DSpace: an Inclusive Repository for Cost-Efficient Development of Accessible Control Interfaces

Otilia Kocsis, Gregg Vanderheiden, Ignacio Peinado, Eva de Lera
Raising the Floor - International (RtF-I)
Geneva, Switzerland
otilia@raisingthefloor.org
gregg@raisingthefloor.org
ignacio@raisingthefloor.org
eva@raisingthefloor.org

Lukas Smirek, Gottfried Zimmermann
Stuttgart Media University
Stuttgart, Germany
smirek@hdm-stuttgart.de
gzimmermann@acm.org

Till Riedel
Karlsruhe Institute of Technology (KIT)
Karlsruhe, Germany
till.riedel@kit.edu

Nadia Fendrich
Fraunhofer IAO,
Stuttgart, Germany
nadia.fendrich@gmail.com

***Abstract*— The great increase of information and communication technology functionality in every-day living environments, from home appliances to public services, introduces complexities and inter-dependencies between heterogeneous devices and services, and imposes higher demands with respect to our digital literacy and technical knowledge. While young people seem to keep the pace, a large portion of the population world-wide cannot benefit of these advantages, especially people with disabilities, senior citizens and those having literacy and/or digital literacy problems. The development of cost-efficient solutions for those left behind, which would provide them with necessary assistive technologies and personalized user interfaces, can be achieved through reusability of resources and development of interoperable solutions. In this paper we present the design and implementation of a unified repository for developers – the Developer Spage (DSpace) – that was developed in the Prosperity4All project. The DSpace has an inclusive character and provides building blocks and resources for fast and cost-efficient integration of accessibility elements into new or existing applications and services.**

Keywords*— *inclusive repository; adaptive user interfaces; assistive technologies; accessible controls; smart environments

I. INTRODUCTION

The great increase of embedded Information and Communication Technology (ICT) functionality in every-day living environments, from home appliances to public services, introduces complexities and inter-dependencies between heterogeneous devices and services, and imposes higher demands with respect to our digital literacy and technical knowledge. While young people seem to keep the pace, a large portion of the population world-wide cannot benefit of these advantages, especially people with disabilities, senior citizens and those having literacy and/or digital literacy problems [1]-[3].

The terms digital divide, digital literacy and digital inclusion have been widely used in close connection to the Internet for a long time, although their meanings shift with changes in technology, from having access to being able to use and create a wide range of ICT resources. While the digital divide implies the gap, the digital literacy encompasses the skills and abilities necessary for access once the technology is available, the digital inclusion is the policy developed to close the digital divide and promote digital literacy [4]. The digital exclusion could be defined as the lack of access to and use of ICT resources for certain groups of individuals due to missing technological means and/or digital literacy skills/abilities. Many factors contribute to digital exclusion, ranging from infrastructure availability (e.g. internet, mobile communication, etc.) to missing appropriate assistive technologies for those in-need. It is also very often the case that accessibility is seen as a "black art" by most developers — understood only by a few experts, fraught with subtle design and legal issues, and generally difficult to penetrate for the uninitiated even in the case of development of official information services in developed countries [5]. It is also very challenging to find out which development tools have been built with inclusion in mind, and then how to best use them to their full potential [6].

In order to cope with these challenges, the Prosperity4all project aims on supporting the development of cost-efficient solutions for those left behind, which would provide them with necessary assistive technologies and personalized user interfaces. This can be achieved through reusability of existing resources at their full potential and development of interoperable solutions. Thus, the developers need an appropriate ecosystem and infrastructure, including resources and solutions, which enable reuse and integration of assistive functionality into existing or new software applications, without any concerns about the programming language and/or the platform used to implement and deploy the applications. Furthermore, they need support and feedback mechanisms from the end users of their access solutions, through an ecosystem that fosters co-design and co-development.

In this paper we present the design rationale and first prototype implementation of a unified repository for developers, the Developer Space (DSpace), a major component of the Prosperity4All inclusive ecosystem, which is shortly described in section II.D. The DSpace inherits the inclusive character of the entire ecosystem and provides developers with

information, building blocks, resources or even entire assistive solutions, for fast and cost-efficient integration of accessibility elements into new or existing applications and services.

Section II of this paper provides a generic theoretical background of assistive technologies and collaborative development environments, along with an overview of the Prosperity4All ecosystem and technological infrastructure.

In Section III the design rationale, including some illustrative use cases, requirements, and a first prototype implementation of the DSpace repository are presented. The current building blocks repository is also described, including the integration of major assistive frameworks to provide flexibility and efficiency to developers in the implementation of new solutions or enhancement of existing ones with accessibility features.

Section IV concludes the paper with a discussion about the design and implementation of the prototype, open research questions and the potential of such a repository with respect to inclusive products development in the future.

II. Background and Technology Overview

A. Inclusion and Assistive Technologies

Social exclusion/inclusion gained conceptual prominence across Europe in the early 1990s, with the European Union's Lisbon Summit in 2000 positioning poverty and social exclusion at the heart of the European social policy. Each member state was required to construct a biennial national social inclusion action plan where objectives included a priority to address marginalized groups at particular risk of exclusion [7]. Within the European developed countries, initially, affordability and access to facilities were the major exclusion factors. With better infrastructure and the falling prices of computers and Internet services in the recent years, the main barriers are now related to illiteracy, as well as to a negligence of linguistical and cultural diversity and lack of local content (e.g. government information portals, e-libraries, etc.). Currently only ~75% of the European citizens (individuals aged 16-75) in the developed countries are internet users, and the percentage of those holding basic digital skills (e.g. to access/use information and services) go further down to less than 60% [8]. Basically, 40% of the European Union population is still insufficiently digitally skilled to function effectively in the digital world. The results of a recent research, focusing on the influence of mobile technologies on social exclusion, demonstrate that although significant interventions in the form of new technologies may be aimed at less advantaged sections of the community, a range of barriers to information access and use still exists and prevent the full realization and ultimate success of these initiatives even in a well-developed country, such as the UK [9]. The direct access model, which considers direct access to information through technology as an efficient and cost effective way of addressing social inclusion, might fail if the information needs and barriers (e.g. digital literacy, social-emotional issues, etc) are not well understood and addressed ahead of digital inclusion initiatives.

For over three decades, the main technological stream was oriented towards reaching the "many" and providing unified solutions, designs and interfaces who would fit all users. Recent studies have indicated that innovative solutions and techniques, considering the provision of person centered interdisciplinary assistive technology services should be promoted in the future in order to decrease the gap between the digitally skilled and those left beyond [10], [11].

More importantly, too much time and effort has been spent "reinventing the wheel" due to poorly designed or inflexible components and tools. Today's software workflow often finds developers reusing "off the shelf" components that were designed for a specific purpose, usually without accessibility in mind. Although this initially appears to save time and effort, developers usually end up rewriting or replacing these components once their limitations become fully apparent. Instead, developers need to be able to draw from a pool of reliable, tested, and inherently adaptable user interface components, development frameworks, and debugging and design tools. As software development continues to evolve into a new era of cross-device "ubiquitous computing," including physical sensors, cameras, computer vision, and alternative control mechanisms, there is an incredible opportunity to produce novel assistive technologies at a lower cost, assuming that there are good-quality, "born accessible" building blocks to start from.

B. Colaborative Development Environments

The software engineers community is confronted with an increased need to design, implement and deploy multi-featured ICT applications which combine different computing paradigms and are developed using various technologies (e.g. web, mobile, sensor technologies), thus requiring dedicated development environments with adequate collaborative support (business, online learning, social networks, etc.). Standard collaborative development tools, enabling the facilitation, automation and control of the entire development process, include: (a) version-control systems, which allow software sharing in a controlled manner (e.g. SVN, Git); (b) trackers, which are used to manage software development issues such as defects, changes, support requests (e.g. Jira); (c) build management tools used to schedule the workflows (e.g. Maven), (d) modelers to create visual models using the Unified Modeling Language (UML); (e) content management systems used to share explicit knowledge on the web (e.g. Eclipse); (f) communication tools for synchronous and asynchronous collaboration (e.g. Google Wave, WebEx).

A collaborative development environment or ecosystem usually combines many of these tools together with other specialized infrastructure (e.g. business models, engagement technologies) to increase developer productivity and comfort, and optimize the entire product development cycle. Some of the most used environments, SourceForge (www.sourceforge.net) and GitHub (www.github.com), implement version control systems and trackers, but do not provide remote repositories and build management tools. Specialized collaborative software development platforms, such as the crowdsourcing one, require various kinds of communication, collaboration and coordination among the requesters, providers and platform vendors in parallel with a well-defined business model to encourage crowd members to

participate in development tasks and submit their solutions [12]. Software development in collaborative communities with social relationships requires community support and real-time interaction between the developers and people of special interest, thus dedicated collaborative development platforms should allow for user profiling, awareness and user access management [13]. Emerging complex cloud environments require additional collaborative tools, such as a testbed capable of emulating several multi-node Cloud environments and tools for automatic deployment of artifacts into such environments [14]. FIWARE is a recently build collaborative development environment, which provides an enhanced OpenStack-based cloud environment along with a set of open standard APIs for developers, to enable easier connection to the IoT, processing and analysis of big data and real-time media or to incorporate advanced features for user interaction in newly implemented solutions [15]. The ITHACA framework provides an environment for open source development of augmentative and alternative communication applications targeting end-users with disorders of speech-language production and/or comprehension [16].

Each of these environments has features that target specific type of projects, developer groups (e.g. cloud application developers) or end-users group, but do not provide sufficient flexibility, necessary tools (e.g. repository, infrastructure) and design features to support cost efficient implementation and personalization of assistive solutions employing various heterogeneous technologies. Alternative solutions, including free assistive technology software, are being investigated by various projects in an attempt to answer the multitude of problems of the market, especially the products' high cost [17].

C. *Global Public Inclusive Infrastructure (GPII)*

The GPII is a cloud-based software and service enhancement of the global broadband infrastructure designed to allow users to invoke and use access features in a cross-platform and device-independent fashion, and, at the same time, improving the interoperability between mainstream and assistive technologies [18]. In this scope, platform independent user preferences and settings are inferred from one device and translated into appropriate ones for another (eventually new) device, such that the user experiences common interaction modes/interfaces on all devices, either these are personal devices (tablet, laptop, mobile, home TV, etc.) or public devices (ATM, ticket vending machine, library PC, school PC, etc), old or newly acquired ones. The GPII is designed to support different delivery models in order to address the different platforms, degrees of lockdown, and type of adaptation a person requires: (i) User agent based solution, for access solutions installed and running on the user's computer/device, including: access features built into the operating systems or browsers, downloadable add-ons to platforms, commercial assistive technologies installed on a computer (e.g. FireVox, LowBrowse plug-ins, IBM Home Page Reader); (ii) on-demand web services, which provide transformations on demand when called automatically from content, by a user or by other web service; (iii) proxy-based transcoding, which is represented by proxy services that sit between the user and the content and interpret or modify its presentation on its way to the user; (iv) web-based user agents, which include web-based access technologies that can be used anywhere, from any internet-enabled device (e.g. WebAnywhere). It is also possible to have solutions that involve combined aspects of all these approaches, and take advantage of the strengths of the different approaches, while avoiding some of their limitations [19].

D. *Prosperity4All Ecosystem*

The Prosperity4All inclusive framework builds on the GPII infrastructure in order to create a self-sustainable and growing ecosystem, where developers, implementers, consumers, prosumers and other directly and indirectly involved actors (e.g. teachers, caregivers, clinicians) may interact with and play a role in its viability and diversity [20]. The Prosperity4All ecosystem employs modern techniques (i.e. crowdsourcing, gamification) and new strategies for developing accessibility services, and introduces a new approach to accessibility solutions development addressing marginal consumer needs, most notably people with disabilities [21], [22].

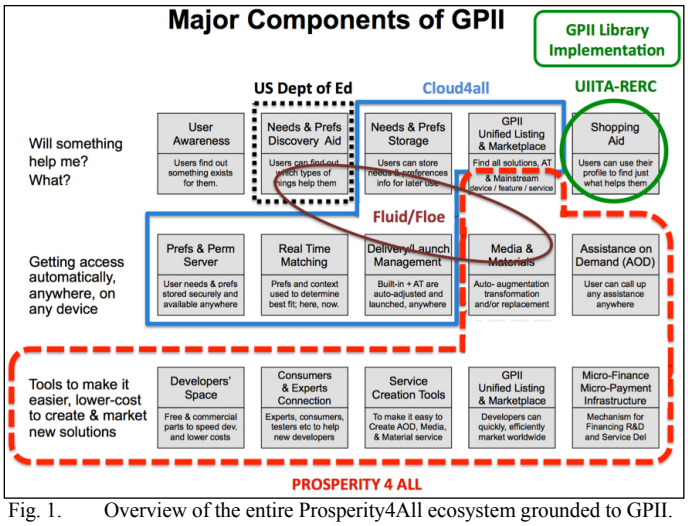

Fig. 1. Overview of the entire Prosperity4All ecosystem grounded to GPII.

The proposed infrastructure targets a highly diverse group of stakeholders, including but not being limited to: people requiring inclusively designed services or products; those who have services or products to offer, share or refine; financial interaction facilitators; trainers; policy makers; public services providers, etc. The DSpace presented in this paper is only a solution of the entire ecosystem, which addresses the needs of developers, who are designing and implementing assistive services, products or solutions. Fig.1 presents an overview of the entire Prosperity4All ecosystem grounded to GPII and other projects building on or extends parts of it: the GPII Library Implementation, a full production environment deployed in libraries in the USA; the Fluid/Floe project – (http://fluidproject.org); the Shoping Aid tool implemented by the Universal Interface and Information Technology Access Rehabilitation Engineering Research Center (UIITA-RERC), etc. Fig.1 clearly shows the variety of tools and solutions which can be used by the developers in connection to the DSpace in order to easier and cost-efficiently create and market new solutions (e.g. payment infrastructure, unified listing and marketplace, etc.).

III. DSPACE DESIGN AND PROTOTYPE

The design process of the DSpace followed the Inclusive Design Guide established at the early stages of the project [23], which provides details on the Principles, Practices, Tools and Activities to be employed from the very beginning when implementing a new solution, instead of trying at the end to add accessibility features. In the first step co-design was applied, with the developers being involved as active participants in the design process of DSpace prototype.

A. Use Cases and Personas

The identification of the requirements of each component of the Prosperity4All ecosystem, including the DSpace, started with the drafting of an initial set of personae (representative, fictive person of a user group) based on initial interviews with the developers, which were further refined in an iterative fashion through additional surveys and interviews. Similar to real users, these personae have diverse capabilities, needs and skill sets. For each personae, the use cases of the various ecosystem components were further analyzed to establish the functional requirements.

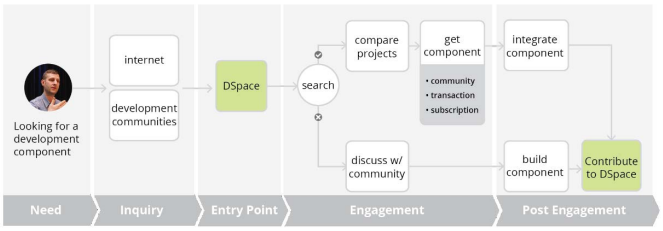

Fig. 2. Use case showing the role of the DSpace as entry and contribution point within the overall Prosperity4All ecosystem

Fig.2 presents a use case where the DSpace is the main entry point for developers in their engagement with the Prosperity4All ecosystem, providing both a way to obtain components and support for their work to implement/enhance a product, and a way for them to contribute their work back to the community if they desire. Similar use cases derived from the initial set of ten (10) personae were analysed and formed the ground for the functional requirements of the DSpace, further detailed in the following section.

B. Functional Requirements

The co-design step consisted in a series of usability evaluation sessions, to establish the general requirements, including the structure of the collaborative environment (main sections), and the requirements per identified section. Further details on the DSpace sections are provided in section III.C.

1) General Requirements

Structure: provide a simple navigation and an overview, through clearly structured sections, in order not overstrain the user and support him handling the content (e.g. four-parts/category design).

Contribution levels: support contribution level assessment for community members, with a competitive character.

Gamification elements or strategies: Using different gamification elements and strategies to motivate the user to actively interact on the DSpace platform (e.g a reward system where the user can earn points by answering a question in a forum, fixing a bug, providing a certain accessibility feature).

Analysis, critics and feedback are identified as mandatory features of DSpace design.

Accessibility: provide accessibility at all platform levels.

Sharing options: options like for example social media channels are desirable.

Must be useful: must offer valuable content to serious developers, to allow create new products that get to market.

Must be usable (easy to use): take into account the variability among potential users, thus should contain a different door for consumers (that are not technical).

Further links: using a blog and news page, it is possible to provide further correlating links to different topics.

Comfortable feeling: all users of the DSpace should feel comfortable using it.

2) Requirements for the Welcome Page as Entry Point

Standard requirements: support user authentication functionality for interactive usage, together with content search functionality.

Introduction: provide the user an insight into the content and what they can expect (e.g. implemented with a video) to arouse interest and motivate the users.

Get started: tutorial to introduce the platform to new users - how the website is working/ structured (e.g. video, teaser, infographics); adaptable to user experience level.

Four-parts/category design, as indicated by the usability evaluation: resources, parts & tools, people and service infrastructure (briefly introduced on first screen).

Field report/quotes/comments: allow for constant input assessment of end-users that are already using the DSpace, covering both developer and customer opinions.

3) Requirements of the People Section

Complexity: reduced complexity, friendly style to not overstrain non technical users.

Communities: supported by forums and question and answer portals, organized by content categories.

4) Requirements of the Resources Section

Research: enable developers to find and categorize different resources, and help the user easily locate specific information

Categories: optimization for best overview (e.g. relating topics) and sorting by different qualitative and quantitative metrics (e.g. popularity, number of votes).

Voting: implement voting functionality on various content type (e.g. questions, answers, topics, tutorials).

Tags: support content classification through tags collected in a library, to allow for fast identification of relating topics.

Badges: support a reward system, such as earning badges for achieving different tasks.

Search option: allows the user to find specific content within the research category.

Download or buying option: implement download and/or buy functionality (e.g. with a payment system in place).

Statistics of Resources: provide functionality for easy understandable statistics (e.g. infographics), that are showing different information (e.g. downloads within the last months, positive/negative votes, number of new products integrating the resource, etc.).

Quality metrics: implement quality metrics to summarize the hard facts of a resource and provide a quick overview (e.g. developer information, publishing date, quality of resource).

Reviews: support comment and rate of the resources.

Bibliographies: provide/link to collections of books and articles providing more general information about accessibility.

Strategies: share knowledge on proven successful strategies, to offer the user different approaches to find, build or create successful solutions.

Tutorials: implement a tutorial repository (e.g. video), to learn from experts or other community members.

Quicksheets: implement a quicksheets collection to help the user to catch information very quickly, either it is about a solution or a certain application domain.

5) Requirements of the Parts & Tools Section

Use: technically oriented look and feel, as it will be mainly used by developers.

Search and browse: advanced search (looking for a specific thing) and browsing (discover more while looking for one thing) mechanisms should be provided

Commercial Section: implement a dedicated section to offer the developers commercial solutions (e.g. applications, dlls, web services, etc.).

Open-source Section: offer the developers building blocks that can be freely modified and used to enhance or develop new solutions.

DIY-plans: this part of the DSpace requires fabrication plans with permission to replicate.

Description: all parts and tools included in the DSpace should be appropriately described, including both a summary (i.e. quick overview), a detailed description, and, optionally, an example of use accompanied by multimedia elements (e.g. videos or photos).

Similarly to the resource section, the following should also be considered for the Parts & Tools Section: tags, badges, categories, search option, reviews, download or buying option, statistics, quality metrics.

6) Requirements for Service Infrastructure section

Structure: similar to that of the parts and tools sector, taking into account the general requirements.

Barriers: lower barriers between developer and user.

Service: provide a generic and flexible infrastructure for users to create a service, which will be further promoted and made available through the Unified Listing of the Prosperity4All ecosystem.

Links: provide a collection of links to the real services, which are located elsewhere (e.g. Amazon hosted services).

Similarly to the Parts & Tools section, the following should also be considered for the Service Infrastructure Section: description, tags, badges, categories, search option, reviews, download or buying option, statistics, and quality metrics.

C. DSpace Prototype

The Prosperity4All Developer Space is designed to support developers in efficiently finding, using, and contributing to inclusive software development tools. Recognizing that tools alone will not produce better software, and that good software is a blend of technology, design, and knowledge, the Developer Space will also provide community resources and documentation that will help foster the adoption of accessible and flexible components. Inclusion has to be an integral part of the whole development lifecycle. Once a developer has selected a framework and set of components, there continues to be a need for visualization, testing, and debugging tools that can support the process of building flexible applications. The Prosperity4All Developer Space is designed to also support the creation and use of such tools.

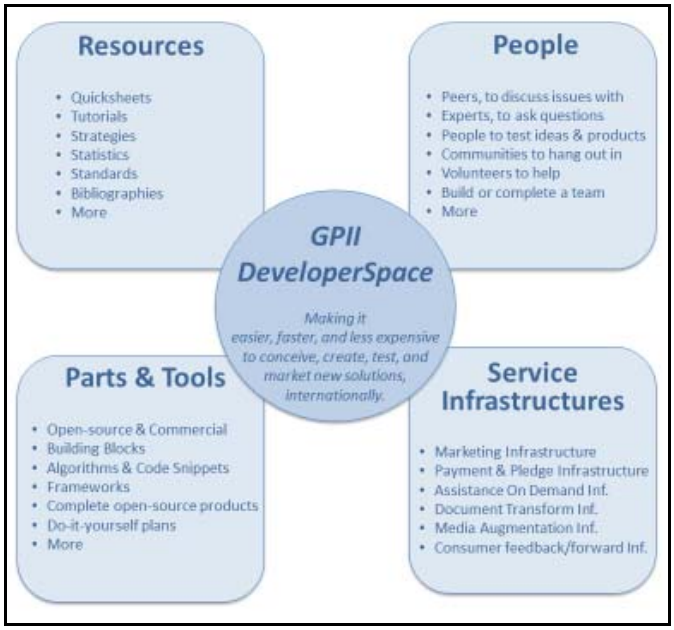

Fig. 3. Overview of the DSpace contents

Following, an expanding outline of what is currently available in the Developer Space is provided.

Parts Shelf: a collection and cataloging of software components and services that a developer can use in creating new commercial and free accessibility solutions. The

Prosperity4All Building Blocks will considerably increase this shelf and help collecting parts usable by developers.

Tools: as opposed to the parts shelf which holds components that are useful in an application, the Tools section contains things that are useful when building a product (e.g.an accessibility checker, versioning tool, testing tool). Parts and Tools together are also referred as Building Blocks, and we further detail on them in section III.D.

Frameworks: complete solutions that developers can use when creating their product. Frameworks are more along the lines of complete base, platform or environment from which to choose to build an AT solution. They can be considered a special class of parts that provide a wider range of abilities, parts, structure etc. Further details on the major Frameworks which are integrated with GPII and DSpace are provided in section III.E.

Resources: a collection of useful information for assistive technology developers. The information found here is not limited to the implementation part of AT development. Amongst other, it provides mainstream designers with the information they need to make their products more accessible from the start - including personae, design patterns, use cases, and other design resources that take into account the needs of people with disabilities. Resources on currently available solutions, types of needs, etc., can all be found here. The following are some examples of the types of resource information (about other resources, tools, and software) that are available in the Developer Space:

The **Fluid Design Handbook** is a how-to guide filled with user-centered design techniques you can use to learn from your users and design better user experiences. The handbook includes information on a variety of user-centered design practices, from performing user research and creating models (such as personas and scenarios to inform the design process) to performing user-experience walkthroughs and user testing of your website or application.

Dasher is an information-efficient text-entry interface, driven by natural continuous pointing gestures. It is a competitive text-entry system wherever a full-size keyboard cannot be used

Haptic RIA Maps is a web application (java applet) that retrieves maps from OpenStreetMap and enables their haptic exploration through the usage of ATs while listening to supportive audio information

Java Tutorials are practical guides for programmers who want to use the Java programming language to create applications. They include hundreds of complete, working examples, and dozens of lessons.

An important factor for the success and usability of the DSpace is that users (i.e. implementers) find useful tools and that developers can offer their tools in a fashion that they are found specifically by stakeholders in the accessibility domain. Therefore it was particularly important to look at categorization schemes. While this might be not so important for mainstream software developers looking for concrete functionality, many non-classical developer types we want to address, like AT product developers, healthcare professionals or relatives of peoples with disabilities have a domain specific view. Furthermore procurement might be a driving factor for accessibility improvements and the need for adoption of components, so that alignment with existing schemes might prove as an opportunity in some cases.

D. Building Blocks Repository

Since the accessibility community is rather small, the DSpace can't afford to position itself as a single, monolithic clearinghouse for inclusion-related tools and knowledge. Instead, it needs to serve as a means to connect and sustain a network (or federation) of contributors across a variety of open source projects and communities, without undermining the support and identity of these communities and yet addressing the fragmentation of knowledge that is systemic with the accessibility.

The initiation of the Prosperity4All ecosystem, and subsequently of the first prototype of the DSpace repository, was based on an extensive research on already available open source modules, libraries and components by 3rd party developers, thus establishing a comprehensive collection of AT-related resources for developers to complement the Prosperity4All specific and newly implemented building blocks and accessibility frameworks. Through the repository, the developers have the possibility to provide feedback on the existing solutions, comparatively assess them, contribute with use samples and tutorials, etc.

The editing interface of the Building Block repository is built on top of Drupal 7, and it provides an easy to use web interface that allows developers to add content. The categorization is done via a tagging interface, whose categories were derived through interface testing with end users taking into account terms bootstrapped from existing sources like the solution master list [24]. The tagging interface also allows the user to specify new categories, if needed, thus providing valuable feedback e.g. on missing dimensions (categories).

In addition to the 3rd party building blocks, several hardware and software modules have been further developed or refined for use within the Prosperity4All ecosystem, and made available in the DSpace. These modules serve various kinds of Human-Computer Interaction (HCI) tasks and/or allow interfacing of multimodal sensor data for application in assistive applications [25], and include: (a) microcontroller platforms for interfacing sensors or actuators to desired computing system (i.e. Arduino UNO, Universal HID Actuator), and (b) camera input modules which use computer vision algorithms for alternative computer input and haptic/touch I/O modules for adding haptic feedback to various user interface components (i.e. FacetrackerLK, P4A Haptic Module, Android Vibration Module). A special focus was put on the inclusive aspect of smart environments that allow spontaneous interactions of users with that environment, i.e. the fact that anything that can be controlled by user standing in front of a switch should be able to be controlled by anyone at a similar position with the same ease. Such building blocks in DSpace are: (1) EnOcean, an energy-harvesting wireless sensor network for home- and building automation tasks; (2) KNX

standard for building automation; (3) Point and Control, a module for special interaction through pointing gestures; (4) IndianaJS, a spatial location and interaction library for the Web-of-Things-enabled web sites; (5) Context-WiFi Login, a module for tag and context based authentication schemes for Wi-Fi access for so-called captive portals. As far as real-time user monitoring is concerned, dedicated building blocks are being integrated or fully developed in the Prosperity4all project (e.g. Fall Detection Module, Affect Sensing Module, jActivity - activity recognition module, open BCI – bioelectric signal acquisition and processing, etc.).

E. Major Assistive Solutions Integration

The below-mentioned set of frameworks that enable special input- and output capabilities for building alternative HCI solutions and accessible interaction strategies for novel (or existing) products, have been updated and modified for their integration in the Prosperity4All ecosystem, and are major assistive frameworks in the DSpace.

The MyUI framework provides an environment to generate a wide range of user interfaces based on multimodal design patterns, and render and adapt them to the user context during runtime [26]. The interaction modes and capabilities offered by an application to the user are abstractly defined in an application interaction model, based on UML2 State Machine Diagrams, thus allowing the developer to focus on the application itself and not on the adaptivity of the user interfaces. In Prosperity4All, the MyUI architecture has been updated to allow for modular extensions: different user interface solutions can be represented by different situation factories, additional data sources and functionality can be integrated using additional services.

The Assistive Technology Rapid Integration and Construction Set (AsTeRICS) is an open framework for the development of Assistive Technologies, with the main focus on novel, affordable and flexible AT-solutions [27]. The current technological market provides a plethora of sensor, processing and actuator plugins which need a powerful, AT-centred infrastructure, in order to efficiently control and combine ambient assistive services and/or sensors without programming. Interested 3rd parties in the field of AT can use the framework to easily integrate their products into the existing AT-landscape. In the scope of the Prosperity4All ecosystem a pure network based communication is envisaged, thus the AsTeRICS was upgraded, considering the Representational State Transfer (REST) software architecture style, to allow the implementation of scalable web services.

The aim of the Universal Remote Console (URC) framework, which has been standardized in ISO/IEC 24752, is to provide a mechanism, enabling users to control any target with any controller devices fitting best the user's needs [28]. Targets can be devices or services, usually such that can be found in the Smart Home or Ambient Assisted Living domain. Controllers can range from user interfaces running on PCs, Smart Phones over traditional remote controls to regular or specialized hardware. Controllers can download user interface components according to the user's need from a dedicated resource server. In order to apply the URC mechanism to non-standard-compliant targets and to connect several of them the Universal Control Hub (UCH) was developed. In the scope of Prosperity4All, a new, standalone, version of UCH was developed, which ships with an embedded tomcat server and enables the integration with the GPII infrastructure, making it possible to easily deploy and configure additional components at runtime.

During the Prosperity4all project the three mentioned technologies were integrated with the GPII and are a good example to show how different technologies, listed in the DSpace can benefit from each other. Users can be provided with personalized and adaptive access to various devices by combining the three technologies: AsTeRiCS provides alternative I/O modalities, MyUI provides an adaptive graphical user interface, and the UCH connects the tow interface technologies to all kind of Smart Home devices and solutions.

Although the major frameworks, AsTeRICS, MyUI and URC, were developed independently from GPII and from each other, it was considered that a solution integrating them in a lightweight and flexible way would benefit further the developers, and give them the freedom of feature choice from a pool, rather than limiting them in using one very complex monolithic system. Thus, in the current prototype the chosen integration approach based on common web technologies provides a more flexible the architecture [29].

IV. Discussion and Conclusion

While assistive technology repositories have been previously successfully implemented and reported [16] [30], the DSpace collaborative environment provides enhanced functionalities compared to that of the reported repositories through its ecosystem integration and provision of design assistance, interoperability infrastructure and end-users connectivity. The DSpace does not focus on a specific disability, a specific technology (e.g. mobile applications), but targets on providing the means to adapt/modify existing solutions to fit the needs of a very narrow niche of end-users along with the best-fit search.

The DSpace tools and solutions have been already used in demonstrators and real-world implementation of accessible solutions [31]. The Guadalinfo-enhanced Telecenters, the telecenter network focused on equal opportunities in access to ICT in the South of Spain, currently uses the GPII integrated AsTeRICS solution in the Guadalinex OS to allow developers to easily integrate alternate input devices to their developments (e.g. allow users to move the computer's mouse with little movements of the head). The module has been implemented in 800 Guadalinfo's telecenters in ~10.000 workstations.

Although the current prototype of the DSpace provides already an extensive collection of assistive technology building blocks, the interoperability of solutions and their integration with the GPII has been only partially achieved or it is ongoing. Furthermore, an essential aspect of the DSpace is the support of the solutions with useful tutorials and code samples, which still have to be prepared and implemented especially for the building blocks developed within the Prosperity4All project. A very important aspect is the need for an appropriate security

mechanism that protects the DSpace from malware injection. Since any third party can contribute its solutions and make them available via the DSpace, there is always the risk of introducing malware. In a first step, a review process for resources has been considered, similar to that implemented by some app stores for mobile applications. However, by the end of the project, the entire Prosperity4All ecosystem will implement an appropriate security framework. Finally, although initial testing with developers and end-users has started through the co-design process, further technical validation and evaluation of the DSpace prototype needs to be conducted.

ACKNOWLEDGMENT

The research leading to these results has been partially conducted in the Prosperity4All project, which is funded by the European Union's Seventh Framework Programme (FP7/2007-2013) grant agreement 610510, the Ontario Ministry of Research and Innovation, the Canadian Foundation for Innovation and the Consumer Electronics Association Foundation. Work leading up to Prosperity4All was funded by the European Union's Seventh Framework Programme (FP7/2007-2013) grant agreement 289016, by the National Institute on Disability and Rehabilitation Research, US Dept of Education under Grants H133E080022 (RERC-IT), by the Flora Hewlett Foundation, the Adobe Foundation, the Ontario Ministry of Research and Innovation, and the Canadian Foundation for Innovation. The opinions and results herein are those of the authors and not necessarily those of the funding agencies.

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