Developing an ENABLED adaptive architecture to enhance internet accessibility for visually impaired people

C C Tan[1], W Yu[2] and G McAllister[3]

[1,2]Virtual Engineering Centre, [3]Sonic Arts Research Centre,
Queen's University Belfast, Malone Road, Belfast, UK

[1]*s.tan@qub.ac.uk*, [2]*w.yu@qub.ac.uk*, [3]*g.mcallister@qub.ac.uk*

[1,2]*www.vec.qub.ac.uk*, [3]*www.sarc.qub.ac.uk*

ABSTRACT

This paper gives an overview of the current status of Internet accessibility and offers a brief review of the existing technologies that address accessibility problems faced by visually impaired people. It then describes an adaptive architecture which is able to integrate diverse assistive technologies so as to allow visually impaired people to access various types of graphical web content. This system is also capable of adapting to user's profile and preferences in order to provide the most adequate interface to the user.

1. INTRODUCTION

We rely very much on the Internet to acquire a wealth of information on different subjects and areas in our daily life. Due to the ability of the Internet in making many kinds of information and services easily accessible, it subsequently turns the Internet into a disputable communication and information medium that can be accessed by everyone. However, people with visual impairments have been prevented from taking the full benefit of this prominent new technology due to the accessibility issues and barriers attributed to the predominantly visual content of the Web (Hackett et al, 2004). One of the disadvantages faced by blind people is that, they are not able to fully access graphics available on the Internet, which might carry a comprehensive set of information. They can only get a general idea about the graphics from the text descriptions provided within the graphic via speech output systems, for example a screen reader, or Braille display, provided that the text descriptions are available and precisely describe the graphic. In order to improve graphics accessibility, much research has been performed in an attempt to present information embedded in graphical Web content to visually impaired people. Many studies showed that haptic feedback can serve as a substitute for visual feedback, due to the high similarity between visual and haptic modality (Keyson, 1996; Gibson, 1966). For instance, Picard et al (2003) has used both cross-modal matching and transfer task to show that vision and touch were perceptually equivalent for natural textures perception. Henceforth, numerous haptic technologies and research related to this area have been introduced and carried out respectively in accordance with the results of these studies. For instance, an online virtual graph construction tool which allows blind people to create and explore a virtual graph using a force feedback mouse has been developed by Yu et al (2003). TRIANGLE, a computer program developed by Gardner et al (1998) uses non-speech audio as an alternative technique to traditional graphing methods.

Despite that there is so much research aimed to boost the accessibility of graphical content on the Internet for visually impaired users, they provide their own solution to a particular problem based on a fixed set of hardware. For example, the applications only works with a force feedback mouse to explore graphs, a Braille display for text, or audio sonification methods to present computer games, etc. There is a lack of an integrated platform that allows visually impaired people to access any graphical Web content without worrying about the type of device to use. Therefore, it is important to have an interoperable system that is able to handle various existing assistive technologies and competent of allowing users with visual impairments to access a variety of graphical Web content.

This paper firstly describes the main objective of a European research project – ENABLED, and details an adaptive architecture that has been designed and developed as part of this project. This architecture is developed to be capable of incorporating different assistive technologies to access diverse types of graphic content on the Internet. As an adaptive system, this architecture also adapts to the user's need and enhances

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user interaction with the system by considering user's profile and preferences. The paper is then followed by a short scenario that presents the use of the adaptive system. Finally, the paper concludes by presenting the potential impacts of this system architecture to people from various realms.

2. PROJECT DESCRIPTION

ENABLED (Enhanced Network Accessibility for the Blind and Visually Impaired) is an Integrated Project funded in the Framework 6 Programme and consists of 13 partners across Europe. The ultimate goal of the ENABLED project is to improve blind and visually impaired people's access to the information and services available on the Internet. Both desktop-based and mobile-based access are being investigated. In the mobile scenario, information about users' surrounding environment is provided on portable devices, for example a PDA, in order to improve their mobility. In order to achieve its objective, this project (1) develops technologies that create universal accessible content for the Web, and algorithms that convert existing inaccessible contents to be accessible; and (2) develops ubiquitous tools that enable easy access to information and interfaces that are adaptable and interoperable regardless of the location of the user and the equipment the user is using.

ENABLED is an ongoing project where one of its aims is to develop an adaptive interface for blind people to access different graphical content on the Web (Tan et al, 2005). The notion of developing such architecture is to create a system that is able to adapt according to various requirements and criteria. Therefore, it is developed to be interoperable and scalable by supporting multiple assistive technologies, is independent of graphical Web content and can adapt to a diverse range of user's profile and preferences. The rationale of this architecture is explained in further detail in one of the following sections of this paper.

2.1 Related Work

An adaptive system is a physical system that is capable of self-adapting its behaviour in response to its environment. The adaptation of a system is often relevant to achieving a goal or objective. It tries to adapt to relevant variables in order to achieve its goal. Normally, the goal can be realized in systems that have feedback (Bar-Yam, 2000). Adaptive systems have been considered in a wide range of recent research efforts, in which two of the most common domains are mobile computing (Sun and Sauvola, 2003) and hypermedia (Stephanidis et al, 1998a). The variables in which an adaptive system can adapt to vary according to the main objective it intends to accomplish, for instance users, environment, media devices, input/output devices, platforms, network services and so on. Nevertheless, adaptation to users has always been considered when developing an adaptive system, in accordance with the definition given by Oppermann (Oppermann, 1994), where an adaptive system should be able to change its own characteristics automatically according to the user's needs. Designing a user adaptive system alone can be one significant area of research. Individual user adaptation may include adapting their needs, goals, preferences, knowledge, interests, skills, impairments and so on.

Attempts have been made to achieve interoperability between different input devices. For example, Gammenos et al (2005) has developed UA-Chess, a universally accessible Internet-based chess game that uses a variety of alternative input/output modalities and techniques in any combination according to various user profiles. Meanwhile, another reference project, AVANTI, has developed and evaluated a distributed system that provides hypermedia information about a metropolitan area for a variety of users (Fink et al, 1997). In this project, the integration of input and output devices is provided by a Device Software Layer to uniformly control and communicate with different input and output devices (Stephanidis et al, 1998b). In order to adapt to existing Web content to meet the specific needs of user, Huang and Sundaresan (2000) has developed an extensible transcoding system, Aurora, to help the broadest population of users, particularly in the disabled community, to obtain various Web-based services, such as online auctions, search engines, etc. It uses a transaction model to characterize user's abstract goals, and then extracts and adapts only the Web content relevant to the goal in order to be presented to the user.

Basically ENABLED adaptive architecture possesses similar objectives to most of these systems, which is to create an adequate interface to its user by adapting to the user's requirements and favourites and other variables. However, in addition to adapting to user's needs and preferences, the ENABLED system also focuses on the adaptation of different assistive technologies that are available for people with vision difficulties so as to enable them to gain access to the common types of Web graphics.

2.2 System Architecture Overview

An adaptive system should be designed to be aware of and adaptable to different variables according to its aims. In the domain of mobile computing, research and studies are carried out to find models and techniques to design an adaptive application which is able to support different devices (for example cell-phones, PDAs), adapt to the environment (if it is noisy room, low light), or perform adaptation based on user requirements. The goal of this research is to develop an adaptive system which enables visually impaired users access to various graphical contents on the Web through existing assistive devices. Therefore, there are three main variables that are to be considered in this system, which include (1) various existing assistive technologies; (2) diverse types of graphical web content; and (3) user's profile and preferences. The fundamental concept of the ENABLED adaptive architecture is depicted in Fig. 1, which also illustrates the interaction between these variables and its end-users.

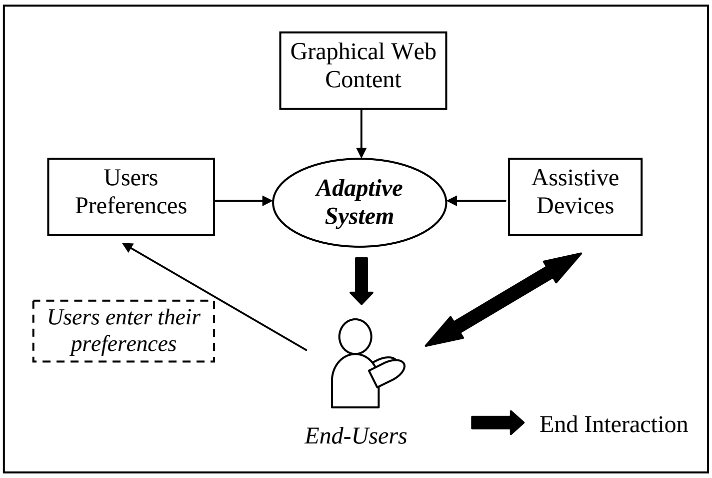

Figure 1. *Graphical presentation of the basic concept of ENABLED adaptive architecture, which adapts to assistive devices, graphical content and users.*

Nowadays, there is a wide range of assistive technologies available to improve Internet accessibility of users with visual difficulties: tactile or haptic modalities, 2D or 3D devices, low or high cost technologies and so on. Users are free to choose the assistive device they like or they could afford. Hence, it is vital to ensure the architecture is capable in adapting at a device level. On the other hand, as graphics have become one of the dominant components in Web pages, there is a wide variety of graphic information offered online. Examples of available Web graphics include information-oriented graphics such as graphs, interactive maps, images, drawings, photographs, and so on. These graphics can be in numerous file formats, for instance, the most commonly used computer graphics file formats on the Internet are JPEG, PNG, SVG and so forth. By considering the diversity of the graphics, users who utilize this architecture are not restricted to explore only certain type of Web graphics. An adaptive system often involves adaptation to its users. Interaction between user and system is crucial and the latter ought to be able to have the competency to meet the individual abilities, requirements, and favourites. In the following section, a detailed description of the ENABLED adaptive system that is capable of adapting to users, assistive devices and graphical web content will be presented.

3. SYSTEM ARCHITECTURE DESCRIPTION

This adaptive system is compatible to most of the Microsoft Windows-based browsers, including Windows Internet Explorer and Mozilla Firefox. This is one of the advantages of this system as statistics show that both of these browsers are the most popular and commonly used by Internet users (W3Schools, 2006). The architecture basically composed of five main components, namely: (1) Web Content System, (2) Context Manager, which consists of Configuration System and Preferences System; (3) Core Processor Module; (4) Application Database; and (5) End Interface. Each of these components is responsible for different roles and interacts closely with each other so as to constitute a seamless adaptive system. The interaction between all the aforementioned components and end-user are depicted in Fig. 2. The end-user provides input information about the graphical Web content and chooses the assistive technologies to be used for the graphic exploration. The information about the graphical content, which is the type and the file format of the graphic, are then perceived by the Web Content System. Adaptation to users is handled by the Preferences System, which is part of the Context Manager. Besides taking care of the user's requirements and favourites, Context Manager also presides over the computational and device technical information with the help of the Configuration System. By gathering the provided inputs, the Core Processor Module processes and administers this information and locates the most appropriate end interface for the user from the Application Database. The Application Database stores stand-alone sub-applications which are responsible for both graphics and haptic-audio rendering. The End Interface communicates with the assistive technologies, which could be an audio speech output and/or haptic modalities, so as to be presented to the end-users.

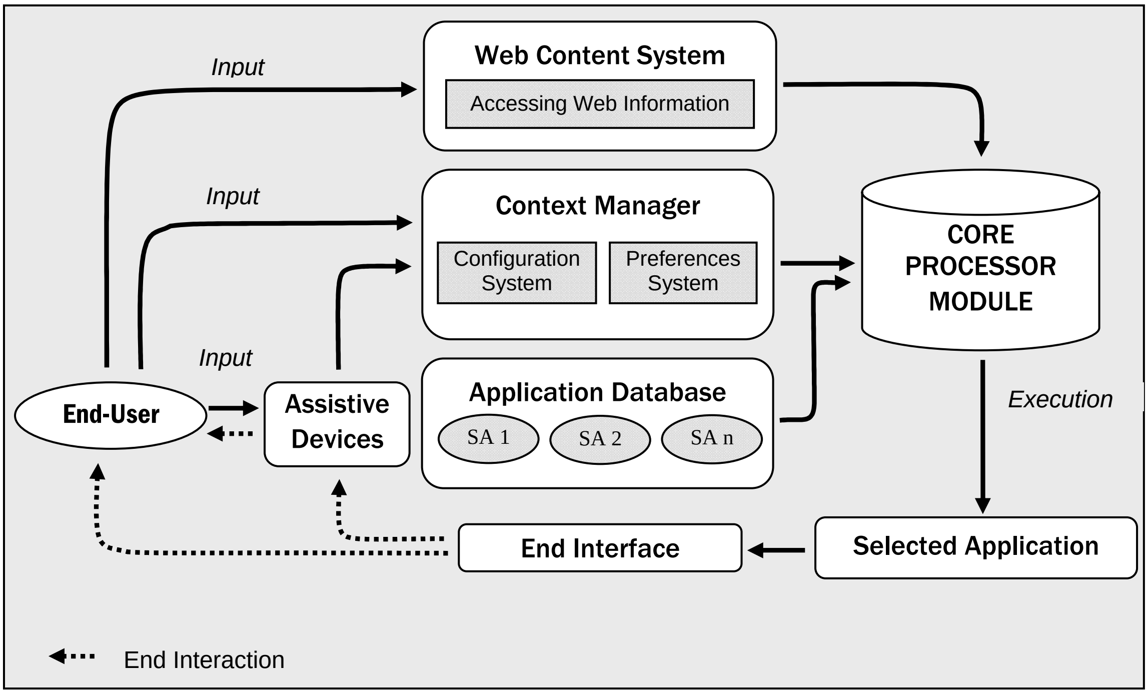

Figure 2. *Architecture of the ENABLED adaptive system.*

3.1 Web content detection and system launching

The first part of the system has been developed, which is to detect the types and formats of graphical Web content, and also to launch adequate interfaces for its users. The following sub-sections elaborate the underlying design principles of the developed system and interaction between the system and end-users.

3.1.1 Design considerations for the system launching. During the process of designing and developing, a number of significant design factors which are closely related to the end result of the use of the adaptive system have been considered. One of the apparent aspects that ought to be considered when designing a human-computer interaction system is the user interaction issue (Schmidt, 2000). The interaction between user and system should be simple, straightforward and understandable especially when the user target group for this adaptive system is people with vision impairments. The involvement of users should be kept to a minimum. Additionally, the main input and output devices that blind people use on a computer are the keyboard, Braille display or text-to-speech engines due to the use of mouse to navigate could cause frustration and disorientation to them (Yu et al, 2004). Therefore, the human-system interaction in this architecture can be accomplished by using keyboard or mouse independently. The restrictions faced by visually impaired users have been taken into account, for example, by reducing the number of pop-up or prompt boxes displayed to blind users. The problem of having prompt boxes is that, most versions of text-to-speech synthesizers are not capable of reading the content of these message boxes. They only read the title bar of the pop-up boxes, which in many cases, the title of the pop-up windows tell nothing about the message, and this may cause difficulties and confusion to people with visual difficulties.

3.1.2 Design rationale of the system launching. The ENABLED system is a stand-alone application. It is developed by adopting the features provided by Microsoft Active Accessibility (MSAA) technology, which was introduced by Microsoft to provide a standard programmatic access to user interface (UI) elements of Windows-based applications (Ford, 2004). By implementing this approach, the system is able to manipulate the UI elements that are currently accessed by users on a Web page. In order to have access to a graphic contained within a Web page, this adaptive system needs certain information about the graphic. Therefore collaborations from Web developers are required. Web developers who would like to allow visually impaired users access to graphical content embedded in their Web page need to provide an additional button, the *"ENABLED"* button for each of their graphics. These buttons carry information about the graphics types and formats, and also the data file of the graphics. Data file is a file that contains raw data and information about a graphic so as to create the graphic. It could be in many file formats. For example, a graphic with SVG extension contains a mixture of script and XML for defining the graphic. It is required by the sub-application in order to create a suitable interface to users. To differentiate a button from one graphic to another, it is essential for Web developers to include keyword(s) for each graphic on the button after the "*ENABLED*" text. For instance, if a button associates to a map of Europe, the text of the button could be "*ENABLED: Europe Map*".

3.1.3 Trigger action and its rationale. By installing this adaptive system onto their machine, users are able to run the system in the background whilst they browsing or surfing the Web. A user who is prepared to employ the adaptive system to explore Web graphics should understand that Web pages that integrate with this system would have buttons with "*ENABLED*" text on them. These buttons act as the *trigger switch* of the system.

As recommended by various multimedia accessibility experts (National Council on Disability Washington, 1998), in order to ensure that blind users have full access to the Internet, there should be a keyboard equivalent for each designed feature in any of the human-computer system, in which mouse access should never be the only method of access. Consequently, the launching of this system is developed with the reference of this accessibility rule, in which it can be in the complete trigger by keyboard for the benefit of blind users who are not familiar with the use of the mouse. For users who are familiar with the use of the mouse, once they decide to know more about a graphic, they could simply click on the button, and press the *ENTER key*. Alternatively, the key can be pressed whenever the keyboard focus is on the button. On the whole, this trigger action notifies the system that the user is now ready to know more about this graphic. For user who uses a screen reader to navigate the Web, when they are sure that the keyboard focus is on the button which refers to the graphic they are interested (via their assistive technologies), they should press the *ENTER* key once to confirm the selection of this graphic. If JAWS screen reader is used, to turn off the virtual cursor used by JAWS, user has to press the "-" on the num pad or "*INSERT + Z*" simultaneously. By pressing the *ENTER* key once again, it notifies the system to go for the subsequent stage.

3.1.4 Results of the trigger action. The notification from users leads to subsequent operations. The system firstly downloads the data file of the graphic from the server to a specified folder that automatically created during the installation of the ENABLED system. It also determines the type and format of the graphic and notifies the Core Processor Module about the findings. The information about the graphic is vital as to allow the adaptive system to make the correct choice in launching the suitable sub-application accordingly.

3.2 Sub-applications

Both functions of graphic rendering and the generation of the haptic-audio interaction are encapsulated in the stand-alone sub-applications. It could be developed independently by researchers and developers in computer graphic rendering or haptic interactive techniques, and subsequently integrated with this adaptive system. A sub-application can extract the essential information of a graphic from its data file and translate them into their internal representation; for example, the internal data for a graph would be its numerical data, title of the graph, name for both axes, and so on. It is important to create and support the geometric representation of the graphics such as lines, curves, surfaces, etc so as to be used to get the corresponding haptic and audio feedback by analysing the user cursor position regarding the geometric model of the graphic. The available sub-applications have to be registered with the adaptive system so as to be recognised and stored in the Application Database in the system. In order to do so, information about the new sub-application needs to be provided to the system and included into the database.

3.3 Adapting to the user's context

In order to be able for the adaptive system to launch the correct sub-application in accordance with the selected graphic, the Core Processor System carries out a number of specific tasks by accumulating and manipulating the crucial information which has been transmitted to it.

The Context Manager is a cache that stores all the context information about the users, operating systems, assistive technologies and the available sub-applications, which are taken care by the Preferences System and Configuration System. The information is grouped into four main categories: (1) computational information, which is about assistive technologies (haptic, tactile, sound, speech), web browsers, computer operating system (version, language) and so on; (2) user information, which explains about their visual and other impairments, haptic/tactile and audio experience, and it also helps to identify users with their unique identification; (3) user preferences, which includes their preferable language, interaction methods, input and output interface and also about their computer and Internet skills; and (4) application preferences, which gives the information about available sub-applications that are recognised by the adaptive system.

There are two stages of checking before the related sub-application is called (see Fig. 3). After the detection of the type and format of the graphic selected by the user, the system compares this information with the configuration system to look for the appropriate sub-application that is able to handle this graphic format. If the result denotes that there are two or more sub-applications stored in the database which is capable of handling the same type of graphic, the system then searches for the user's preferable interface from the Preferences System and compares it with the feedback offered by those sub-applications. There is a possibility that two sub-applications provide the same kind of feedback to their user. When this situation happens, the system informs the user about the features, functions and limitations of both of the sub-applications. The user could choose from the sub-application selection according to the interaction style and other utilities, for example haptic utility or zooming, panning, scaling and so on, that offered by the sub-applications.

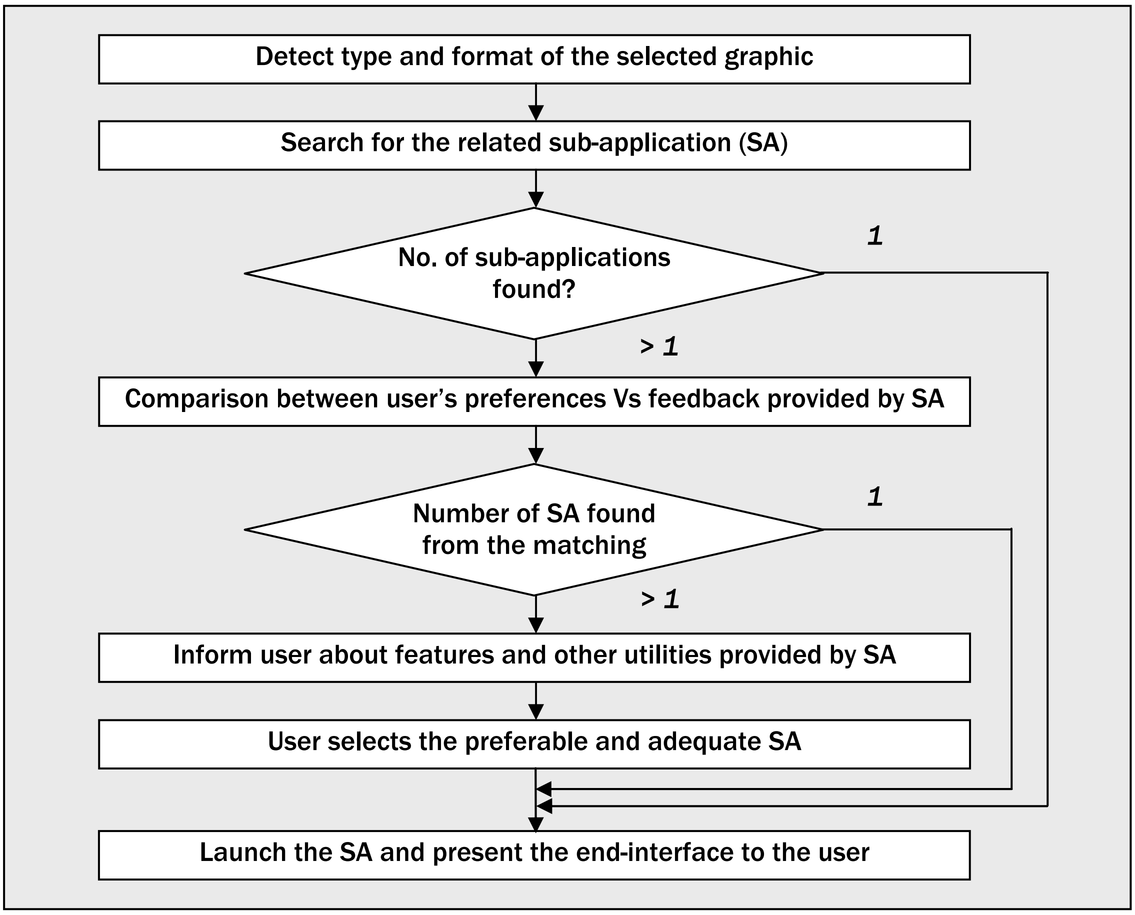

Figure 3. *Flow chart illustrates the process of launching the adequate sub-application which adapts to the graphic content and user's preferences.*

4. CONCEPTUAL EXAMPLE

A short scenario is depicted to present the use of the adaptive system described in this paper. Adam, who is a congenitally blind computer user, encounters a lot of graphs in his job. He decided to use the ENABLED system so that he is able to discuss with his colleagues about the graphs he found on the Internet. With the help of his colleague, the ENABLED system is installed on his computer and he is familiar with the specification of the system by reading through the readme file of the system, as well as from the online training on the ENABLED website (ENABLED online training website). He then creates his own profile and preferences with the system and sets them as the default settings.

Every morning, he runs the ENABLED system and also the screen reader application before he starts browsing the Internet using a standard Internet browser. As he is a JAWS screen reader user, Adam normally uses the up/down arrow keys and also JAWS quick navigation keys to navigate a Web page. When the keyboard focus is on a link or button, the text of these elements will be heard via his screen reader. One day, he found there are a few graphics on a Web page but he is only interested in one of them, which is a statistical graph indicating the trend in browser usage in 2006. By knowing that there is an ENABLED button for this graphic via his screen reader, he can differentiate that the Web page he is accessing is compatible with this adaptive system. Therefore, he presses the *ENTER* key once when he is sure that his keyboard focus is on the ENABLED button for that graph. Then he turns off the JAWS virtual cursor by pressing the num pad minus before he presses the *ENTER key again to start accessing the graph.*

The system then detects that it is a spreadsheet graph and downloads the excel data file of the graph to Adam's machine. From the Application Database, the system determines that there are two sub-applications which are able to handle an excel graph. On the other hand, from the Configuration and Preference system, the system identifies that there is no haptic device connected to the computer and the user prefers to have audio feedback and does not have any haptic/tactile experiences. Therefore, the system goes through the specification of both sub-applications and configures the features and feedback provided by them. As one of the sub-applications offers both haptic and audio feedback, whilst another provides only an audio interface, the system therefore launches the second sub-application and presents it to Adam. As a result, Adam is able to know more about the graph through his audio feedback and he is able to discuss this with his colleagues.

5. POTENTIAL IMPACTS OF ADAPTIVE ARCHITECTURE

The most noticeable merit that can be gained from the ENABLED adaptive architecture is dedicated to people with visual impairment, in which the system provides the ease of accessibility of Web graphical content to these users. Apart from the benefits it brings to the end-users, the system is able to incorporate different assistive technologies to increase the accessibility of graphics for users with visual difficulties. It is capable to make provision for the emergence of new assistive devices which might be introduced in the future. It gives the opportunity to adapt the system to future new developed functionalities and technologies. Software developers or researchers can develop new accessible applications based on this architecture in order to make more types of graphical contents accessible via different forms of assistive technologies. An assistive technology developer or a device manufacturer could easily integrate their interfaces with the ENABLED system by providing a hardware interface according to the ENABLED specifications. In additional, this architecture can act as a frame of reference to developers in other realms when they intend to develop a similar system of their own in their domains.

6. CONCLUSIONS & FUTURE WORK

In this paper, an adaptive architecture has been presented which is interoperable and capable in incorporating multiple assistive devices to gain access to diverse types of graphical Web content in different formats, and also adapting its user's context. The primary development of this system, which is to detect the graphical Web content that a user is interested in and to launch an appropriate sub-application, has been performed and presented in this paper. The fundamental concept and design of the continuing development of this adaptive system are also included as part of the paper.

This adaptive architecture has foreseen substantial benefits to people from diverse realms. Users with visual impairments would be able to gain the most advantage as the ENABLED adaptive system could improve their accessibility in exploring graphical web content and make such a task easier for them. With the existence of such architecture, it can save a lot of effort in developing systems that are capable of adapting to forthcoming devices and provide a significant solution to future needs. This adaptive system is believed to have the ability to enable more efficient interaction between the new assistive devices and the users, thereby increasing user experience. This is an ongoing project to show the feasibility of developing such system which is able to adapt and cope with several variables concurrently. Evaluation has been completed to assess the usability and accessibility of the developed prototype, which requires users to trigger an action to launch an adaptive interface. The results of the evaluation is being analyzed and further development on the architecture will be carried out in order to achieve the ultimate objective, which is to produce an adaptive and extensible system.

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