Digital Accessibility for People with Special Needs: Conceptual Models and Innovative Ecosystems

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Abstract

Digital technologies in present day interconnect globally, providing a dynamic environment to support the educational needs of any learner within a novel technological ecosystem. The paper discusses the identified aspects of providing relevant digital accessibility to learners with various needs by this ecosystem, such as sensor support, knowledge provision from a variety of digital and non-digital repositories, and support to the motivation of the learner to acquire better knowledge in the classroom, museum, or in rehabilitation. A novel tool for assessment of such technological ecosystems, called Accessibility Barometer, is described.

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***Abstract*— Digital technologies in present day interconnect globally, providing a dynamic environment to support the educational needs of any learner within a novel technological ecosystem. The paper discusses the identified aspects of providing relevant digital accessibility to learners with various needs by this ecosystem, such as sensor support, knowledge provision from a variety of digital and non-digital repositories, and support to the motivation of the learner to acquire better knowledge in the classroom, museum, or in rehabilitation. A novel tool for assessment of such technological ecosystems, called Accessibility Barometer, is described.**

Keywords—Technological ecosystem, accessibility barometer, special educational needs, healthcare, robot assistants

I. Introduction

Digital technologies in present day interconnect globally, providing a dynamic environment to support the cognitive needs of any learner, linked to the web via the appropriate interface. They are being defined as *ecosystems* of "developed and linked software, hardware, and people working collaboratively" [1]. One class of such ecosystems are intended to provide digital solutions in the special case of people with disabilities. "These ecosystems use open-access technologies that have a large scale impact, with results that support people with disabilities and provide an enjoyable user experience, in addition to helping them improve their health" [1] (p. 7). We have adopted a similar framework to account for three different types of *needs*, mirrored in the respective accessibility barriers, when providing digital resources to learners – the *sensor* barrier, the *knowledge* barrier and the *motivation* barrier as central elements of the developed conceptual model. The accessibility model, proposed in [2] has placed the human in the centre, surrounded by several layers of accessibility barriers. The closest layer is the layer of human knowledge, experience and motivation. When providing knowledge, harvested from the web or any other repository – museum, library, school, etc. - this central barrier to accessibility is called *intrinsic* since it depends on the profile/personality of the learner – motivated, experienced, etc. Educational scenarios/tools, increasing learner motivation, are being employed, including robots as mediators to knowledge [2],-[3], [4]. Next is the layer of the sensor barrier to knowledge. For overcoming this barrier a variety of interfaces of different modalities are being proposed (3D printed objects, Braille keyboards, etc.) or social networks of volunteers to help improve knowledge accessibility, e.g. [5]. The external – i.e. *extrinsic* layer is the layer of social-economic barriers – the affordability of a device, or of enrolment in a course for people with special educational or sensor needs, etc. according to [6].

The present paper discusses three identified issues in designing digital systems for help in overcoming various barriers to knowledge in the present-day social environment being a complex innovative *ecosystem*, integrating in itself ubiquitous web access, devices such as robots and systems such as intelligent chatbots. The three issues are sensor support, knowledge provision from a variety of digital and non-digital repositories, and increase of the motivation of the learner, supported by a novel tool for assessment of such technological ecosystems, called Accessibility Barometer [7].

The Accessibility Barometer is foreseen as a universal tool to assess the inclusion in the technological ecosystem a variety of digitally enabled means to support access to knowledge of any learner any time and place [8].

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II. Accessibility Barometer Design

A. *Conceptual Structure of the Proposed AB Ecosystem*

A project on design of an "Accessibility Barometer (AB)", aiming to be able to assess the digital resource at the respective Url as sufficiently, or insufficiently, accessible for people with different needs, is currently being developed [7]. A print-screen of the AB website is given in Fig. 1. [8].



Fig. 1. Accessibility barometer website.

The "Accessibility Barometer" concept implies creating optimal and applicable conceptual models for digital accessibility; context-dependent use and content sharing in accessible socially-grounded ecosystems; specialized training for digital accessibility, incl. with cloud-based robotic technologies; development of accessible repositories and software environments with open access for improved access to knowledge in digital collections.

The conceptual structure of the proposed AB tool is given in Fig. 2. As pointed out in [1], the main components of the technological ecosystem are: *software*, *hardware* and the *people*, *working collaboratively* on its design and implementation. Some issues, addressed in relation to the implemented *software* are discussed in [7]. In support of accessibility for people with severe or total vision loss, a site with accessibility and QR codes, a training site, and a system with appropriate digital representation and encoding of information, are analysed.

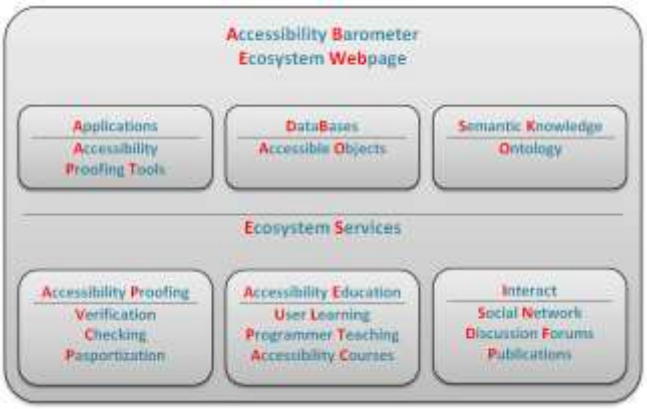

Fig. 2. Accessibility barometer (AB) conceptual structure.

The free-licensed platform Protégé by Stanford University to build the ontology structures is being used [9]. RDF-, RDFS- and OWL- description technology is used to record the knowledge and semantic connections between each element in several ontological structures, divided by the purpose of knowledge use. These include: teacher and co-teacher ontologies, describing human teachers' roles in the educational process and containing knowledge of their behaviour; student ontology, oriented to a specific subject area of knowledge, based on recent theories of learning, personality, cognitive and neuro-cognitive development, containing knowledge of the individual student learning and psychological profile (incl. talents and needs); lesson ontology, describing the teaching materials, teaching methodology, the content of teaching materials and other activities in the field of training, needed to construct a better teaching resource; robot ontology, containing explanation and means for optimization of the robot's actions and roles in performing tasks in the innovative classroom, based on the AB concept (still under development).

Integrating the new language models in every-day technologies or specialized assistive technology devices or apps can significantly improve the life of the people with disabilities. Here we give two working examples. The first one is the implementation of GPT-4 [10] into specialized smart glasses [11] that help blind users to read printed or screen text, recognize objects, colours, currencies, etc. The recent implementation of GPT-4 is set to help visually impaired people to easily access and understand the world around them. They can ask questions about the just scanned text as menu cards, cooking instructions, a book, an electricity bill and so on. The questions can be context specific like choices for vegetarians in the menu, healthy meals, calories, taxes in bills. According to the developers the feature increases the access to information, gives more independence and opens new opportunities [12].

In relation to the *people*, *working collaboratively* [1] as part of the innovative ecosystem, an example is a free mobile app, which recognizes not just text, but pictures as well. The app's name is "Be my eyes" and its voluntary base is the largest in the world. The app connects almost 500 thousand registered blind and visually impaired people with over 6.5 million volunteers worldwide [5]. The users also have a number of big technology companies they can call for a sighted assistance with their products. The newest feature, still in private beta, is called "virtual volunteer" [13]. Based on gPT-4, it allows uploading a picture, analyses it and returns the results. The AI can describe the visuals and answer contextual questions about the objects, their position in the composition, the colours, the time it is taken, and so on. These readily available applications are compatible with the developed AB system for better access to knowledge of people with visual difficulties both in textual or pictorial format.

In relation to *hardware*, except from the communication infrastructure behind the implemented software for support of people with some sensor deficit, robotic technologies are implemented in support of children/learners with special educational needs. To the rest of the paper we will discuss issues related to the Accessibility Education, focusing on User Learning (Fig. 2).

B. *Digital and e-Learning Accessibility for People with Special Educational Needs - a Robotic Perspective*

A novel conceptual model for efficient provision of knowledge from the web for children/learners with special

educational needs with the help of humanoid robots was described in [2]. The experimental situation was similar to one of the tests of Piaget for overcoming the so-called "intellectual egocentrism" at the age of about 7-8 [14]. Within this framework children learn to "see" the world through the eyes of the other human in the room. This projection is equally transferable to a robot NAO, according to our demonstration to children, which is also much enjoyable by them. The child infers the mental picture of the robot depending on the facts about the robot witnessing an action or not. The deployment of robots improves the accessibility of scientific (digitally presented) knowledge by making it memorable and enjoyable, therefore by increasing the motivation to learn of the child. We plan to bring the scenario to a day centre to see if the effects to children with learning difficulties will be comparable to the observed demonstrations.

The attitudes of teachers, parents and children on the appropriateness of the inclusion of robotics and information technologies in schools were examined in an especially designed survey in several European countries [15]. Interestingly, parents were more enthusiastic about inclusion of digital and robotic education in schools from an early age than teachers and even children. Moreover, they were also convinced that that robotic and digital technologies are beneficial in special education, which is an essential outcome, relevant to the present research.

A framework for an educational technological ecosystem in inclusive classes is depicted in Fig. 3.

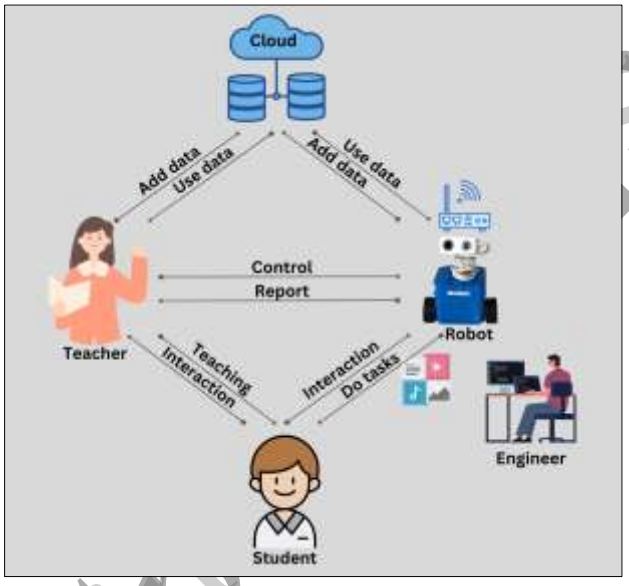

Fig. 3. Robotic and digital technologies in support of the teacher in inclusive classes.

The technological ecosystem allows inclusive education to take place outside any present day limitations, related to schools, such as – number of children in class, reliance on average performance of tests to define progress, lack of attention to the subjective state of the individual child, or the comfort in class, demand for physical presence in class, lack of adequate attention to children, possibly vulnerable due to pre-existing conditions, including sensor deficits learning difficulties or lack of motivation to learn. A notable feature of such a school is emphasizing collaboration, instead of the competitiveness in class, and encouragement for talent and imagination of all children.

C. The Inclusive Classroom of the Future

Fig. 4 illustrates the potential of the technological ecosystem to support every individual child during the lesson in a concerted with the teacher way. This support can be equally beneficial to the slow, as well as the fast, learners, and to learners with sensor deficits. This classroom will require, however, a higher level of autonomy of the robots, on the one hand, and a larger extent of orchestration of the software performance outside the classroom – i.e. in the cloud. The proposed inclusive classroom of the future is depicted in Fig. 4.

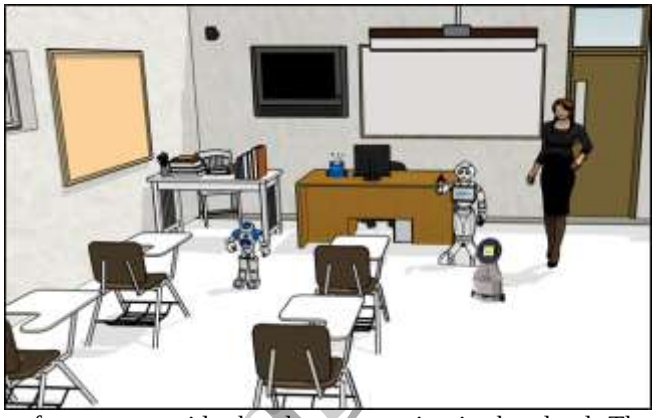

Fig. 4. The universal classroom of the future.

The concept of the Inclusive Classroom of the future was piloted in an educational experiment carried in the Day center for children and youth with disabilities "Sveta Nedelya" (Sandanski, Bulgaria) [16]. Figure 5 represents the reinstated classroom where teachers and robots pay attention to each individual child according to their current learning need.



Fig. 5. Robot-assisted teaching in the classroom

A cyber-physical system has been created, made up of the following elements (Fig. 5):

- ✓ Educational service robot BeBot controlled with a custom developed software framework;
- ✓ Laptop for programming and managing of the robot;
- ✓ WiFi router, which ensures connection between devices and also high speed Internet connection to the cloud;
- ✓ Teachers, from the Day center, especially trained for educating and assisting of children with special needs;

- ✓ Robo-engineers to ensure robot programming and safety operation of the equipment;
- ✓ Cloud to fetch educational content and to store experiment log and results.



Fig. 6. Robot BeBot is helping teacher for a math lesson

The robot used in this scenario - BeBot (Fig. 6) is developed at the Institute of Robotics – Bulgarian Academy of Sciences (IR-BAS) and have the following capabilities:

- ✓ to do precise movements and rotations of the mobile base;
- ✓ to speak using a TTS engine that supports 127 languages;
- ✓ to project images and videos on the wall (the robot head is a high resolution DLP projector);
- ✓ to express different emotions using specially designed emoticon images and the head-projector.

The robot programming and choreography are done using the software framework, called ERICS, also developed at IR-BAS. The educational experiment in general is a robot assisted math lesson, where the children can be taught to sum the numbers from 1 to 10. The robot projects a movie with the lesson, speaks and makes funny moves. The teacher guides the entire process and gives confidence to the student so that the acquired knowledge is retained. The BeBot robot with its projection capabilities captures the interest of the child and makes the teaching process much easier. The teacher has the main and leading role in the teaching process and the robot is assisting the process, greatly improving the attention focus of the child on the educational topic. According to the teachers, involved in the pilot of this scenario, the proposed robot-assistive education has enormous potential for enhancement of the accessibility and teaching results, especially in students with attention deficits. The received feedback from the children, participating in the study, was strongly positive.

The usage of various cloud services enhances the educational content available to the teacher and also enables data processing and storage in real-time, as received from the robot hardware, which is essential for the smooth teaching process.

If robots can be successful ‘cyber-physical teachers’ in inclusive classrooms, they can also be efficient ‘cyber-physical guides’ in museums or any place where guiding is necessary in order to approach the object of attention – art galleries, theaters, concert halls, performing art places, etc. The learner can be assisted by the robot in using different sensor modalities – touch, sound, smell, etc.

A digitally accessible website audio-guide system with audio, photo, and text, connected to QR codes and physical Braille signs at the location has been developed for the Regional Ethnographic Museum of Plovdiv, Bulgaria, in cooperation with the digital accessibility team of the AB project [8]. It can be accessed locally in the museum with a phone and Internet access, as well as digitally and remotely online from anywhere [17]. The goal is to provide accessibility for a broader local, national and international audiences, as well as people with special needs and, in particular, visually impaired and blind people, to the specific tangible and intangible cultural heritage of the museum and the local region. It includes information about musical instruments and music, local traditions, crafts, rituals, clothing, religion, family live and everyday life artifacts. The QR code can be used by the robotic guide if the person needs such an assistance.

A special feature of our approach is that the implemented AB tool aims to link together education, entertainment and healthcare via the implementation of conceptually similar: the ‘cyber-physical teacher or museum guide’ and the ‘cyber-physical nurse’ [18]. The similarity is in the implemented ‘essential’ human features in the robotic agents – the behavior of the robot has to be accepted well by the person, seeking assistance, similarly to the help, offered by a human.

D. Human Features of the Collaborative Service Robot-Assistant in Healthcare as Part of the Ecosystem

A number of professional roles in healthcare are related to function recovery and relearning in rehabilitation of children, adults and the elderly. In recent years the number of incidents, e.g. on the roads, is increasing, leading to injuries which require recovery of sensor, motor or intellectual functions. In cases of long term injuries, for example, it is possible to bring the entire classroom to the hospital ward as designed to help the learners according to their individual conditions and needs for access to knowledge.

The AB tool can be of help in tailoring the relearning process and the rehabilitation of various functions of the injured individual of any age. In addition, with the increase of the Alzheimer cases in society [19] – the AB platform will become an even bigger necessity.

A crucial aspect of the implementation of robotic technologies in the social sphere or in healthcare is the level of motivation of the learner to interact with the robot, which, in itself, is an important research topic. A definition of the acceptable ‘cyber-physical nurse’, in this sense, is given in [18]: “If we imagine the 'perfect' robotic nurse, it will probably be a cyber-physical agent, who is best described as 4P - 'pleasant, patient, polite and powerful'” (p. 36979). Similar features are ‘essential’ for the acceptable cyber-physical trainer/rehabilitator as well and, possibly, the cyber-physical teacher, or museum guide. The AB tool can be useful in a number of technological settings where support to accessibility is needed and can be provided via digital means.

III. Conclusion

The paper presented the currently developed approach of the team of authors for design of an Accessibility Barometer, capable of assessing the appropriateness level of the employed tools for accessibility for different users of a variety of knowledge providers – Urls, smart classrooms, museums and art galleries, as well as rehabilitation systems in healthcare. The focus is on the universality of the

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undertaken steps towards digital and technological accessibility. Future research aims at testing the proposed AB tool in real-life situations.

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