On modelling assistive technology systems – Part I: Modelling framework

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Abstract. There has been increasing recognition of the importance and benefits to society of social inclusion and the full participation of disabled people. Many countries have also enacted legislation aimed at removing discrimination against disabled people. Removing barriers to full participation by disabled people will require the development of new assistive technology systems and improved information and distribution systems for existing assistive technologies.
This will require an effective and ongoing dialogue between the disabled end-user community, social services, the clinical rehabilitation services, and the professional engineering disciplines involved in the development, provision, assessment, and ongoing support for assistive technology. To support this dialogue there is a need for common terminology, concepts, and definitions, embedded within a single, unified model framework. This paper presents the Comprehensive Assistive Technology (CAT) model, which was designed to meet this need.

Keywords: Assistive technology, design for all, modelling framework, technology analysis, end-user studies

1. Introduction

The work reported in this paper arose from a need to find a succinct yet comprehensive framework to describe and analyse the engineering design and the use of assistive technology systems and applications. One of the main motivations was the need, arising out of the authors’ work on new communication devices for deafblind people [18,19], for a well-defined framework to investigate and formulate end-user and engineering requirements and to structure the development of new assistive devices. The second motivation was pedagogical, arising from the need to provide an appropriate structure for the presentation of educational and archive material to students and researchers [16,17]. However, it soon became apparent that the methods and models for assistive technology definition and analysis are not well developed. There are a number of different definitions of assistive technology, with the differences determined, at least in part, by the model of disability used. There are two main approaches to understanding disability: the medical and social models. The approach taken here to modelling assistive technology is based on the social model of disability. The background to, and the implications of the social model of disability and the definitions of assistive technology are presented in Section 2 of the paper.

Reviews of the concepts and frameworks that support modelling of assistive technology are notably scarce. To fill this gap, Section 3 opens with an overview of assistive technology modelling approaches, including the objectives and validity of the different models. This review is followed by three detailed subsections that examine three important modelling methods. Section 3 closes with a discussion of the requirements for a new modelling framework that draws together and extends the best features of these existing approaches.

The main contribution of this paper is the presentation of a new modelling framework that is given in Section 4. It is claimed that the new Comprehensive Assistive Technology (CAT) model provides a simple, effective, and unified modelling framework to support the
ongoing dialogue that occurs between end-users, medical practitioners, clinical rehabilitation professionals, social support staff, and the engineering community. This unified modelling framework and terminology will also enable the common structure of assistive technology systems to be understood by distinct professional domains and provide a pedagogical basis for educational and training courses in the assistive technology field. Conclusions are presented in Section 5.

2. Social model of disability and its implications

This section presents a brief discussion of the social model of disability and its implications for modelling assistive technology. Section 2.2 considers definitions of the domain of assistive technology.

2.1. Social model of disability

Since assistive technology is generally provided for disabled people, obtaining an understanding of disability is the first stage in setting up a modelling framework for assistive technology, with different understandings of disability resulting in different approaches to modelling assistive technology. There are two main approaches: the medical model and the social model.

The medical model originates with the World Health Organisation (WHO) and therefore is the perspective of professionals who are largely medical and other health care practitioners, whereas the social model originates with an organisation of disabled people, the Union of Physically Impaired Against Segregation (UPIAS) and therefore gives the perspective of disabled activists and campaigners. The original version of the medical model (sometimes referred to as the ICIDH model) uses the classification of “impairment”, “disability” and “handicap” developed by the World Health Organisation (WHO) in 1980 [25]. The WHO defined “impairment” as “any loss or abnormality of psychological, physical, or anatomical structure or function”. A “disability” then occurs when the impairment prevents a person from being able to “perform an activity in the manner or within the range considered normal for a human being”. Hence, a “handicap” results when the person with a disability is unable to fulfil their normal role in society and the community at large. Thus, the medical model views disability as residing in the individual and focuses on the person’s impairment(s) as the cause of disadvantage leading to the approaches of occupational therapy and clinical rehabilitation. The updated version, the International Classification of Functioning Disability and Health (ICF) [27] considers disablement to result from the interaction between an individual’s health and contextual factors. However, it is still the individual’s condition rather than external factors that is the main driver of the classification.

The social model was first developed by the Union of the Physically Impaired Against Segregation [24] and then modified by the Disabled Peoples International (DPI) [3]. The model is based on the two concepts of impairment and disability. “Impairment” is defined as the functional limitation caused by physical, sensory, or mental impairments. “Disability” is then defined as the loss or reduction of opportunities to take part in the normal life of the community on an equal level with others due to physical, environmental, or social barriers.

The social model of disability thus emphasizes the physical and social barriers experienced by disabled people [28] rather than their impairments and considers the problem to be in society rather than with the disabled person. The focus is therefore on social barriers rather than the individual. The social model [29]:

- Recognises the creation of disability through the interaction of structural and attitudinal variables and the political processes that oppress disabled people and deny them civil rights.
- Recognises the voice and opinions of disabled people and aims to increase the control that disabled people and their organisations have over power and information.

In terms of the social model, engineers and designers have the following two areas of responsibility:

1. Design for all; that is designing and constructing devices and environments to be accessible and usable by as wide a range of the population as possible, including disabled people.
2. Design of assistive technology systems, for example, the design of devices to overcome existing environmental and social barriers thereby extending the opportunities and options open to disabled people.

2.2. Spectrum of assistive technology activities

Although the terms ‘assistive technology’ and ‘rehabilitation engineering’ are frequently used in the literature and there is a generalised understanding of both of them, there has been little coordinated work on definitions. The medical model is better known and has had a
greater influence on practitioners than the social model, probably due to the much greater size and resources of WHO compared to the DPI.

The term ‘rehabilitation’ refers to the restoration ‘to normal life by training and therapy’ of someone who is or has been ill, disabled (or in prison). Rehabilitation technology can then be considered as the technology, devices, processes, systems, or services required to support this process. One of the commonly used definitions of rehabilitation technology expresses this concept as follows [9]:

1. Any tool for remediation or rehabilitation rather than being part of the person’s daily life and functional activities,
2. Those technologies associated with acute care rehabilitation process, and,
3. The segment of assistive technology that is designed specifically to rehabilitate an individual from their present set of limitations due to some disabling condition, permanent or otherwise.

Thus rehabilitation technology is used to act on and modify a disabled person in order to overcome their ‘limitations’ rather than to modify their environment to overcome barriers they might experience. Thus, the underlying philosophy of rehabilitation technology is based on the medical model of disability. This is not the case for assistive technology, the underlying philosophy of which can be based on the medical or social models, a combination of them, or even a totally different approach. Although the term ‘assistive technology’ is frequently used and generally understood, there is no universally accepted definition. In the UK, [30] a consultation meeting of the King’s Fund in March 2001 agreed the definition ‘Assistive Technology (AT) is any product or service designed to enable independence for disabled and older people’ to replace the previously used term ‘disability equipment’. This definition acknowledges the overlap between assistive technology designed specifically for older people and mainstream technology that has been made available to disabled people through design for all, but does not provide a means of distinguishing between them. It has the advantage of being very broad-based, but the disadvantage of lacking specificity and therefore not making clear what is and is not included. However, another slightly later UK definition due to the Audit Commission considers ‘assistive technology’ to be ‘any item, piece of equipment, product or system that is used to increase, maintain or improve the functional capabilities and independence of people with cognitive, physical or communication difficulties’ [31].

In the USA, the Technology-Related Assistance for Individuals with Disabilities Act 1988, the Assistive Technology Act 1998 and the Access Board’s Electronics and Information and Technology Accessibility Standards all contain the following formal legal definition of ‘assistive or adaptive technology’: ‘products, devices or equipment, whether acquired commercially, modified or customized, that are used to maintain, increase or improve the functional capabilities of individuals with disabilities’ [32]. The terminology of this definition has clearly been influenced by the medical model of disability. The focus is on rehabilitation and specifying the assistive technologies that are eligible for funding rather than a wider range of applications.

In the European Union, ‘Assistive Technology refers to products, devices or equipment that are used to maintain, increase or improve the functional capabilities of people with disabilities. Assistive Technology can help to compensate functional limitations and enable people with disabilities to participate in the activities of daily life, including employment and training.’ [33]

Although assistive technology is sometimes still defined in terms of a specific list of technologies, devices, or equipment related to particular applications areas, there is increasing recognition that a broad-based approach to definition is preferable. The derivation of a definition for assistive technology raises a number of issues, including the following:

- The purpose for which the particular definition is intended. Thus the US definition focuses on the types of ‘assistive technology’ that provide ‘rehabilitation’ and are eligible for funding, rather than, for instance, examining how ‘assistive technology’ can be used to overcome the infrastructural and other barriers that disabled people currently experience. It is clearly desirable that funding should be available for this much wider range of ‘assistive technology’.
- Whether components of a larger system, device, or service, such as audio announcements and Braille markings in lifts or vibrating indicators at traffic lights, should be considered assistive technology or design for all applications.
- Whether it is useful to make distinctions between assistive technology and design for all applications.
- Whether defining assistive technology as being used solely by disabled (and elderly) people could lead to discrimination and therefore a more generic approach is required. In this context the following definition has been proposed [34]: ‘Assistive
technology consists of a procedure(s), process(es), equipment(s), material, activity(ies) or system(s) that allows an individual or a group of people to perform a task that they would be otherwise be unable to perform or increases the ease and safety with which the task can be performed. However, because definitions of this type do not refer to disabled and elderly people, they are too all embracing to be particularly useful. In particular, they cover almost all equipment, procedures and processes, most of which are used to enable people to carry out activities either more easily and safely or which otherwise would be impossible. Thus, unless there is a classification that, for instance involves overcoming the barriers that would be otherwise be experienced by disabled and/or elderly people in carrying out activities easily and safely (or at all), tools such as ordinary knitting needles or a knitting machine would be covered. It is not possible to knit a jumper without using either knitting needles or a knitting machine. However, classifying them as assistive technology seems problematical. This is also contrary to the approach taken by the journal of the Association for the Advancement of Assistive Technology in Europe (AAATE), Disability and Society. Although it does not have a definition of assistive technology, it considers the end users of ‘assistive technology devices and services’ to be persons with disabilities and their family members [35].

Examination of some of the definitions of assistive technology [9,30–35] shows that it has the following features:

- It is a generic or umbrella term.
- It covers technologies, equipment, devices, apparatus, services, systems, and processes used by disabled or elderly people to increase their independence and participation in society and/or enable them to carry out activities that would be difficult, dangerous, or impossible otherwise.
- Many of the definitions seem to have been influenced by the medical model of disability and therefore talk about assistive technology being required to overcome limitations due to impairments and to increase, maintain or improve functional capacities and ameliorate the problems faced by disabled people. However, there is no reason why definitions should not be formulated in terms of assistive technology being required to overcome the social, infrastructural, and other barriers that reduce the independence of disabled people and their ability to carry out activities and participate in society.
- Many of the definitions of assistive technology exclude environmental modifications, such as dropped curbs. However, there could be benefits in including environmental modifications in definitions of assistive technology.
- There is not currently a clear definition of the distinction between mainstream products designed using a design for all approach and assistive technology. For instance, an AAATE position paper [36] considers that assistive technology and design for all should be considered as ‘components of a continuum whose primary aim is to exploit the individual’s capabilities at their fullest’ and that they ‘should be looked at as part of the same domain of knowledge, rather than . . . two distinct domains’. However, there is still a need for a distinction between assistive technology and design for all approaches, while recognising that as assistive technology is more widely adopted it may become part of a design for all approach. Therefore, for instance, dropped curbs are now widespread in many countries and should therefore be considered ‘design for all’ rather than ‘assistive technology’.

This discussion has led the authors to propose the following definition:

‘Assistive technology is a generic or umbrella term that covers technologies, equipment, devices, apparatus, services, systems, processes and environmental modifications used by disabled and/or elderly people to overcome the social, infrastructural and other barriers to independence, full participation in society and carrying out activities safely and easily.’

The specifications of use by disabled and/or elderly people and use to overcome different types of barriers are required to distinguish between technology used by disabled people as assistive technology and mainstream technology used by disabled people, as well as between assistive technology and design for all. While it is useful to distinguish what is currently considered assistive technology from design for all technology, it should be recognised that they comprise the two ends of the same continuum and that over time what is currently termed assistive technology may become a design for all component of a mainstream product.

However, it is also useful to distinguish the assistive technology end of the continuum by specifying that it is used (largely) by disabled and/or elderly people to
overcome barriers. Whereas design for all technology is used by the wider population and the design is such that there are no longer any barriers to the activity of interest rather than a specific technology being required to overcome them.

Assistive technology (see Fig. 1) is used in a social, cultural, political, economic, and environmental context. This context may facilitate the development and use of assistive technology, pose barriers and constraints, or be neutral. Although the infrastructure for the provision of assistive technology is more developed in the industrialised countries, assistive technology is required in the so-called developing countries as well and should be available worldwide. Users and potential users of assistive technology also vary greatly in their characteristics, interests, skills, values, and impairments. In addition, assistive technology is required for a wide range of different types of tasks and applications. A model for assistive technology should attempt to capture all these aspects of the domain.

3. The modelling response

3.1. Overview

A review of the literature reveals that only a limited number of researchers have studied the development of assistive technology and that there are three main approaches to disability and assistive technology modelling, as listed below.

1. Classification methodologies
2. System modelling methods
3. Assistive technology outcomes modelling

There are one or two key developments in each of these methodological areas, making a modelling review particularly straightforward. This situation is captured in Fig. 2, which shows the three methodological branches and a small number of named methods in each branch.

Classification approaches are taxonomic systems for defining the domain categories in the disability and/or assistive technology fields rather than being modelling methods per se. There are currently two main classification systems available: the International Classification of Functioning, Disability and Health, denoted ICF, and the International Standards Organisation standard ISO 9999: 2002 Technical Aids for Persons with Disabilities, Classification and Terminology. Both classification systems have had some influence on standardising terminology definitions, data collection requirements and setting standards in the field.

The ICF is one of a group of international classifications developed by the World Health Organisation and has been accepted as a United Nations social classification, making it relevant to consider the impact of this classification system on modelling assistive technology. The ICF is reviewed in Section 3.2.1. ISO 9999: 2002 is product and application orientated, but does not give a basis for understanding the engineering structure and societal application of assistive technology systems. The issue of classification is also relevant to the development of searchable databases of assistive technology products, devices, and services, including the Disabled Living Foundation (http://www.dlf-data.org.uk/) and ABLEDATA (www.abledata.com) databases.

System modelling approaches

The assistive technology outcomes and service delivery modelling approach has received greater attention than assistive technology system modelling, though further work is still needed in this area. The main or indeed sole significant model in the system modelling category is the Human Activities Assistive Technology (HAAT) model due to Cook and Hussey [6], which is discussed in Section 3.2.2.

Assistive technology outcomes modelling approaches

One of the reasons for the better development of the literature on outcomes modelling is probably the connections to the field of health related quality of life assessment, which has over a thousand citations each
year [12]. In addition, quality of life measurements are often used in clinical trials [4,5]. However, a definitive quality of life definition has not yet been obtained. For instance, a review of 87 studies from diverse literature found 44 different definitions [20]. In addition, the quality of life approaches often have limitations and a tendency to focus on medical issues, which is not surprising since medicine is the domain of origin of many of these approaches.

Quality of life approaches are but one tool in the much broader task of modelling assistive technology outcomes and service delivery processes. There is a basic model framework established by Cook and Hussey [6] and amongst others the Matching Person to Technology framework due to Fuhrer et al. [13]. Although these models do not model assistive technology per se, they are reviewed in Section 3.4.3, due to the need of a modelling framework for assistive technology which is able to combine system and outcomes modelling. Section 3.2 presents a detailed model review, with one subsection devoted to each of the three main model areas presented in Fig. 2.

3.2. Model review

The model review considers the three main modelling approaches and presents a brief discussion of the main methods and their uses for each area. The section concludes with a discussion and comparative analysis of the main methods in the three different areas.

3.2.1. World Health Organisation: International Classification of Functioning, Disability and Health (ICF)

The first version of ICF was published in 1980, and the revised version was approved for publication in May, 2001 [27]. It is considered to be complementary to the WHO’s International Classification of Diseases Tenth Revision (ICD -10) [26]. Its aims are to provide a scientific basis and common language to describe health and health-related states, to facilitate the comparison of temporal data across countries, health care disciplines and services, and to provide a systematic coding scheme for health information systems.

As shown in Fig. 3, the ICF classification is a hierarchical scheme based on a two part taxonomic structure, with each part having two components. The classification continues through the definition of constructs by the use of classifiers and then by domains and categories at different levels.

Part 1: Functioning and Disability: this contains umbrella terms for body functions, structures, activities and participation; and impairments, activity limitations and participation restrictions respectively:

(a) Body functions and Structures: respectively physiological and psychological functions; and anatomical parts of the body i.e. organs, limbs and their components. The factors at the constructs/qualifiers level are changes in body functions and structures

(b) Activities and Participation: respectively ‘the execution of a task or action by an individual’ and ‘involvement in a life situation’. However, the difference is ambiguous. There are nine classifications covering activities, such as communication and mobility and participation as in relationships and community, social and civic life. The two classifiers are performance and capacity or the highest probable level of functioning relative to the statistical ‘norm’ for humans.

Part 2: Contextual Factors

(a) Environmental Factors: contains five classifications which cover all aspects of the external or extrinsic world that form the context of an individual’s life, and as such, have an impact on that person’s functioning. This is illustrated in Fig. 4 in tree diagram format. At the constructs/qualifiers level, facilitators and barriers are the factors in a person’s environment
Changes in body function

Facilitator
- Barrier

Performance
Capacity

Changes in body structure

Table 1
Example of ICF code structure: ‘d4503.3’

<table>
<thead>
<tr>
<th>Part 1 Functioning and disability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
</tr>
<tr>
<td>1st Level/ Chapter Level</td>
</tr>
<tr>
<td>2nd Level</td>
</tr>
<tr>
<td>3rd Level</td>
</tr>
<tr>
<td>Qualifier (.Performance, d4503.3</td>
</tr>
<tr>
<td>Capacity)</td>
</tr>
</tbody>
</table>

that through their absence or presence respectively improve functioning and reduce disability or limit functioning and create disability.

(b) Personal Factors: contextual factors that relate to the individual such as age, gender, social status, but there is only the single top-level heading and no further classification is given.

However, the focus on ‘capacity limitations’ and ‘performance problems’ due to ‘change in body structures’ or ‘change in body function’ indicates a continuing medical model focus on the problems resulting from the individual’s impairments rather than a social model focus on social, infrastructural and other barriers. In addition, the sole mention of assistive technology is in the Products and Technology classification of the Environmental factors component in which a distinction is made between general technology products and assistive technology per se (see Fig. 4.) Further, the assistive technology areas are covered by just six sub-classes.

A complex alphanumeric coding system is used to represent the classification. This is illustrated by the decomposition of a particular code shown in Table 1, with ‘d’ representing activities and participation. Further complexity results from the potential for using the ‘Activities and Participation’ list in four different ways with associated coding options [27].

It has been suggested [27] that the ICF can be used as a statistical and research tool for collecting and archiving health related data and quality of life data, as a clinical tool for assessing needs and evaluating outcomes, as well as a social policy tool to support the benefits and compensation systems. However the potential usefulness of the suggested educational social awareness and advocacy applications would be significantly increased if the model had an explicit way of including the perspectives of disabled people. It should also be noted that such perspectives are frequently better described in qualitative rather than quantitative terms and that the ICF approach is better suited to capturing and encoding quantitative rather than qualitative data.

3.2.2. Human Activities Assistive Technology (HAAT) model

The human activities assistive technology model is described by Cook and Hussey in their book Assistive Technologies: Principles and Practice [6]. The model is given pictorial representation as shown in Fig. 5.

The HAAT model is a re-statement of a well-known human performance framework used by human factors engineers and psychologists to study the operational behaviour and performance of humans doing technological tasks. The original human performance model comprised the three components of “human, activity, and context” [2]. Cook and Hussey added the assistive technology component as shown in Fig. 5, giving the following framework:

- Context, which defines the social framework and the physical environment in which the person and the assistive technology have to operate.
- Human person represents the person at the centre of the HAAT model, who is considered to have the attributes of sensory inputs, central processing and effectors (motor outputs).
Fig. 4. Tree diagram for the ICF component, Environmental Factors.

Fig. 5. HAAT model of an assistive technology system (after Cook and Hussey [6]).

- Activity defines the procedure, operation or task that the person would like to achieve. The activity component is one of the more flexible terms within the model and depends on the use of the model.
- Assistive technology defines the external enabler (device) used to overcome any contextual barrier or obstacle.

This approach is one of the very few attempts to present a general systems structure for the technology of the assistive system. For this, Cook and Hussey use block diagrams to capture the general input-processor-output nature of the assistive technology system.

Cook and Hussey [6] have used the HAAT model as a general introductory conceptual framework for the performance of a person-plus-assistive technology system. This allowed them to discuss the general content of the four components in the model and provided a number of technical labels for technology components in the assistive technology system. In the USA, the model has been influential in providing a pedagogical framework for assistive technology studies. However, there has been very little work developing new extensions of the HAAT model approach, one of these being where the HAAT model has been embedded in a human-centred design procedure for the development of an application using a robot [14].

3.2.3. Assistive Technology outcomes modelling

This approach covers the whole process from determining what assistive technologies and services end-users could benefit from through to the assessment of end-user requirements and characteristics, followed by assistive technology device procurement, and concluding with (evaluation of) the longer-term outcomes for the end-user. The methodologies in this area provide a framework for modelling and measuring the performance of the assessment service, the supply service, the assistive technology per se and ultimately, the end-user satisfaction with the assistive technology provision.

Probably the best known and most commonly used modelling framework of this type is the Matching Persons and Technology (MPT) Model [13,23], which is divided into the three main components of the person using the technology, the technology and the milieu or environment. However, the model is very closely tied to the associated six-step assessment procedure for use in determining outcomes and the appropriate assistive technology for a particular person in a given environ-
Fig. 6. Conceptual framework for AT outcomes assessment, based on MPT (after Fuhrer et al., [13]).

Fig. 7. Assistive technology service delivery model (after Cook and Hussey [6]).

ment [23], rather than having a detailed classification structure. There are two versions of the assessment procedure for adults, developed in Ireland and the USA, with the US version translated into French and Italian and one for children under 15, known as the Matching Assistive Technology and Child (MATCH) version. The assessment procedure requires the service provider and end-user to complete slightly different versions of a number of forms, followed by discussion of outcomes and action. The approach is influenced by the medical model of disability and aims to determine ‘limitations’ on functioning and identify goals and technologies that could be used to improve functioning, as well as characteristics of the person, environment or technology that could lead to inappropriate use or abandonment of these technologies. In addition, the model includes some personal characteristics, experiences and attitudes to technologies and degree of satisfaction with different aspects of life.

Figure 6 shows the schematic of a conceptual framework to be used in assistive technology outcomes assessment [13]. It is based on an adaptation of the approach frequently used in the health sciences and most of the factors considered to influence the outcome of device and service provision are obtained from the MPT model. There are three key stages: device procurement, introductory use, and longer-term use and two decision points in the model, indicated by a diamond representing the flow chart ‘OR’, where the end-user may continue to use the device or reject it. Each of these three stages is a complex process that will support detailed models incorporating activities such as assessment, training, and outcomes analysis. Thus the model recognises that there are time-dependent elements in assistive technology use, including feedback from previous use, changes in circumstances, increasing skill in device use and emotional factors.

A similar framework for assistive technology service delivery has been obtained from the HAAT model [6] and is shown in Fig. 7. It has the same three main stages as the conceptual framework. However, the sample questionnaire [6] to support these process stages has a very strong rehabilitation emphasis and there is limited investigation of the user’s requirements for more general assistive technology support. There are only a very few examples of the use of the HAAT model in assessment procedures, one of which is due to Fay [11].

Other instruments that have been developed for measuring assistive technology device outcomes include the Psychosocial Impact of Assistive Devices Scale (PIADS) [7,21] and the Quebec Users Evaluation of Satisfaction with Assistive Technology (QUEST 2.0) [8].

3.2.4. Discussion and comparative analysis of the ICF, HAAT and MPT models

A model is generally designed to be used for a particular (group of) application(s) and is influenced by a particular philosophy, which originates with the modeller and/or the context in which the model has been derived. Although it is possible to design a model for
multiple or even multi-dimensional applications, there are generally tradeoffs between the range of applications and the degree of complexity of the model. While models that cover all possible applications are generally so complex as to be of little practical value, careful model design to cover a wider range of applications than those considered each by the ICF, MPT and HAAT models on its own is possible.

In terms of their intended applications and underlying philosophies, the ICF, MPT and HAAT models are all good models. The drawbacks of these models with regards to modelling assistive technology systems relate to the influence of the medical model of disability, whether implicitly or explicitly, and the much wider range of modelling applications required than are covered by these models, either singly or collectively.

Human centred design approaches are particularly suited to assistive technology, due to the importance of focussing on what the end-user wants. This leads to the four components of the human factors framework approach [6], namely person, context, activity and assistive technology, as an appropriate basis for modelling assistive technology systems. These components are all present to some extent in the four models, though not always explicitly. However, the presentation of the four components in the three modelling frameworks and their degree of detail is determined by the intended applications and therefore in most cases unsuitable for the modelling of assistive technology systems. Both the HAAT and MPT models are better suited to regions or countries with a modern infrastructure, due to the lack of categories covering infrastructure, societal attitudes and legislation. These categories are present in the ICF model (often under different names), but the nature of the detail is more appropriate to health data than assistive technology applications.

All four components are present explicitly in the HAAT model [6] and this modelling approach is important as the first attempt to apply this framework to assistive technology applications. However, the focus on providing a conceptual framework for assistive technology applications means that the treatment of these components is not necessarily suitable for other aspects of assistive technology modelling. In particular the discussion of the activities component [6] refers to the three performance areas of ‘daily living, work and productive activities and play and leisure’, in the Uniform Terminology for Occupational Therapy [10] activities model, but does not specify it in detail. End-user aspects of the assistive technology component, such as usability, documentation and training are also lacking.

The detail of the ICF model categories is much more appropriate to its intended application of the collection of health related data than assistive technology applications. However, it should also be noted that even for the health data context the proliferation of detail and the need to encode the data reduces the user friendliness of the model. The four components of the human factors approach are spread across the two part structure of Functioning and disability and Contextual factors.

The ICF classification is based on health and health-related states rather than people, though it does include a completely unclassified personal factors component. The very large number of medically inspired categories of body functions and structures, the lack of classification of personal factors, and the division of person related classifications between different categories of the ICF does not facilitate its use in assistive technology modelling and means it does not support design for all approaches or particularly encourage holistic approaches based on consideration of social, infrastructural and environmental barriers. Assistive technology classifications are only considered in one chapter of the Environmental Factors component of Contextual Factors. The granularity of the sub-classes in this Products and Technology chapter is very poor [1,22] and there is some overlap between the different classes. The system of classifiers seems to be designed purely for data coding purposes and therefore does not facilitate obtaining an overview of the field or insight into holistic results and outcomes. The activity classification is based on the Component Activities and Participation, but the WHO documentation [27] recognises that there is some ambiguity and overlap between the two terms.

The MPT model is intended to be used in outcomes modelling and the matching of assistive devices to a particular end-user. Therefore, the person component of the model, including personal characteristics, preferences and social interactions and support, is better developed in the MPT that the other two models. However, though all four components are included, the model lacks a formal structure and is based on data obtained through the associated MPT assessment forms. These include questions about performance of, and/or satisfaction with a number of activities, but there is no systematic framework or classification of activities and the choice seems to be based on assumptions of what types of fundamental activities disabled people might experience problems with. The MPT model does consider the human and assistive technology system interaction as part of the consideration of outcomes. This includes issues, such as device effectiveness, device satisfaction
and end-user well-being, which should be an important part of assistive technology. However, technology details and factors such as ergonomic design, technical reliability and cosmetic appearance are lacking.

In summary, the following comments can be made:

– All three modelling approaches have been influenced by the medical model of disability to differing extents.
– The three models are reasonably well suited to their intended applications, the collection and analysis of health related data for ICF, provision of a conceptual framework for the general discussion of assistive technology applications for HAAT and matching assistive technology to the end-user and assessing outcomes for MPT. However, they are not suited to the much wider range of assistive technology applications being considered and defined in this paper.
– Although all three models consider the four components of the human factors framework to some extent, even if not explicitly, the treatment has a number of limitations and disadvantages. These include the focus on health and health related states and the use of coding rather than a more user friendly classification in ICF; the lack of detail of many of the model components and tendency towards an engineering rather than end-user focus in HAAT; and an implicit classification based on factors identified in the associated assessment procedures, rather than an explicit classification in MPT.
– An inappropriate level of classification detail, missing classifications and/or implicit rather than explicit classification characterise all three models. They all lack a number of important classification areas, particularly in the person and assistive technology domains. The ICF classifications are too detailed to be user friendly, whereas the MPT classifications are only defined implicitly through the associated assessment framework, rather than explicitly.

With regards to the three modelling approaches on which the ICF, HAAT and MPT are based, classification approaches have the tendency, illustrated by the IFC, to include excessive detail, but ignore the interaction between categories, whereas outcomes modelling, as illustrated by MPT, has too limited a range of applications, namely all aspects of assistive technology provision and outcomes assessment. Despite the limitations of the HAAT approach, systems modelling has considerable potential and therefore the new Comprehensive Assistive Technology model will be developed within a systems modelling framework.

3.3. Proposals for a Comprehensive Assistive Technology (CAT) model

3.3.1. Need and applications for a CAT model

The model review in the previous section has identified that the established approaches to modelling assistive technology systems only provide a basic outline structure for such models and are far from meeting all the requirements of a well-developed framework. For instance, the existing modelling structures cannot be applied to investigate the adequacy or quality of existing assistive technology provision and identify areas where it is lacking. In addition, they are unable to provide a technological framework for the design specification (synthesis) and development of new assistive applications and devices.

The first stage in any modelling process is often specifying or clarifying what is being modelled. In this case this has been done through the derivation of a new definition of assistive technology in Section 2.2. This definition will form the basis of the subsequent modelling process. For ease of reference this definition is repeated here:

‘Assistive technology is a generic or umbrella term that covers technologies, equipment, devices, apparatus, services, systems, processes and environmental modifications used by disabled and/or elderly people to overcome the social, infrastructural and other barriers to independence, full participation in society and carrying out activities safely and easily.’

Drawing on the modelling review in the previous section and the new definition of assistive technology, the following requirement for a new modelling framework for assistive technology systems can be stated:

(i) Applicable to any assistive technology system, with assistive technology characterised in the broader sense of the above definition.
(ii) Able to provide a classification and archival framework for assistive technology systems.
(iii) Capable of identifying where new assistive technology applications are required. This will require accessibility barriers to be identified.
(iv) Provide a framework for modelling the generic structure of assistive technology systems and lend itself to analysis and synthesis (design specification) procedures.
Modelling human activities is an important feature in all the three modelling approaches described in Section 3.2. For example, a checklist of activities can be used to identify where accessibility barriers exist for an individual or group of individuals. Thus, prior to presenting the detail of the model in Section 4, the modelling of ‘activities’ is discussed next.

3.3.2. Modelling human activities

One aspect of assistive technology modelling that has received some attention is that of modelling human ‘activities’. A model is needed to determine whether and what type of assistive technology support may be required for the individual or within the societal infrastructure generally. There are several different ways of creating a human activities model depending on the desired end-use of the model and/or the perspective of the modeller. The discussion here follows the overview modelling review of Section 3.1.

Part 1 of the ICF approach contains the category of Activities and Participation. For the purpose of this discussion the components of Activities and Participation will be represented in a tree diagram form, similar to that to be used in one of the representations of the Comprehensive Assistive Technology model, and shown in Fig. 8.

The ICF defines activity as the execution of a task or action by an individual and participation as the person’s involvement in a life situation. The figure shows the partition of the classification into these two groupings. Although, as recognised by WHO [27], this distinction is rather imprecise, there is an important distinction between what can be considered fundamental or basic activities and activities which are specific to a particular type of situation or context. Examples of basic activities include face-to-face communication and moving short or long distances, whereas examples of a situation or context specific task include teaching and shopping. It should be noted that both teaching and shopping frequently involve both face-to-face communication and moving short or long distances.

Thus the CAT model includes a partition of activities into fundamental and contextual activities, which is related to, but not identical to the ICF distinction between activity and participation. The ICF comprises nine activity classifications with extensive subdivisions. However, the number of categories is so large as to be unwieldy and making it difficult to obtain an overview of the model. In addition, there is an excessive degree of detail. Therefore, appropriate choice of a smaller number of less detailed activity categories is required to give a model structure which can be easily comprehended and overviewed. The selection in the CAT model is discussed in Section 4. It should be noted that, despite the similarities at the higher levels, the CAT model structure is not identical to that of the ICF.

Another route to modelling human activity is to use the classification of assistive technology products and devices. Although only indirectly a model of human activities rather than assistive technology, this is the basis of the ISO 9999 standard. It is also the approach used in the EU HEART project after the first level technical area categories. The HEART project [15] defines the four technical areas of communication, mobility, manipulation, and orientation, with each area further divided into activities and categories of assistive technology devices, as follows:

(i) Communications: interpersonal communications, reading/writing, computer access/user interfacing, telecommunications
(ii) Mobility: manual mobility, powered mobility, accessibility, private transportation, public transportation, orthoses, prosthetics, seating and positioning.
(iii) Manipulation: environmental control, robotics, orthotics and prosthetics, recreation and sports.
(iv) Orientation: orientation and navigation systems, cognition.

The HAAT model uses the Occupational Therapy categories to describe the activities component of the model. The occupational therapy categories derive from the Uniform Terminology for Occupational Therapy [10] and these are based on the three basic performance areas of daily living, work and productive activities, and play and leisure. Although these categories
are useful for end-user assistive technology system assessment, there is a degree of ambiguity and overlap between them. It is interesting to note that the end-user questionnaire devised by Cook and Hussey only has sections on the fundamental activities and on the single contextual activity, Daily Living. Categories in the ICF are not used.

Discussion
All the approaches described above have their limitations. In particular, they may restrict the activities covered to those for which there are assistive technology categories or which are considered appropriate in some sense for disabled people. As a result, some activities, including those where barriers exist for some disabled individuals or groups of disabled people, may be missed. In addition, the ICF and the occupational therapy categories are characterised by overlap, as well as some categories that are too finely detailed and others that are too broad. It is not easy to define the appropriate breadth and specificity of activity categories and a trade-off is required between sufficient precision to avoid overlap and maintaining a reasonable number of categories at each level.

Over-precise task decomposition is also generally inadvisable for the following reasons:

(i) Many higher-level activities take place within a particular context and often have more than one possible decomposition as a sequence of basic tasks. It is generally the ability to achieve the higher-level activity that is important rather than the ability to carry it out in a particular way. Since the contextual information is generally lost when higher-level activities are decomposed into basic tasks, this may result in a misunderstanding of what is required. For this reason, it is valuable to have fundamental(basic) activities and contextual activities (participation) categories.

(ii) A very detailed decomposition into basic tasks can lead to overlap between some of the basic tasks resulting from high-level activities, which should then be removed. For example, a number of high-level activities, including listening to a radio, choosing the programme on some designs of washing machine or choosing the temperature of an electric oven, involve turning dials. Consequently, a model based solely on decomposition into simple tasks is inappropriate.

The above discussion shows that a new approach to classifying human activities is required to support assistive technology development, analysis, and selection. The approach used in the new Comprehensive Assistive Technology model presented in Section 4 is therefore required to meet the following specifications:

(i) To cover all (major) human activity areas whilst minimising overlap between categories
(ii) To provide a systematic structure with an underlying logical justification for the categories chosen
(iii) To define activity areas of an appropriate breadth and with a precise degree of specificity
(iv) The activity areas should be able to identify the real barriers encountered by different groups of disabled people in carrying out a wide range of social and domestic activities.
(v) The activity areas should be based on a hierarchical structure with two main levels and not more than eight categories on each branch to
give a model of manageable size and complexity.

4. The Comprehensive Assistive Technology (CAT) model

4.1. Justification of the choice of model representation

Model development generally involves tradeoffs between comprehensiveness and simplicity, since complexity increases with the number of factors and aspects covered. An assistive technology framework which can be used for the classification, synthesis, and analysis of particular devices and for supporting the development of new devices and the appropriate matching of technology to the user is likely to be very complicated. This complexity can be managed by the choice of an appropriate modelling framework. The CAT model presented here was developed out of the HAA T modelling framework introduced by Cook and Hussey [6] and also has some relationship to the MPT model and ICF. This approach has been chosen for the following reasons:

(i) The model can be represented by a set of tree diagrams, as shown in figures 9–14, with a limited number of variables on each branch. This makes the model much easier to understand. However, the diagrammatic form of the tree structure is purely for the convenience of sighted readers and the model is not inherently visual.

(ii) The top level of the model contains the four components that define all assistive technology systems, namely the user, who should be at the centre of assistive technology design; the context(s) in which they will be using the assistive technology; the activities for which they want to use it; and the technology.

(iii) The CAT approach gives a generic framework for the categorisation, development, assessment and person matching of assistive technology systems. This framework includes all the main factors, including the social and engineering dimensions of assistive technology.

(iv) The tree-structure approach is very flexible. As presented, the model is comprehensive, without being complicated and it can easily be simplified by omitting variables that are either not relevant or important in a particular context. This structure also facilitates software implementation. Furthermore, the tree diagrams lead to other representations, in particular, labelled attributes and tabular forms that can be used in different applications studies.

This is a considerable extension of the approach in the HAAT model. The model of the person has been extended to avoid reinforcing the tendency of engineers and designers to ignore the wider aspects of human-centred design, such as aesthetics and values. These wider human aspects often determine whether a device is actually used or rejected and whether it really meets users’ needs. Using the model review and the consideration of previous human activities models, a new decomposition of the activity category has been introduced. The model is globally applicable to assistive technology both within and without the industrialised nations.

4.2. Description of the Comprehensive Assistive Technology (CAT) model

The Comprehensive Assistive Technology model has a tree structure that does not use an excessive number of branches at any level. This has the advantages of being easy to understand, navigate, and modify, as well as facilitating the development of interactive software. The model is based on decomposed layers of attributes that cover the relevant aspects of a person, their environment, and the assistive technology system being used to support their activities. These attributes are ordered to give a structure that makes sense of the different components, and this structure can be represented diagrammatically, as attribute sets or in words, amongst other ways. The first or top level has the following four branches, illustrated in Fig. 9, Person, Context, Activities, and Assistive technology system.

The model is then developed by carefully defining further branching levels for each of these top-level categories. The definitions of these branches and levels are motivated by the requirement to use the model to analyse existing technologies and develop new ones. Details of the sub-branches for the first level branches of the person, context, activities, and assistive technology system will now be presented.

4.3. Person attribute in the CAT model

The person, or group of people, who are going to use a particular assistive technology is central to the success of the system. The second level components
Fig. 9. Comprehensive Assistive Technology (CAT) model.

Fig. 10. Model for person attribute.

are Characteristics, Social aspects, and Attitudes (see Fig. 10).

At the third level, the Characteristics variable consists of Personal information, Impairments, Skills and Preferences. Personal information includes age, gender and ethnic origin. Impairments involves sensory, physical, cognitive, mental health and other impairments. These impairments affect the activities where the person may experience barriers and therefore might require assistive technology and the suitable design of this assistive technology so they do not experience problems in using it. Skills may be innate or the result of education and training. Most people have a wide range of very different types of skills, not all of which are relevant to the use of assistive technology. Preferences include preferences for the type of interface, device appearance, receiving basic or detailed information and the way information is presented, for instance as speech, text, pictures or as a combination of several formats.

The social aspects variable comprises (at the third level) Community support, and Education and employment. Community support may have emotional, practical, and/or financial aspects. It involves the availability of support and friendship from the local community and/or family and friends. This support and encouragement can be an important factor in a user having a successful experience with an assistive device. Education and employment include current employment status, employment history, education and training history and qualifications. Education and employment history can contribute to confidence or lack of it and education and training will have an effect on determining levels of knowledge and skills.

At the third level, the Attitudes variable comprises Attitudes to assistive technology and General attitudes. User attitudes to assistive technology include experiences with assistive and other technologies, and how willing they are to try new technology. It also includes preferences for assistive technology, personal assistance or a combination of the two. General attitudes include self-esteem, self-identity, attitudes to disability, (self-)motivation and their degree of perseverance.

4.4. Context in the CAT model

The second level describes the main types of context, whereas the third level specifies these contexts in
more detail, as shown in Fig. 11. It is important that assistive technology design is based on the user’s existing context and does not require them to change it, for instance by requiring a modern infrastructure or the use of English. However, the provision of assistive technology can enable the user to work towards improving their context, either on their own or together with other people.

There are three main types of context at the second level (see Fig. 11):

- Cultural and social context
- National context
- Local settings

At the third level, the cultural and social context is divided into Wider social and Cultural context and User’s social and cultural context (See Fig. 11). These two contexts are often very similar, particularly for people who form part of the dominant cultural and social context. There are frequently differences for members of minority groups, including disabled people. Variables of interest in both these contexts include language, other cultural factors, attitudes to disabled people and attitudes to assistive technology. Language and other cultural factors are particularly important since many features of existing assistive technology devices are only provided in English and, sometimes, a small number of European languages. Both speech output, if any, and documentation and manuals needs to be in the local language. In addition, the choice of symbols or other labels for controls should be unambiguous in the particular cultural context.

The national component is able to distinguish between the contexts in countries with very different histories, socio-economic situations, and states of infrastructure development. Together with the wider social context, this is one of the features of this model that makes it applicable beyond the industrialised countries. The third level of the national component is divided into Infrastructure, Legislation, and Assistive technology contexts. The infrastructure context includes factors such as the availability and reliability of an electricity supply and the state of development of information and telecommunications technology, as well as the proportion of the population that have access to them. Other infrastructure factors are the development of a road and rail infrastructure and the extent to which public transport and public and private buildings are accessible, as well as the state of repair of the infrastructure. It would clearly not be very useful to supply an assistive device that requires a mains power supply in a country where the electricity supply is intermittent and unreliable and/or the majority of the population are not connected to the supply. The legislative context includes legislation about accessibility and social inclusion for disabled people and any relevant building or other regulations and national standards that affect assistive technology. The assistive technology context includes the local, regional or national system(s) for distributing, paying and providing support, training and maintenance for assistive technology. This includes the availability of direct payment schemes for disabled people to employ personal assistants or purchase assistive technology of their choice, the extent of availability of sign-language interpreters and guide-communicators for deafblind people and how these services are funded.

The local settings context describes the various settings in which the user would wish to use assistive devices. Its third level components are Location and environmental context and Physical variables. The location and environmental context includes indoors, outdoors or both, by the user on their own or accompanied by other people. Indoor settings could be further classified according to the type of building or its main use, for instance as an apartment in a multi-storey block, one storey house, multi-storey house or as a home, workplace or educational establishment. Outdoor settings can be further classified into urban, rural or natural/‘wild’ e.g. montan-
tain or seaside. It should be noted that some devices are intended for use in one particular setting or type of setting, whereas others may be used in several different (types of) settings. For instance, a lift with Braille markings will be used inside in a multi-storey building, whereas a wheelchair may be used both inside and outside and in a variety of different types of location and terrain. The local settings context includes any constraints or limiting factors arising from the setting, such as door or room size or the need not to disturb other people. Physical variables include temperature, noise levels and types, humidity, the level and type of illumination and the types of surface and the state of repair of the local infrastructure.

4.5. Activities attribute in the CAT model

The activities attribute categorises the various activities a person might want to carry out, for some of which they may require support from assistive technology. The six activities categories based on the following two main groupings:

- The major fundamental activity categories of mobility, communications, and access to information, and cognitive activities.
- The major contextual activities of daily living, education, and employment, and recreational activities.

It should be noted that the definition of fundamental activities and contextual activities mirrors the categories of activities and participation in the ICF schema. The three fundamental activity categories are similar to those in the ICF scheme, and cover most of the activities in the four HEART project technical areas. The three contextual activities are similar to participation activities in the ICF but are more closely related to the three occupational therapy performance areas. Thus, the activities model could be considered to combine the advantages of previous approaches whilst simplifying and reducing the excessive detail of the ICF approach. This then gives the following six main components in the second level from the activity component of the CAT model (see Fig. 12):

- Communication and information
- Mobility
- Cognitive activities
- Daily living
- Education and employment
- Recreational activities

It should be noted that each of the contextual activity categories involves activities from all of the fundamental activity categories, namely, some communication and/or use of information, cognitive activities, and mobility activities. This is one of the reasons that the activities in these categories are considered ‘fundamental’. For instance, computers and the internet can be used in daily living and the workplace or educational establishment, as well as to obtain information about leisure activities. Many daily living, education and employment and recreational activities require some planning and organising, decision-making and analysis of information, as well as sitting and standing and/or lifting and reaching. Therefore, to avoid ambiguity and duplication, cognitive, mobility and communication and information activities are not repeated in the contextual categories.

Communication and information covers all the activities related to communication, whether carried out directly or via technology, as well as those related to accessing information in all its forms. These activities comprise Interpersonal or face-to-face communication, Access to print media, Telecommunications, Computers/internet and Communications and accessing information using other technologies (see Fig. 13a).

Interpersonal or face-to-face communication involves one-to-one, small group and large group communication. Access to print media covers both the production of print media and reading print media produced by other people. All the communication categories include artistic and imaginative as well as factual communications. Communications and accessing information using other technologies includes the use of information kiosks and smart cards.

Mobility involves all the activities associated with movement and safe travel (see Fig. 13b). This includes...
availing obstacles, as well as the navigation and orientation activities required to reach the right destination by a desired route. It also includes moving objects, sitting, and standing. This then gives the following categories at the third level: Reaching and lifting, Sitting and standing, Short distance locomotion inside and outside, Long and medium distance locomotion, Movement on ramps, slopes, stairs and hills, Obstacle avoidance, Navigation and orientation, and Access to the environment.

Cognitive activities involve all the mental activities or activities related to thought processes i.e.: Analysing information, Logical, creative and imaginative thinking, Planning and organising, Decision making, Categorising, Calculating, and Experiencing and expressing emotions and feelings (see Fig. 13c).

Daily living involves all the different activities used in everyday life. Most people will carry out some of the activities in each category (except possibly Sexual and reproductive activities) on a regular basis and possibly every day or even several times a day. These activities can be categorised as: Personal care, Timekeeping, alarms and alerting, Food preparation and consumption, Environmental control and household appliances, Money, finance and shopping, and Sexual and reproductive activities (see Fig. 13d).

Personal care activities include personal grooming, washing, toileting and sleeping. They also include per-
sonal care activities carried out for a baby or small child. Timekeeping, alarms and alerting includes fire or smoke alarms, alerts to a range of activities, such as the telephone ringing, the door bell (including an indication of who is at the door), a baby crying and a wake-up signal. Food preparation and consumption includes the use of cookers, microwaves and blenders to prepare and cook food. Environmental control and household appliances includes the use of washing machines and vacuum cleaners, as well as turning lights on and off, opening and closing curtains, blinds and doors and control of the heating system. Sexual and reproductive activities include assisted conception, such as donor insemination and in-vitro fertilisation, and the use of contraception.

Education and employment comprises the wide range of different activities involved in education, training and employment, both paid and voluntary. Education and employment can further be categorised as follows (see Fig. 13e): Learning and teaching, Professional and person-centred, Scientific and technical, Administrative and secretarial, Skilled and non-skilled trades, and Outdoor work.

Recreational activities can be divided into the categories of Accessing the visual, audio and performing arts (TV, cinema, theatre, radio, music, dance), Games, puzzles, toys and collecting, Holidays and visits: museums, galleries, heritage sites, Sport and outdoor activities, DIY, art and craft activities and Friendships and relationships (see Fig. 13f). There is some overlap between the three contextual activity categories. For instance, painting and decorating can be either an employment activity (skilled trade) or a recreation activity (DIY and craft activities) and cooking a meal can be
either a daily living activity (food preparation) or an employment activity (skilled trade).

4.6. Assistive technology attribute in the CAT model

Since the community environment is generally not designed for disabled people, many disabled people require assistive technology to carry out their desired activities. In some areas, appropriate assistive technology systems are not (yet) available so that some groups of disabled people will have considerable difficulties or even find it impossible to carry out some desired activities. At the second level, as shown in Fig. 14, the assistive technology system attribute can be divided into the following components:

- Activity specification
- Design issues
- System technology issues
- End user issues.

At the third level, the activity specification component includes: Task specifications and User requirements. In task specification, a task or activity is decomposed into a list of the subtasks that the assistive technology has to accomplish. User requirements cover the physical, sensory and cognitive demands made on the user, such as the ability to lift a certain weight or to follow a sequence of instructions. In general the fewer and less demanding the user requirements, the wider the group of people who can use a particular technology. At the third level, design issues can be categorised as Design approach and Technology selection. The design approach is the overall design philosophy or strategy used. This includes whether it is based on design for all or design for specific groups of (disabled) people and/or design for environment or design for maintainability. Design for all aims to design for as wide a population group as possible, independently of factors such as age, gender, ethnic origin, size or disability. Technology selection involves determining the main technologies on which the design could be or is based. For example, in the case of an obstacle detection device the technology choice may lie between infrared and ultrasonic technology and the selection process would consider factors such as performance, the user interface, reliability, technical specifications and cost.

At the third level, the assistive technology system comprises System interface, and Technical performance. Specification of the system interface includes whether it is single or multi-modal and which modalities are available, for instance speech, text, icons and/or Braille. Technical performance includes a range of factors, such as reliability, robustness, safety features and ease of maintenance. At the third level, end-user issues can be categorised as Ease and attractiveness of use, Mode of use, Training requirements, and Documentation. Ease and attractiveness of use covers a range of factors, including whether the assistive technology is ‘user friendly’ and intuitive to use, as well as size, weight, portability and appearance. Mode of use includes whether the device is portable or remains in a given location and whether it is stand-alone or forms part of a larger system. Training requirements specify the types of training (different groups of) users are likely to require in order to use the assistive technology successfully. This may involve training before using the technology for the first time and ongoing training. Factors associated with documentation include the formats it is available in, such as on-line and hard copy, how it is structured and whether it is targeted at novice or expert users or there are different sections for both these groups of users.

4.7. Applications

The CAT modelling framework has a number of important applications, including the following [17]:

- Identification of gaps in assistive technology provision. This could lead to the development of assistive technology systems for areas where there are currently no systems available, or an extension of the capabilities of existing systems to offer more options to end-users.
- Analysis of existing assistive technology systems. This could lead to design modifications to improve performance, user satisfaction and/or increase functionality, as well as the specification of new devices.
- Design synthesis. This could lead to the development of design specifications for new devices, for instance to meet identified gaps in provision.
- The provision of support for design for all i.e. the design and construction of devices and environments to be accessible and useable by as wide a range of the population as possible, including disabled people. The model could be used to structure the design approach. Consideration of the personal characteristics (person attribute) of a particular group or groups of end-user is used to identify the barriers they will encounter in carrying out a de-
fined set of activities using a particular technology (technology attribute) or in a particular environment (context attribute). The (assistive) technology and context attributes can then be used together with the person attribute to determine the required design features to make the technology or attribute accessible to the end-user groups. This approach can either be carried out separately for each end-user group being considered and the design specifications combined or all potential groups of end-users can be considered together from the start.

A number of applications in the area of analysis and design synthesis for blind and deafblind people are discussed by the authors in the book [17].

5. Conclusions

Assistive technology is still a relatively young subject in which the underlying theory is still being developed. One of the areas of assistive technology in which the theory is still relatively undeveloped is that of modelling assistive technology. Currently, only a few modelling approaches are available, with only a limited range of applications. In addition, researchers have generally not taken the step of defining assistive technology precisely before developing a modelling framework and existing models are rarely based on a specific definition.

Since disabled people are one of the main users of assistive technology, definitions of assistive technology require an understanding of what is meant by the term 'disability'. Therefore the paper commenced with a discussion of the two main models of disability, the medical and social model. The social model, with its stress on overcoming barriers and design for everyone, was considered more appropriate as a basis of assistive technology. This led to the examination of existing definitions of assistive technology and the development of a new definition based on the social model of disability.

This definition provided the basis on which the modelling framework was developed. However, first existing assistive technology modelling approaches were reviewed. It was found that they could classified into three main categories:

1. Classification methodologies
2. System modelling methods
3. Assistive technology outcomes modelling

Although these models were found to be useful, none of these models covers the full range of applications. Analysis of the limitations of the existing models and full range of desired applications was used to draw up specifications for a new assistive technology modelling framework.

This framework was then used to develop the main contribution of the paper, the Comprehensive Assistive Technology model, a new modelling framework derived by the authors. Although the CAT model has some relationship to existing modelling approaches, particularly the HAAAT model, it has significantly greater flexibility and a much wider range of applications, as well as considerable differences of detail and lower level structure.

The CAT model has a number of applications, including the following:
(i) Identifying gaps in assistive technology provision.
(ii) Analysing existing assistive technology systems.
(iii) Developing specifications for new assistive technology systems.
(iv) Supporting the provision of assistive technology for particular end-users.

Model validation will be carried out through investigation of applications. This will be done in Part 2 of the paper, where examples of a number of different types of applications will be presented that exploit the representational flexibility that exists in the CAT model framework.

References


