the lead in the development of minimum, measurable, open accessibility standards for hardware, software, operating systems and navigation tools as an integral part of generic products to cover the visual impairment market. The availability of Tactile Interface Peripheral has allowed, for the first time, the instantaneous display of information in a two-dimensional form, for instance work sheets from Microsoft Excel. The interface has exceeded the capabilities of existing products by a considerable margin in the amount of information to be displayed at one time. The limited in resolution is controlled by technical constrains, i.e. the smallest feature size that can be detected by the human finger, and the need for compliance with the Braille standard spacing of 2.5mm for the dual function of displaying graphics and multi-line text. It is also limited in overall size by constraints of ergonomics and portability. Considerably more value for money is offered to the visually impaired over existing systems, and the introduction of albeit simple graphics has shown that great benefits in terms of presenting graphical information is now available. The interactive dimension will greatly increase the rate of information throughput between machine and user.

Amongst the raft of EC policies some are directed towards a “Better Quality of Life”, “In Support of Employment” and against “Social Exclusion.” The development of the Tactile Interface Peripheral has, for blind and visually impaired persons, facilitated a probability of an acceleration of implementation of such policies by providing the means whereby persons with visual impairment can fully participate in Information Society thereby enhancing their quality of life, providing more opportunity for employment and the promotion of social inclusion rather than exclusion.

The market for IT related products for the visually impaired falls into the following categories – keyboards, haptic mouse systems, optical character recognition, personal data assistants, refreshable Braille displays, screen magnification, screen readers, text-to-speech systems, voice recognition systems and word prediction. The Metec and KGS Braille cells are market leaders and are incorporated into several OEM products. Australia has several niche companies that use the Mitsubishi cell. The US has several companies involved in refreshable Braille display systems. There will be community added value in terms of a profound European presence in the refreshable display market with this product that cannot be matched technologically by any current system.

4.3 Contribution to Community Social Objectives

Europe has become an “Information Society” and it is widely recognised that it important to make it accessible to all people. The Information Society is typified by the widespread use of electronic services by the citizen. It has been EC policy, and individually in member states, over several years that public services use e-documents and move towards e-administration. A consequence of electronic services is that there is a significant possibility that blind and visually impaired persons will be excluded from such services due to the complexity of translating the e-service into a service that the visually impaired citizen can access. Take for example the increasing number of public access points to the Internet through libraries, community centres and Electronic Village Halls; these have led to the idea that information is more accessible then ever before. Many information services, ranging from the Citizen Advice Bureau to Tourist Information, are now developing the use of Internet points as the 'first point of contact'. Theoretically this will improve people's access to information and allow them to make informed decisions, yet access for visually impaired person has been largely ignored. Further, in the commercial world, whether it comes in the form of on-line shopping/internet purchasing or tourist information, e-services have mushroomed over the recent past and continue to grow.

The development of a Tactile Interface Peripheral has provided a significant advance in a visually impaired person’s speed of acquiring and then ingesting information. At present visually impaired people are at a comparative disadvantage, particularly in an environment of information overload. The introduction of Graphical User Interface (GUI) has in many cases not taken account of the accessibility needs of blind or partially sighted people. The Tactile Interface Peripheral has provided the situation where the design of web pages and other sources of information do not now pose a problem to the visually impaired. Assistive technology, such as the Tactile Interface Peripheral, has provided the facility to efficiently access information from the Internet, overcoming some of the ‘access to information’ barriers that visually impaired people face in an information world previously dominated by print. The developed

Tactile Interface Peripheral now has the potential to be of tremendous benefit to blind and partially sighted people in relation to enhancing the home shopping experience as it will tell one in advance, the stock the shop holds and has on offer. Many older blind and partially sighted people have mobility problems and find it difficult just to get out of the house. The convenience of home shopping for sighted people has the potential to be transformed into a significant improvement in standard of living for the visually impaired.

In addition to the benefits associated with the 2-dimensional presentation of information, the introduction of interactive tactile graphics has increased effectiveness in the place of work and in the classroom. Tactile graphics currently produced on microcapsule printers are used to illustrate mathematical functions, assist in the understanding of the geometry, statistical functions and process flow. These are examples where fine resolution of the device is not required, and yet no medium can portray this information other than tactile graphics. Animation, and interactivity with PC can introduce new and more effective methods for presentation of this sort of information. It is understood that persons who have been sighted at some time in their lives will often have familiarity with similar diagrams and will have little difficulty in interpreting this information. There is however likely to be a little more inertia to be found in persons who have been blind for their whole lives, but it has been found that following a short amount of familiarisation and training, they also can enjoy the benefits of tactile pictorial information.

The availability of the Tactile Interface Peripheral will stimulate greater employment opportunity. Visually impaired persons will be able to carry out tasks for which they previously were ill equipped, and sometimes, could only be performed inefficiently. Take for example the efficiency rise of a visually impaired person analysing a data cell presented in a spreadsheet, the Tactile Interface Peripheral will allow presentation of whole sheet information rather than by the limited individual line or column. The time taken for comprehension of the contained data will diminish considerably and understanding will be at a level previously difficult to obtain. Thus, comparative, and effective, efficiency will rise and any associated concerns of a potential employer as to the suitability of a visually impaired person's ability to perform will become unfounded.

Probably more important is that visually impaired persons will be able to undertake occupations previously denied to them. Take for example web design – a previously difficult task for a visually impaired person. With the use of a Tactile Interface Peripheral the design of the web page is made more accessible. The designer can feel the layout, has recognition of the available two-dimensional space such that the elements within the design can be strategically, if not aesthetically, placed. Drop down menus can be designed and tested. These simple examples show how employment opportunities will be greatly increased.
In the above paragraphs contribution to Community social objectives have been identified in relation to the Quality of Life, Support of Employment and Education and Training. The cited examples and evidence illustrates how the development of the Tactile Interface Peripheral will make a key contribution towards implementing those policies for the visually impaired.

4.4 Economic Development and S&T Prospects

The aim of the ITACTI project was to develop a novel interactive display that facilitates access the modern IT world for the visually impaired people. Graphic user interfaces for PCs and almost all types of modern communication are new used widely. Unfortunately a segment of the society has not been able to make use of these useful tools due to the previous limitation of the current technology.

This new development will make it possible to further integrate the visually impaired population into the Communication Society, enabling their access to e.g. Internet pages by offering a much better and natural display.

There are few methods to present information to the visually impaired community, but we believe, the most effective route to pursue would be the use of Braille to interface to the computer. Today, available piezo-activated displays are very expensive due to their complexity. Therefore they are unaffordable and unsuitable to meet the expectations of many due to their limitations. The manufacture of these devices is time consuming and requires skilled labour, and expensive parts. The production cost of a standard Braille reading line (Braille cells only) today is approximately € 3.4 per dot and for a matrix display is about € 4.0 per dot.

The new ITACTI interactive tactile display makes use of operating principles that allow production techniques until now not applied to the production of such displays and more common to the electronics industry, where large quantities can be produced at reasonable cost. This is allowing the development of a completely new family of access devices, starting with standard Braille displays up to screens of 128x64 dots to show graphic structures.

It is estimated that the production cost per dot, with the new technologies, is below €2. A Full page (128x64) is looking as though it will cost below €20,000 (Compare this to ~€ 10,000 Euro for an 80-character-Display with only 640 dots), giving much more comfort in handling and presenting much more information to the user than a single Braille-line ever could do.

The manufacture of the displays and of the basic software is to be undertaken by the industrial partners of the consortium, Smart Ltd and Metec AG. Since mass production technologies are used there will be a reduction in the production cost. It is planned to concentrate the production in one or two places to reach the necessary quantities. An agreement between the partners has been reached to maximise the benefits of this research.

The integration of the newly developed tactile display is shortly to become available to interested organisation as on OEM device to ensure that much wider use of the technology.

Following the conclusion of the project, it is planned that there will be further incremental design improvements that were regarded as being outside of the scope of the project and are subject to market demand and technical feasibility. The following are foreseen as possible future developments:

- Introduction of wireless (bluetooth) or infrared communication between peripheral and host
- Integration of interface and PC into a single self contained unit to improve portability.
- Porting all software to other operating systems.
- Development of low power smaller devices suitable for portable use analogous to personal organisers, pagers etc.

The extent to which this new device can be used with software applications is dependent on the quality of the documentation and the availability of software functions suitable for driving and controlling the device. For this reason, a software library has been produced This offers a rapid development route for third party software developers to write software specifically for use with this device, or to integrate it thoroughly into their existing applications. The advantage of producing a library rather than operating an open source policy is that the software is designed for incorporation into generic products, and the consortium can maintain control of the intellectual property arising from the software development.

There has been targeted dissemination of results and this will now gather momentum The industrial partners are at the decision point as to whether to file provisional patent applications on the developments. The TIP sets out the development of the IPR portfolio.

The consortium IPR agreement has set down the ground rules covering the sharing of information and ideas. Since there is no core competition in the consortium each partner has a market for exploiting their intellectual property; their tasks have been agreed so that each owns the appropriate know-how. It is planned that the IPR generated during the project will be licensed for use in connection with and during the project to other partners without charge, and subsequently at market rate. The agreement sets in place procedures where in the event that any partner does not wish to protect the knowledge they have developed, the project manager will be free to seek appropriate protection. No partner shall unreasonably withhold technological information from another that is needed to meet the objectives of the project, subject to the consortium agreement governing, A consortium IPR agreement is in place

5.0 Deliverables and other Outputs

5.1 List of Deliverables

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D7.5-15	QMRs	

Major Deliverables

D1.1 Device Specification

Probably the most important deliverable that set out a full design specification for the device based on research as to what existed in the marketplace and the technology choices that were pertinent to take forward.
The deliverable reports on an extensive survey of existing accessibility equipment and competing technology. The shortcomings of existing technology was identified and the conclusions drawn. A user survey was designed and user groups in two countries surveyed for their opinion on the existing available technology. Standards relating to electrical safety and EMC requirements were identified. A full specification fro device that will enhance accessibility of IT applications for the visually impaired was set down. The deliverable contained several annexes appertaining to the surveys undertaken.

D2.1 Pre-prototype assessment and working specification of drive circuitry

The deliverable reported on the completion and demonstration of a 3*3 array prototype based upon the technology appertaining to the ERF valve. This enabled the development of the specification for the required electrical circuitry. Experimental assessment of the 3*3 array pre-prototype yielded information that was used to calculate the electrical characteristics of a full sized (128*64) ERF valve matrix. The developed specification was used for the development of electrical drive circuitry for the 128*64 array.

D3.1 Documentation of hardware interface

A comparison of possible IBM PC interfaces was made and a suitable interfacing technology was chosen according to a developed list of criteria. A one-chip solution was identified as being compact, flexible and cost effective enough to handle low-level protocol for the chosen interface as well as having sufficient power to control all envisaged functions. A board was designed based on the selected interface controller. The designed layout of the board provided sufficient flexibility for the necessary functions and for future tactile products. The existing interface protocol was analysed and a suitable method to progress was deducted.

D4.1 Document of driver protocol

The driver protocol has been fully documented and an Application Programmable Interface Users Manual produced. The Tactile Driver Application Programming Interface has been written in ANSI C. The driver is presented as a Dynamic Link Library (DLL) containing ANSIC compatible functions. The driver acts as a layer between a Windows (USB) device driver and a user application. Both the tactile driver and the device driver will support plug and play (PnP). The Windows PnP feature enables the user to plug-in and unplug the tactile array whilst the computer is powered on and running. The PnP devices need to be configured only once the first time the operating system recognises it. The driver communicates with the tactile array and the user application without altering any data. The supplied data is copied directly to the device and thus the device display looks identical to the original data.

D2.2 Demonstration of completed actuator arrays

The second level of pre-prototype developed was a 128*4 line actuator array. The 128*4 was used to validate the design features of the chosen technology. The experimental assessment of the pre-prototype device allowed the identification of remaining weaknesses in the design and technology used and therefore provided a vehicle for purposeful development of the 128*64 full actuator array. The 128*4 line actuator array was demonstrated, and shown to be working effectively, at the third review meeting in Brussels.

D3.2 Demonstration of completed electronics interface

A precursor deliverable (D3.1 Documentation of Hardware Interface) had provided a comparison of PC interfaces and a one-chip solution was chosen such that the identified criteria of operation could be met. The one-chip solution provides a low-cost, compact, reliable interface and also allows control of every defined function. The developed driver is compatible with current and predicted new Microsoft operating systems. The interface electronics as an integral component of a 128*4 actuator array was demonstrated, and shown to be working effectively, at the third review meeting in Brussels.

D4.2 Demonstration of completed driver software

The driver Software provides the communication link between the PC and the tactile device and actually translate the PC – output into steering commands of the display. It was demonstrated at the second project review meeting.

D5.1 Demonstration and assessment of self contained peripheral

D5.3 Demonstration of completed application software

A demonstration of the TAWIS (Tactile Windows) driver software was made at the third project review meeting. The programme development for the TAWIS software package was undertaken by Metec's Friedrich Luthi. His expermintal workbench included an old expensive tactile display produced by a consortium partner in the 1980's and where appropriate standard Braille line.with a command line interface and the basic functions were demonstrated on a display screen of 128 x 54 pixels corresponding to the ITACTI Full Page display unit which was not available when demonstration took place.

D2.3 Device Performance and Operation

Report which summarises the operation of the 128x 64 device and its performance

D6.1 First feedback report

Experimental work was undertaken to verify the performance of the pre-prototype and assess compliance with design targets and quality standards as defined in deliverable D1.1. Performance and utility of the prototype was assessed to provide confirmation of the functionality of the software, where the performance specification was not met refinement of the applications software was undertaken to correct shortcomings. The preliminary testing of the 128*4 actuator line array was subjected to testing by a number of different users and performance was found to be satisfactory. Some development of certain technical aspects of the array was identified as being necessary.

D6.2 Second feedback report & D6.3 Technical verification report

A composite evaluation plan has been developed to provide a benchmark for testing. A refined subset of the evaluation plan has been applied and testing and evaluation, in a controlled environment, undertaken by a number of screened 'users'. Important information concerning the performance of pre-prototype ITACTI tablets has been gained from the testing and evaluation. A potential for further development has been demonstrated to exist and knowledge as to the required advances, so as to allow realisation of an operational 'consumer-user' tablet, has been established. Evaluation results were listed including;
Braille text and graphics can be displayed on the tablets. Refresh speed is better than the pre-specified rate of 10 seconds. Touch position accuracy has been shown to be equivalent to one finger width

D8.4 Technical Implementation Plan

A report lists the existing devices which the ITactI product range will be competing with. The market size and potential market share are considered. A clear route to the market is described. A marketing study in four European countries is reported. A marketing strategy is developed including the establishment of a network of value added resellers. The plan also discusses the pricing of the product range and how training, and technical support would be conducted.

5.2 Technical Achievements and System integration:

In summary, the system development can be broken into six specific parts :

A: ER Fluid valve matrix.
B: High voltage driver and control circuitry.
C: Driver Software.
D: Application Software.
E: Touch sensitive feedback
F: System Integration

A: ER Fluid valve matrix

Comprises ER fluid, pump, fluid communications, ER valve matrix, tactile pins, membrane and electrical connections:

- Low voltage (< 400V) ER fluid comprising micrometre sized particles suitable for use in small gaps was developed. A composition that showed sufficiently low power consumption for efficient operation was developed.
- A pumping method and equipment was developed suitable for integration into a compact peripheral.
- Pressure and flow requirements needed for the device were modelled and calculated.
- A suitable ER valve configuration was identified and suitable geometry was designed.
- Manufacturing methods and materials were identified for use with ER fluid s.
- An intrinsically safe design suitable for use in this environment was developed.
- Prototype single-line and full page devices were produced.

B: High voltage driver and control circuitry.

Comprises High voltage circuitry suitable for driving the display, multiplexing control, development of high density, high voltage power supplies:

- A multiplexing technique such as that suggested by Fricke [] was realised.
- Low cost, high-voltage multi - channel circuitry that could reliably drive an ER valve array was developed. Such circuitry addressed multiple challenges including that of high speed operation, and protection in the event of electrical arcing and current surges.
- A microcontroller system for control of the device including real time pressure control and USB communications was developed.
- A dual tracking low cost high voltage power supply with inbuilt arc protection was developed.

C: Driver software:

- A fully documented device driver and application programming interface (API) was developed for use with the device as described in B.

D: Application Software:

TAWIS was developed that offered a means of accomplishing the tasks required of WP5. This has been documented and demonstrated.

E. Touch Sensing Feedback.

Recently available conductive polymer coating formulations originally designed for EMC protection were employed for the development of a novel touch screen. The screen could be applied either by a simple spin-coating or painting procedure in two stages. Firstly a conductive polymer base layer was painted on to the top surface of the device and electrical contacts were made at the periphery using gold plated contacts. This layer is comprised of water soluable compounds, and is designed to be resistive. The second layer to be applied consisted of polystyrene dissolved in a suitable solvent such as petrol, acetone or xylene, which was subsequently painted onto the surface to ensure electrical insulation and environmental protection.

A low voltage alternating current (<10V ~5kHz) is then passed through the electrodes in various permutations to identify any capacitive earth leakage due to the presence of a human finger, and the position of this earth leakage is deduced. This system allowed the identification of the position of a finger to within 5x5 tactile pin spacing.

F. System integration.

A to B:

Fully integrated tested. The driver circuitry was shown to control and drive the valve matrix and provide enough power to drive a 128x64 array filled with ER fluid.

B to C:

Control of the circuitry from a PC via the USB interface was demonstrated, and used throughout the latter stages of the project as this was the preferred means of control in the laboratory.

C to D:

TAWIS was shown to produce Bitmap output compatible with the device API and driver software. Evaluation with end users was performed using static Bitmaps of various tactile diagrams and Braille for evaluation by end users. Initial evaluation with end users was very encouraging, although users of the full page display reported some small areas of pins that did not represent clear images or Braille. In an attempt to rectify this situation, the device was dismantled and reassembled. However, due to the very tight mechanical tolerances to which these devices are made, ability to withstand repeated reassembly was not in the design specification, and insufficient funds were available to purchase new equipment. Therefore the final phase of integration, which should have been a trivial step of displaying the output of TAWIS directly on the array was not completed.

E to A:

Application of the coating to the device has been proved on "top-plates" which were not integrated into the ItactI device. Misapplication of the coating can block the holes in which the tactile pins reside. In order to reduce the risk of damaging the limited set of components available, the concept and operation of the touch sensitive display was demonstrated on equipment other than the functioning full-page display. Single line and 2 dimensional touch sensing was demonstrated.

5.3 Other Notable Deliverables:

KUT undertook research as to the physics of generating an electrical potential in a cylindrical cavity without the need of a central conducting pin on the axis centre line of the cylindrical cavity. This work emanated out of the consideration of feasible technology and was pursued as the research of a doctoral candidate at KUT. This work has come to a successful conclusion and has demonstrated that it may well be possible to generate a strong enough electrical field to freeze certain ERFs.

Subsequent to the gaining of the new understanding by KUT the consortium undertook to build an experimental realisation of the proposed technology and to fully test out as to its practicality and effectiveness. Within the timescales of the ITACTI project this was not possible. The two industrial partners intend to undertake further investigation of this technology that if successful will vastly simplify the manufacturing of an ITACTI actuator array and reduce manufacturing costs by an estimated factor of two.

5.4 Papers Produced and Presented.

A list papers (and copy of these papers) produced and presented by the ItactI consortium members are included in Appendix 1

6.0 Project Management and Co-ordination

The ITACTI consortium was a small compact consortium comprised of five partners with two subcontractors. The coordination of the project was undertaken by De Montfort University and Technical coordination by Smart Technology Group Ltd.

No major problems were encountered with any aspect of the management of the project with respect to performance of the coordinator, individual partners or in their dedication to effect their efforts to produce the deliverables assigned to them.

Good management starts with a first rate project plan in which each partner has full knowledge with the tasks assigned to them and with the timescales for production of the required output.

The dedication of the consortium to the achievement of the set goals was first class. The consortium were faced with significant technological challenges that had to be overcome in order to effect technology that would work reliably and consistently. The make up of the consortium, of course, provided the overall expertise that enabled the project to move forward.

Ten formal project meetings were held by the consortium and at each one every partner was represented, in most cases by their senior staff involved in the ITACTI consortium. In addition to consortium meetings attended by representatives of all partners, several technical meeting of the technical staff of the partners took place. The consortium operated a project management regime that was pro-active in ensuring that partners were aware of due delivery dates for their aspect of the consortium work. In general deliverables were delivered for reviews in a timely manner.

The external assessment of the project by an outside expert took place regularly and reports were filed on time.

There was little or no problems with the production of QMRs by the consortium.

The work of the ITACTI consortium was reviewed in Brussels by review experts four times. In October 2002, June 2003, June 2004 and March 2005. With respect to the first three reviews the decision was to continue. The conclusions of the March 2005 review was that the project should continue in order to finalise, test and report outstanding work. In early June 2005 the ITACTI consortium was advised that it would be subject to an assessment of work undertaken between March and June2005 by an outside reviewer.

7.0 Outlook

DMU has benefited from ITACTI in that it has added a further area of expertise to its Mechatronics Research Group (MRG). It will continue to work with SMART as the prototype moves through its next development stage to the full production device. It is quite probable that DMU will bid for funding for a Knowledge Transfer Partnership and obtain funding such that technology transfer can continue to be effected in a positive manner from the university to the industrial partner.

The research undertaken as part of the ITACTI device realisation will be further exploited by DMU by the MRG who intend to apply for funding from the UK Research Council which supports engineering and scientific research.

Smart is keen on further develop its ER fluid activities. Smart has prepared detailed business plan for exploiting the ITACTI device developed by the Consortium. External investment is being sought to ensure full commercial exploitation.

KUT will open its European Mechatronics Research Centre (EMRC) in Kaunas in the autumn of 2005. The centre will build on the outstanding work of Professor Bansevicius in the mechatronic research and given the existing level of expertise and talent available it will blossom and become a leading European centre. Many fundamental aspects of the science and technology included in the ITACTI device emanated from the laboratories at KUT. The new EMRC will push further forward the fundamental research needs for further development of ERF powered devices.

Metec will continue to develop the TAWIS software and market it as soon as a feasible dot matrix display becomes commercially available. The final full functionality of such a software package requires additional effort of several man month development. Metec will be seeking further national funding to support such activity. Metec also will continue to work on the hardware part of the ITACTI device and use its marketing expertise for promoting the new device.

Ans have direct and regular contacts with distributors of assistive devices for the visually impaired, state sanitary institutions and ophthalmologists, and libraries. All these organisations are eagerly awaiting a full page tactile display unit. Ans will increase its role in helping such organisation in improving the quality of life of the visually impaired persons in Italy.

8.0 Conclusions

The ITACTI tablet has been subject to testing and evaluation that has demonstrated that it performance complies with the agreed specification (some improvement of the reliability of the device is required and this will be achieved when the second iteration of the prototype is built)

- Braille text can be displayed in a state such that competent Braille readers can read the displayed text.
- When used to display graphics the device is able to display raster images using any number of the pins available.
- Graphics images generated by way of external PC based software can be displayed on the tablet.
- The maximum refresh speed is less than the pre-specified rate of 10 seconds.
- Users found the tablet to be a flexible graphical display comprising a large display that can accommodate both graphics and Braille and its realisation was judged to have exciting potential.
- Touch position accuracy has been shown to be equivalent to one finger width.

Appendix 1

Smart Interactive Tactile Interface Effecting Graphical Display for Visually Impaired

LIST OF PUBLICATIONS

1. Distribution of Electric Field in the Round HOLE of Plane Capacitor / R.Bansevicius and J.Virbalis// ISI publication , Journal of Electrostatics 64 , pp 226-233 (2006)
2. Relief Formation on the plane: Principal Solutions, Investigation and Application for the Blind / R.Bansevicius and J.Virbalis.// ISSN1392-1215, ELEKTRONIKA IR ELEKTROTECHNIKA, No. 8(64), pp.42-46, (2005)
3. Smart Full Page Tactile display unit / M S Ahmed// Tactile Graphics 2005, 1-2 December 2005, Birmingham, Poster presentation E19.
4. Design of ER fluids for commercial applications/ Alexander E Smith, and Linda F Evans// Smart Structures and Materials 2003 – Electroactive Polymer Actuators and Devices (EAPAD)- Proceedings of the SPIE, Volume 5051, pp. 66-77 (2003)
5. Smart fluids move into the market place/ Jennifer Ouellette// Industrial Physicist – American Institute of physics: December 2003- January 2004 pp. 14-17
6. Research of the tangential movement of the tactile device/ M. Azubalis, R. Bansevicius, R. T. Tolocka, V. Jurenas// Ultragarsas – ISSN 1392-2114. – Kaunas: Technologija, 2004, Nr. 3 (52), p. 33 – 37.
7. The research of the magnetic actuator of the tactile device/ M. Azubalis, R. Bansevicius, R. T. Tolocka, V. Jurenas// Proceedings: Vibroengineering: 5th International Conference, October 14 – 15, 2004, Kaunas University of Technology, Lithuania - ISSN 1392-8716. – Kaunas: Technologija, 2004, p. 119- 122.
8. Piezoelectric/ERF array actuators for 2-D Braille Devices/ R. Bansevicius, J. A. G. Knight, S. Ahmed, V. Varnavicius// Actuator 2004: 9th International Conference on New Actuators & 3rd International Exhibition on Smart Actuators and Drive Systems, 14-16 June, 2004, Bremen, Germany: Conference proceedings. Bremen, 2004, ISBN-3-933339.-06-5, p. 468 – 470.
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11. New approach for the design of tactile devices / Mindaugas Azubalis, Ramutis Bansevicius, Rymantas Tadas Tolocka // Mechanika / Kauno technologijos universitetas, Lietuvos mokslų akademija, Vilniaus Gedimino technikos universitetas. - ISSN 1392-1207. - 2003, nr. 6(44), p. 50-54
12. Dynamics of array manipulator drive based on electrorheological fluid application / Ramutis Bansevicius, Rymantas Tadas Tolocka, Vytis Varnavicius // Mechanika / Kauno technologijos universitetas, Lietuvos mokslų akademija, Vilniaus Gedimino technikos universitetas. - ISSN 1392-1207. - 2003, nr. 5(43), p. 35-38
13. Array manipulator actuated by electrorheological fluid / Vytis Varnavicius, Ramutis Bansevicius, Rymantas Tadas Tolocka, Egidijus Dragasius // First International Symposium on Mechatronics ISOM 2002 "Advanced Driving Systems", March 21-22,

2002, Chemnitz, Federal Republic of Germany : proceedings. - Chemnitz : TU Chemnitz, 2002. - ISBN 3-00-007504-6. - p. 618-626

14. Drive device to transmit data in a tactile way / Ramutis Bansevicius, Rymantas Tadas Tolocka, Vytis Varnavicius // Acta of bioengineering and biomechanics : proceedings of the 17th scientific conference "Biomechanics'2001", Gliwice-Zakopane, 3-6 September 2001. - Wroclaw : Oficyna Wydawnicza Politechniki Wroclawskiej, 2001. - ISBN 83-7085-566-0. - Vol. 3, supplement 2, p. 35-40.