Assistive Technologies as Part of a Digital Ecosystem

David J. Calder
Digital Ecosystems and Business Intelligence Institute (DEBII), Curtin University of Technology, Australia
E-mail: david.calder@cbs.curtin.edu.au

Abstract

There is a rapidly growing requirement for a new approach to the design of computer-based assistive systems for the disabled. Within a disparate classification of user requirements, many systems manufacturers have catered for particular disabilities in relative isolation and not necessarily within the wider context of other modalities and areas of disability. The Digital Ecosystems for Assistive Technologies (DESAT) approach would assist therapists, educationalists, manufacturers and academic researchers, by offering a coordinated digital ecosystem from which both the ecologically embedded end user and support teams from diverse disciplines could benefit.

1. Introduction

Along with a plethora of computer-based solutions to the challenges of a varied and complex range of human disabilities, comes the danger of regarding the client as an isolated and static entity. Many people have one or more progressive disabilities. These clients are dynamically interactive within an ecology that is itself constantly adapting and changing in real time. Far from being static, complex human systems are constantly interacting with one another as well as other machine systems within the ecology. As these human systems evolve, so the whole surrounding ecology evolves too.

A technology-centred approach that produces an inherently inflexible solution will be flawed. Many designs based on requirement specifications for disabled users fall short as ongoing adaptive solutions. In practice, it is currently almost impossible to offer an alternative or augmentative technology that will match and then continue to match the user requirements of an ever evolving system, as is the case where human input and output channels and the complexities of human-to-human and human-to-machine communication are concerned. The rejection rate of currently produced assistive devices reinforces this claim and is discussed later in the paper. Each individual is a moving target for the system designer, as the day-to-day progression rate for each user is different. The long-term user requirements are therefore dynamic in essence.

There are also factors such as the time and financial investment involved in designing and manufacturing for one person in a bespoke tailor-made fashion. The answer is often a compromise.

These challenges are compounded if the user has multiple disabilities [1]. The design team, who may be focussing exclusively on one area of disability, does not always consider these multi-facetted demands.

Multiple disabilities can be physical, cognitive or both. Issues of complexity with respect to individual requirements must be seen within the context of a wider ecology of the particular user, with that person clearly at the centre, contributing to a team solution. An established and highly successful ecological approach to designing individualized education programmes for the disabled student has been refined over twenty years into a highly recommended model and is now regarded as 'best practice' [2]. This ecological approach has not as yet permeated all areas of disability support. However, the power of the digital ecosystem framework is now accepted within many other disciplines, particularly with respect to small enterprise collaboration [3].

Within small business, the advent of the web has allowed sales penetration over vast distances. Accompanying these advances have come new modes of marketing and partnership possibilities that would have been impossible only a few years ago. With this connectivity has come a fertile and dynamic business theatre that cannot be avoided if small enterprises are to survive. This interaction has led to collaborative workflow models [4].

The logic behind collaborative workflows is to produce a sequence of activities that not only produce a meaningful result, but also to facilitate small groups working together to achieve common goals. The actual physical distance and associated limitations between these entities then becomes less important as web based tools are used to link enterprises and their common aspirations [5]. The entities themselves may be small companies competing against large predator corporations, or widely dispersed cottage industries (such as those associated with assistive devices) with a common interest [6].

Beyond the standard empowerment the digital ecosystem model has provided, are more specific areas that are pertinent to such groups operating in harmony. One of the most important of these is trust evaluation [7]. Other typical support areas are logistics and privacy [8, 9]. These would act as foundations for the model that is proposed in this paper.

Digital Ecosystems for Assistive Technologies (DESAT) is a collaborative cluster-based ecosystem, neither limited by distance between clusters nor the particular disability types associated with each of the clusters. Individual clusters may include a range of specialist personnel associated with the support of a client requirement. The output of such an environment would not only be the efficient research and development of appropriate assistive devices, but also result in more streamlining for the teams in their everyday support of an individual, be that speech therapy for dysarthria patients or training in the use of a long cane or mobility aid for the visually impaired.

2. A Range of Disabilities

With respect to vision perception in particular, there are a number of theories that complicate the challenges with respect to assistive systems design [10]. The machine vision computational theories of David Marr [11] do not equate with the constructive theories of Helmholtz and Rock [12]. None of this uncertainty makes matters easier for assistive device research and design personnel.

When any one of the major human system input channels is affected, the functional potential of the whole person will be compromised. A loss of vision in particular, presents extraordinary challenges. With time, other viable modalities have been shown to compensate and become enhanced in sensitivity. This enhancement occurs in the compensating areas of the brain [13]. With time, the human system adapts and compensates for the loss of a modality, to some extent at least. For the assistive device engineer, however, there is a continually moving target – the requirement specification is therefore constantly changing and never fixed. Recent advances in the understanding of brain plasticity reinforce this perspective. It has been demonstrated that driving the brain with demanding sensory, cognitive and motor activities on a frequent basis will often result in a positive outcome. The reverse is also true [14].

Whereas vision impairment may often be linked to the input channel that results in sight, physical disability may also be associated with the output channels from the human system. The loss of motor speech is often associated with paraplegia or quadriplegia. Communication and mobility may be simultaneously compromised.

It is generally accepted by interventionists that an early programme must provide the learner of communication skills with a systematic means of restoring and maintaining control over his or her environment. Augmentative and alternative communication specialists have for many years, made use of an ecological model to promote control for the disabled learner of communication skills [15].

The above refer almost exclusively to a means of acceptable two-way communication for the individual within a wider environment. The same individual may also require human and technological support to move around the home and to control that encapsulated environment, let alone the wider environment.

3. Cognitive disability

Physical disability is usually, though not always, accompanied by varying degrees of cognitive impairment. For support teams, whether they are educational psychologists, occupational or speech therapists, computer hardware or software engineers researching and developing assistive devices, the task is formidable.

An early introduction to one of the challenges was faced by the author in designing a portable computer-based speech aid [16], [17]. As long as the subject using the working prototype actually knew what he or she wanted to say, the system would allow a range of alphanumeric or iconic software generated key input options to be used or even a single switch input activated by an eyelash. However, as cognitive impairment often accompanies speech loss, even simple iconic prompts can prove to be futile in the interface. Even today, this problem still rules out the use of a speech aid for many people who have no speech. Although a touch screen interface is usually standard, an essential option is the remote single and dual switches. These cater for a person with quadriplegia who may have limited movement, such as the muscles of the eyelids. Stored interface display options include both written cues and a variety of rewritable iconic keys, allowing for some tailoring to the cognitive state of the patient or user. Nevertheless, the user has to have good cognition and particularly an intact short-term memory as a prerequisite!

4. A Spectrum of Assistive Devices

Categories of assistive technologies generally fall into groups that cater for the impairment or loss of a single modality. Cochlear implant and hearing aid researchers and manufacturers tend to cluster around the associated network of audition therapists, educationalists and even competitors. Assistive devices for the blind or partially sighted fall into a different camp. The more advanced mobility aids for the blind and implant units for the deaf use digital technology, both requiring miniaturisation, precision and robustness. However, the teams working within their respective boundaries, may not be sharing information that could be to the good of all and particularly those disabled people who will be using these technologies.

The author's research has been interdisciplinary but primarily based within engineering and applied science. It has been noted that a software application such as our pronunciation tool for use within speech therapy [18] and speech aid devices (already cited) encompassing both hardware and software design, have some overlap in clusters of interested parties.

However, our current prototype mobility aid for the blind, relates to a completely distinct and different cluster, none appearing to optimise resources and communication with the others. For example, the speech therapists and support teams for a cardiovascular accident victim, who may be likely to use speech therapy software or introduce a portable speech aid, are not readily associated with those comprising a support team for the visually impaired client. Certainly the design and manufacturing teams for these aid examples have been, for the most part, historically separated.

A mobility aid for the visually impaired is a portable electronic device that is either hand-held or worn by the client, which warns of obstacles ahead. These devices suffer from a number of problems, the most important of which are related to the interface that conveys information to the user. Most aids use vibrating buttons or sound alerts to warn of upcoming obstacles, a method which is only capable of conveying very crude information regarding direction and proximity to the nearest object. Some of the more sophisticated devices use a complex audio interface in order to deliver more detailed information, but this often compromises the user's hearing, a critical impairment for a blind user.

The World_Health Organization estimated that in 2002 there were 161 million (about 2.6% of the world population) visually impaired people in the world, of whom 124 million (about 2%) had low vision and 37 million (about 0.6%) were blind [19].

Projections indicate that by 2024, over 800,000 Australians will suffer from visual impairment, and approximately 90,000 will be blind [19]. Vision impairment is responsible for 18 percent of hip fractures by older Americans at a cost of treatment of $2.2 billion each year, according to the Framingham Eye Study. If we could prevent just 20 percent of such hip fractures, it is estimated that US$441 million would be saved annually [20].

5. Rigid Designs and Failure of Acceptance

It is now accepted by Human Computer Interaction (HCI) specialists, that earlier user interface designs were often driven primarily by technology rather than being user centred. Although challenging interface designs [21] require the guidelines and standards of a user centred methodology [22], the results with respect to their implementation and user acceptance are not that encouraging.

An extreme example of a technology-driven user interface design is the commonly used QWERTY keyboard layout [23]. Designed to slow input from the user in order to prevent the (mechanical) typewriter hammers from jamming during operation, the result was constrained by engineering limitations of the time.

Sophisticated and very expensive *cutting edge* electronic travel aids may use sound patterns as a substitution for sight. As proof of a significant user interface problem with some of these, specific examples can be found from Johnson and Higgins who refer to visual–auditory substitution taxing a sensory modality that is already extensively used for communication and localization [24]. Velazquez [25] refers to four shortcomings of existing ETAs. One of these is they provide an acoustic feedback that *interferes* with the blind person's ability to pick up environmental cues through hearing.

Recent studies indicate that a 20 minute usage of acoustic feedback devices causes serious human information registration, reduces the capacity to perform usual tasks and affects the individual posture and equilibrium [26]. Many audio sensory substitution devices fail because of their complex, confusing and restrictive audio feedback to the user, which blocks natural ambient sounds. They are therefore not suitable for a typical blind user who will probably have multiple disabilities. A Study by Ross and Blasch [27] clearly indicated that blind people preferred a simple tapping tactile interface to a device generated sound feedback!

The digital ecosystem paradigm offers opportunities for both knowledge sharing within a wider ecology as well as user cognition-centred adaptability and flexibility for all assistive technologies.

6. Aims of the DESAT Model

With each client representing a nucleus at the centre of his or her support cluster, an individual's local ecological environment has been acknowledged (as discussed and cited in previous sections) as a worthwhile starting point, offering a framework from which specialist support action may be fleshed out.

Each support cluster would have a number of clients within its particular category of disability. Cluster membership would not be determined by distance or physical boundaries. The aim would be to maximize use of the digital ecosystem paradigm in order to break existing physical boundaries.

By applying a DESAT strategy, current digital technologies such as mobile, the internet and video conferencing can be coordinated and optimised to deliver the best outcome for all members of this ecosystem.

Open-ended but novel design solutions would be encouraged from both hardware and software developers. The sharing and exchange of common modular solutions at both a functional and user interface level would be part of the ecosystem membership requirement. The protection of intellectual property (IP) would remain an individual company's prime commercial consideration. The difference would be in the focus and modular consideration of appropriate novel and relevant ideas, when first considering I.P. matters. This will not always be relevant to designs, but when it is, it should in fact enhance the potential for profit and sales within the DESAT community itself, as well as in a wider context (external to the ecosystem).

Those academic cluster members who currently work within a limited research environment with a very small interest group would have the opportunity to share their research and ongoing projects on a wider stage within the digital ecosystem. Cross-disciplinary interaction would be nurtured by DESAT. Members of diverse university schools such as computer science, electronics, psychology and education would be made aware of significant ongoing DESAT research and those projects requiring urgent and immediate input from members.

7. Outline of the DESAT Structure

A cluster of people with a vast range of interdisciplinary skills would focus on a user group of people all with a common disability. There would be many separate clusters, meeting the challenges of specific needs of different disability groups. As now, it may be assumed that special education specialists, therapists, medics, academics, engineers and particularly hardware and software experts would form part of each cluster, the main difference being a recognition of the greater ecosystem in which each cluster coexists and operates.

Users at the center of each cluster, the nucleus, would determine the nature of the environment. Clusters would communicate with each other for a common good and the ecosystem itself would be able to benefit from its size in terms of external links and its critical mass. See Figure 1.

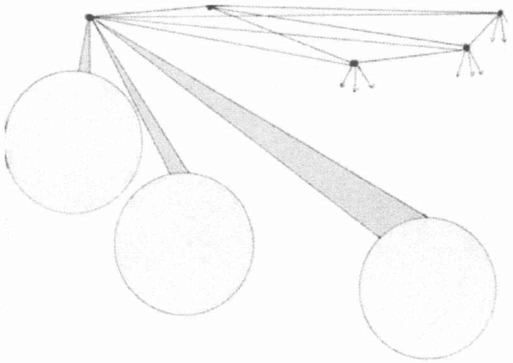

Fig. 1. DESAT structure showing clusters

A starting point for such a structure may take into account the problem as defined by Liu et al when referring to *building the right systems* and the need for better tools and environments in their paper on component-based medical and assistive devices and systems [28]. They put forward a ten-year roadmap, which fits well as a start to implementing the DESAT paradigm. Clusters need to be client centered, taking into account breakthrough research such as that of Bach-Y-Rita into sensory substitution [29] and Merzenich into brain plasticity [30].

8. Operational Benefits

A global advantage and DESAT's greater mass would benefit the ecology on many levels. There would be lower manufacturing costs than is now associated with small-run dedicated systems production. This advantage would result from greater demand for DESAT modular units across clusters and existing boundaries. Relatively large production runs catering for a global DESAT module demand would drive production costs down.

At an academic level, research on large consensus-driven projects could be split, not only between disciplines, but also across campuses and national boundaries. By optimising funding with coordinated grant applications, work need not be duplicated. Projects involving third year undergraduate as well as postgraduate students would have a number of specific benefits. An early introduction of DESAT to students would provide a pathway and assist in nurturing future scientists and other specialists within a variety of disciplines.

DESAT would make use of new and growing technologies such as high speed internet and video conferencing links, mobile phone and other miniaturized digital platforms.

There would, however, be a difference in the way all these technologies are harnessed. Fast and efficient communication channels would be underwritten by each member's awareness and acknowledgement of specific ecosystem guidelines. These guidelines may later form appropriate standards.

9. Guidelines and Standards

Standards institutions such as the International Standards Organisation (ISO) have produced specifications for both hardware and software. As the ecosystem will involve both hardware and software and many existing standards and guidelines already apply, it may be assumed in the early stages at least, that specific DESAT guidelines would also have to be drawn up and adhered to within the boundaries of the fledgling ecosystem.

Guidelines for software and user interface design [31] have been available for many years and offer a good starting point for the conceptualisation of this process. There is no doubt that recent web design standards such as those from the National Institute of Standards and Technology (NIST) work well in that particular context and have indeed been accepted. However, international assistive technology standards are not always adhered to, as they are developed largely for voluntary compliance [32].

In his text on software development ecosystems, Highsmith [33] refers to the dangers of rigid development team processes and the need for a balanced view. Maintaining a team in a generative state where innovation can flourish, requires 'balancing at the edge of chaos'. An excess of order causes stasis whilst an excess of chaotic latitude results in a degenerated random outcome. A compromise balance of the two extremes appears to be needed for the best outcome. Highsmith labels this ideal balanced state as CHAORDIC.

Applying rigid standards and guidelines to DESAT may result in an equivalent ecosystem stasis. A CHAORDIC balance, similar to the above, may prove to be the ideal: particularly in terms of enhanced productivity, considering the dynamic nature of the proposed ecosystem.

10. Conclusion

An ecosystem paradigm has been proposed in order to optimise strategies aimed at improving the quality of life for people with a range if disabilities. The DESAT ecosystem is made up of dynamically changing entities, client-support clusters being the most important. Clusters would be client-centred, with an interactive group representing the nucleus and contributing to a particular cluster direction.

Use is made of digital technology within the ecosystem to help break many conventional restrictive cluster barriers and attain the best outcome. An open-ended and reciprocal modular manufacturing approach has been suggested within the overall boundaries of the ecosystem. Typical production deficiencies in the small-run manufacture of assistive devices may be reduced or overcome. The current concept-to-customer delivery time and cost could be reduced. The dynamic requirement of this model necessitates a fluid approach to guidelines. A balanced structure will be required in order to best harmonise the productivity and overall function of the ecosystem.

11. References

[1] J. Jacko, H. Bautsch, "A Conceptual Framework For The Integration of Clinical Diagnosis, Functional Capabilities and Classes of Technology", *University of Wisconsin Lab for Human-Computer Interaction.* Technical Report series no. 1131, 2000, pp. 1 – 59

[2] B. Rainforth, J. York, C. Macdonald, *Collaborative Teams for Students With Severe Disabilities,* Baltimore: Paul Brookes, 1993, pp. 71- 83.

[3] E. Chang, M. West. "Digital Ecosystems and Comparison to Collaboration Environment". *WSEAS*

Transactions on Environment and development 2, 2006, pp. 1396-1404

[4] L. Pudhota, Chang E, "Modelling the Dynamic Relationships between Workflow Components" ICEISI Porto, Portugal, 2004.

[5] D. Neumann," An Introduction to Web Objects". On-line at http://mactech.com/articles/mactech/Vol.13/13.05/Web Objects Overview. 2004

[6] M. UlieruR. Brennan Scott, *"The Holonic enterprise: a model for Internet-enabled Global Manufacturing Supply Chain and workflow Management"*, Canada, 2000

[7] E. Chang, T. Dillon and F Hussain, "Trust and Reputation for service-oriented Environments: Technology for building Business intelligence and Consumer Confidence," John Wiley and Sons, West Sussex, England, 2006

[8] M. Clark, P. Fletcher et al. Web Services Business Strategies and Architectures. Expert press. 2002

[9] G. Skinner and E. Chang. "A Projection of the Future Effects of Quantum Computation on Information Privacy and Information Security" *International Journal of Computer Science and Network Security 6*, 2006, pp166-172"

[10] J S. Coren, *Sensation and Perception,* Fort Worth: Harcourt Brace, 1994, pp. 328 –360.

[11] D. Marr, *Vision.* San Francisco: W.H. Freeman, 1982.

[12] I. Rock, *The Logic of Perception,* Cambridge: MIT Press, 1983

[13] E. Goldstein, *Sensation and Perception,* Boston: Brooks Cole, 1999, pp. 377 – 378.

[14] M. Woodlee, T. Schallert. "The interplay between behavior and neurodegeneration in rat models of Parkinson's disease and stroke", *Restor Neurol Neurosi,* 2004, 22(3-5); pp 153 - 161

[15] J. Reichle, J. York, T. Sigafoos, *Implementing Augmentative and Alternative Communication – Strategies for Learners with Severe Disabilities,* Baltimore: Paul Brookes, 1991, pp. 61 – 70.

[16] D.J. Calder, P.F. Lister and J.D. Mck Watson, "Large Vocabulary Synthesized Speech Aids for the Vocally Handicapped," *Augmentative and Alternative Communication,* vol 2, no 3, pp 98, Aug. 1986.

[17] D. Calder, "Flexible Speech Aid Designs Requiring Iconic Soft keys", in *Proceedings of the 5th International Symposium on IC Technology, Systems & Applications, 1993, pp. 451 – 456.*

[18] D.J. Calder, B.M. Chen and G.G. Mann, "A Multimedia Training Tool For Speech Impaired Clients," in proceedings of ED-MEDIA 96 World Conference on Educational Multimedia and Hypermedia, 1996, pp 69 – 75.

[19] World Health Organization: Magnitude and causes of visual impairment, p.3, Nov 2004

[20] Vision 2020: the Right to Sight 1999 - 2005 p. 19

[21] A. Edwards, *Extra-ordinary Human-Computer Interaction: Interfaces for Users with Disabilities,* Cambridge University Press, 1995.

[22] A.Dix, J Findlay, G. Abowd, R. Beale, *Human-Computer Interaction,* New York: Prentice Hall, pp. 160 - 173.

[23] B. Shneiderman, *Designing The User Interface,* Reading MA: Addison Wesley Longman, 1998, pp. 308 – 311.

[24] L Johnson and C Higgins, "A Navigation Aid for the Blind using Tactile-Visual Sensory Substitution," Department of Electrical and Computer engineering program, university of Arizona, Tucson USA. 2006

[25] R.Velazquez, E. Pissaloux and F. Maingreaud, "Walking Using Touch", *Proc. Of 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference,* Shanghai, China, 2005

[26] J. Hakkinen, "Postural Stability and Sickness symptoms After HMD Use", *Proc. Of IEEE International conference on Systems, Man and cybernetics,* Hammamet, Tunisia, 2002

[27] D. Ross and B. Blasch, "Wearable Interfaces for Orientation and Wayfinding," *Proc. Of ASSETS 2000,* Arlington, Virginia, USA. 2000

[28] J. Liu, B. Wang, H. Liao, C. Shih, T. Kuo, A. Pang and C. Huang, "Component-based Medical and Assistive Devices and Systems," in *Proceedings of High Confidence Medical and Systems (HCMDSS) Workshop,* 2005, Philadelphia, PA.

[29] P. Bach-Y-Rita and S. Kercel, "Sensory Substitution and the Human-Machine Interface," *Trends in Cognitive Sciences,* vol. 7, pp. 541-546, 2003

[30] M. Merzenich, W. Jenkins, *Memory Concepts,* Elsevier, 1993, pp 437 - 453.

[31] D.J. Mayhew, *Principles and Guidelines In Software and User Interface Design,* Englewood Hall N.J: Prentice Hall, 1992.

[32] R. Cooper, "Harmonisation of Assistive Technology Standards," in proceedings of the International Conference of the IEEE Engineering in Medicine and Biology Society, Vol. 20, No 6, 1998

[33] J. Highsmith, *Agile Software Development Ecosystems,* Boston: Addison Wesley, 2002, pp. 341