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International Journal of Current Research
Vol. 7, Issue, 12, pp.23578-23583, December, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

REVIEW ARTICLE

ROBOTICS-BASED LEARNING IN APULIAN LIVING LABS

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ARTICLE INFO

Article History:
Received 15th September, 2015
Received in revised form
07th October, 2015
Accepted 19th November, 2015
Published online 21st December, 2015

Key words:

Living Labs,
Autism,
Dyslexia,
Robot,
Learning,
LMS.

ABSTRACT

The Living Labs approach represents a new way to address the research activities where innovations, such as new services, products or application enhancements, are validated in empirical environments within specific regional contexts. Apulia Region decided to foster this approach in Apulian ICT Living Labs and the follow-up programme Living Labs Smart Puglia 2020 to facilitate the growth and the development of Apulia SMEs specialized in the Information and Communications Technology (ICT) field, digital services and contents implementing the Apulian ICT Living Labs as a regional policy to improve ICT industry and services in the region. This paper introduces the Living Lab approach and stresses its key principles. It aims to describe how this approach has been implemented in two projects, namely ASTRO and ROBIN, which provide a humanoid robot for autism spectrum disorders (ASD) and dyslexia. The developed advanced tools for education and rehabilitation, are useful in terms of socialization of children, reducing stress due to emotional inference. Fundamental role of end users in the co-design of the learning module through computer interaction between children and robot is underlined. The module also includes a platform of learning management system, based on use of Tablet, PC, Smartphone and robotic multimedia systems for individual learning and for the contents production aimed at students with learning disabilities, in particular students with dyslexia.

Citation: Gianfranco Borrelli, Giovanna Avellis and Stefania Pinnelli, 2015. “Robotics-based learning in Apulian living labs”, *International Journal of Current Research*, 7, (12), 23578-23583.

INTRODUCTION

Dealing with innovation is expensive, risky and time consuming, for the work with innovation is unpredictable. In order to decrease ineffective factors and to create opportunities for success for the innovations it is necessary to have good market contact, meaning to know what the user actually wants and needs. Living Lab research is emerging as a potentially important stream in innovation research as a concept to support the processes of user-driven ICT systems, based on the precondition that Living Lab activities are situated in real-world contexts, not constructed laboratory settings.

Many trends have currently been addressed by the Living Labs research, namely:

- users changed roles from passive consumers to active prosumers of content,
- shortened time to market for innovators,
- a globalized market through internet and IT’s entrance into peoples every-day activities

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We are concerned with the issues above, and will address in this paper how ROBIN and ASTRO Living Labs support the innovation process, presenting the outcome of the Living Lab projects, and suggesting how to effectively we have involved end users in the Living Lab context.

Living Labs approach supports the innovation process for all stakeholders, from manufacturers to end-users, with special attention to SMEs and has the endeavour to focus on potential users, in the centre in their real world context.

Living Lab research can contribute to the innovation practices, since it offers an avenue to promote open service innovation for innovation professionals.

- Section 2 details different types of Living Labs environments and key principle reported in the literature. Then, it addresses the User Center Design methodology used in the ASTRO and ROBIN Living Labs projects.
- Section 3 introduces the two Living Labs above, addressing autism and dyslexia.
- Section 4 reports the results of the research

- Setcion 5 discusses the main strengths of the Living Lab approach in the ASTRO and ROBIN projects and concludes the paper.

MATERIALS AND METHODS

Concerning the definition of the Living Lab concept today there is no agreed consensus as it has been defined as a methodology, an organization, a system, an arena, an environment, and/or a systemic innovation approach. This because there are many different types of Living Lab environments implemented such as:

1. Research Living Labs, focusing on performing research on different aspects of the innovation process.
2. Corporate Living Labs, that focus on having a physical place where they invite stakeholders (e.g. citizens) to co-create innovations.
3. Organizational Living Lab, where the members of an organization co-creatively develop innovations.
4. Intermediary Living Labs, in which different partners are invited to collaboratively innovate in a neutral arena.
5. Time limited Living Lab, as a support for the innovation process in a project. The Living Lab closes when the project ends.

Due to the constant development of the concept other types of Living Labs certainly exist. Living Labs have shown the ability to mould the opportunities offered by new ICT to the specific needs and aspirations of local contexts, cultures, and innovation potentials. This approach is shaping the agenda of Regional Policy and Territorial Cooperation for 2014-2020, but also HORIZON2020 and the “Smart Specialisation” conditionality requirement, engaging all EU regions and to realize a smart, sustainable and inclusive growth, that is Europe 2020, and Innovation Union, which sets out an integrated and strategic approach exploiting and leveraging Europe strengths in new and productive ways. In Europe the potential and opportunities generated by a four helix model, i.e. Public-Private-People Partnership (PPPP) from ENoLL shifted the scope of Living Labs from pure academic experiences to regional or national innovation systems.

The aim of a Living Lab is to accomplish the four helix by harmonizing the innovation process among four main stakeholders: companies, users, public organisations and researchers. These stakeholders can benefit from the Living Lab approach in many different ways, for instance companies can get new and innovative ideas, users can get the innovation they want, researchers can get case studies and public organisations can get increased return on investment on innovation research.

Five key principles are reported in the literature for designing Living Labs, that are valuable and permeate all operations as follows:

- Create value for customers and users (benefits-sacrifices). It gives organisations an opportunity to increase the level of innovation and decrease the risk of developing something that the users do not want: it is important to underline how their needs and motivations have been understood as well as how these needs can be met by an innovation.
- Apply the influence (realisation of feedbacks) principle. One key aspect of the influence principle is to view users as active, competent partners and domain experts and to base these innovations on the needs and desires of potential users. Their involvement and influence in innovation and development processes shaping society is essential.
- Contribute to sustainability (Meet the needs of both present and future). The environmental activities taken today in many organisations are not adequate and can lead to different types of waste such as unused resources, inefficient energy use, and emissions which decrease energy efficiency.
- Implement openness (bidirectional flows of knowledge). Many companies have thus identified a need to open up their innovation processes since innovation stakeholders have become more mobile, venture capital more abundant, and knowledge more widely dispersed across different types of organisations. On the other end, in Living Labs, several stakeholders are invited to participate in the innovation process in collaborative multi-contextual empirical real-world environments. Openness is essential to gather a variety of perspectives that might lead to faster and more successful development, new ideas and unexpected business openings in markets.
- Experience realism (experiences from in and out different situations). One of the cornerstones of the Living Lab approach is that innovation activities should be carried out in a realistic, natural, real-life setting to understand how a digital artefact influences and fits into the actors’ activities and goals.

In the Living Labs projects ASTRO and ROBIN, we strongly stress the importance of the first phase in the concept design cycle, usually referred to as analyses or requirements engineering since this phase creates the foundation for the rest of the process, while errors here become very hard and expensive to correct in later stages. This also is the phase in which users can make the strongest contributions by actually setting the direction for the User Centred Design (UCD) as mentioned in the following sections. Since users’ needs and requirements can change as users gain more knowledge and insights into possible solutions, it is important to re-examine their needs continually and make sure they correlate to given requirements.

In accordance, the method used in ROBIN and ASTRO is iterative and interaction with users is an understood prerequisite. The idea is that knowledge increases through iterative interactions between phases and people with diverse competences and perspectives. Cross-functional interaction enables the processes of taking knowledge from one field to another to gain fresh insights, which then facilitates innovative ideas. Each cycle starts by analysing the results from the usability evaluation in order to generate changes in the needs of and in the innovation. Small changes and adjustments in the needs are quite common, especially in relation to the needs in the innovation, as it develops and users’ understanding of structure, content, workflow, and interface deepens.

The focus is to encourage users to express their thoughts and attitudes towards the design. User experienced goals can be positive and negative, for example both enjoyable and frustrating. They are primarily subjective qualities and concern how the innovation feels to a user and differ from more objective usability goals in that they are concerned with how users experience an innovation from their perspective, rather than assessing how useful or productive the innovation is from its own perspective.

The ASTRO and ROBIN systems, along with the services they provide have been shaped around the UCD methodology. It is a design philosophy and a process, which focuses the attention on the user's need, expectations and limits in respect to the final product. The user is placed at the centre of each step of the development process in order to maximize the usability and acceptance of the product, optimizing it around the needs of the users. The UCD methodology is characterized by a multi-level co-design and problem solving process. It requires designers not only to analyze and foresee how the user will utilize the final product, but to test and validate their assumptions at the same time by taking into consideration the end-user's behaviour during the usability and accessibility tests (test of user-experience) into the real world. The UCD methodology leads to the creation of the final product through an iterative and interactive process that provides the development of a first prototype and a following test and assessment stage on the basis of which to proceed with the development of the next prototype. Each cycle therefore leads to the creation of a product that is closest to the real and practical needs of the user.

The aim of the UCD is to move from a high-fidelity prototype with a focus on users' identified needs to an innovation. This means to include both business model aspects as well as designing a fully functioning innovation. The main objective is to re-design the innovation according to feedback gained in earlier phases.

The ROBIN and ASTRO projects, co-financed by the Apulia Region in Italy by means of the Apulian ICT Living Labs programme, meant to create a multimedia robotic system integrated with the OMNIACARE software platform, developed by eResult, that enables to cope with diverse disability-related conditions. Autism (Autistic Disorder Spectrum, ADS) among the Specific Developmental Disorders, and Dyslexia among the SLD – Specific Learning Disabilities, take on great importance and diffusion among children.

"Autism" is a syndrome that, according to the latest surveys, affects 1 child out of 100 and is the most characteristic group of pervasive developmental disorders. Even though children affected by autism present different functional deficits, however, they are often able to use surprisingly different technologies such as PCs, MP3 player, TV, video games: tools used daily at home and sometimes at school. Teaching can find then a "rich soil" for what concerns the use of new technologies in order to foster learning by children suffering from autism and by taking into consideration that achieving new competences can go through those already learned, using technological devices as operational tools.

"Dyslexia" is a specific difficulty that refers to the ability to read accurately and fluently and which is often characterized by poor writing skills. The dyslexic subjects have great difficulty in learning to read: reading is slow, laborious, and usually inaccurate. The ability to read is hard to achieve through repetitive tasks, rather it requires a major investment of cognitive resources. Reading disability affects about 3-5% of Italian children and it is the most prevalent of all learning disabilities. Developmental dyslexia is diagnosed by specific difficulties in reading that cannot be explained by causes related to intelligence or lack of educational opportunities. Literature prove the usefulness of Information and Communication Technologies to support dyslexic pupils in learning tasks, but often such technological tools are developed to be used in one by one rehabilitation treatments, hardly usable in the context of a teaching class.

The ASTRO and ROBIN Living Labs projects

The main goal of the ASTRO project was to develop a product able to support, by the means of new technologies, pre-school and school-aged children affected by Autism Spectrum Disorders and that can serve as a proper tool to be used during educational and rehabilitation activities. This was achieved by extending the features of the so-called OMNIACARE software platform for the delivery of didactical and cognitive exercises, in order to enable an interaction mediated by a robot to act as an intermediary in the process of socialization, reducing stress introduced by the absence of emotional inferences. The realized system is suitable for domestic use as well, allowing the teacher to intervene in telepresence assisted by a parent. The development of human-machine interaction integrating IT tools with robotic devices provides a solution that contains:

- Flexible and customizable activities to suit different needs and characteristics;
- Shift of the focus from learning to "doing", in an educational design, organized and articulated, careful about timing and method of use;
- Spurring self-use of the tool in order to enhance technical skills as well, increase self-esteem and gratification.

The ROBIN project, by means of the same platform, developed a playful and stimulating environment able to support children affected by dyslexia not only in the cognitive stage in order to facilitate their learning activity, but also and particularly in their relational and growing path, by providing didactical exercises to the pupils, accessible via a PC or notebook. During the execution of the exercises, children benefit from motivational hints by the robot. The robot through automatic pre-set questions verifies then the pupil's understanding level and returns positive and/or reinforcement feedback.

The goals of the two projects were pursued through the use of a kit consisting of an anthropomorphic robot, NAO™, developed by the French company Aldebaran Robotics, and an LMS (Learning Management System) platform, developed on the OMNIACARE system, devised and produced by eResult. NAO™ is a hi-tech robotic device characterized by 25 degrees of freedom, which allow it to perform even the most complex motions and it is suitable for structured and unstructured environments. It is equipped with:

- Ultrasonic proximity sensors pointing towards different directions, that allow to detect and evaluate the physical distance.
- Pressure sensors located under the lower limbs.
- Advanced multimedia system with 4 microphones and 2 speakers.
- 2 CMOS cameras designed for speech synthesis, space location, face and object recognition.
- Interaction sensors such as 3 touch areas above the head of the robot.
- 2 infrared led and 2 contact sensors on the front of the lower limbs.

The OMNIACARE platform is a multi-functional hardware and software system, specifically developed by eResult for the remote monitoring and assistance of frail users. By providing tools to patients and caregivers, the system improves quality of life of those people who need particular assistance in daily living and to those who take care of them.

The OMNIACARE software architecture is modular: each element realizes some specific functions, as to be able to dynamically adapt to a variety of situations and environments. The system allows exploitation of more or less functionalities in a seamless way, by using specific elements, while the overall system keeps running. The system architecture is open to any potential development by just adding new modules.

To cover the aspect of support to children affected with learning or developmental disorders, OMNIACARE implements a Learning Management System that administers provision of multimedia exercises, aided by Information and Communication Technology tools, to make the learning or therapy process more playful, usable and effective. The system also records the pupils' answers and feedbacks to ease teachers and therapists in their effort to properly assess children's capacity evolution and growth.

OMNIACARE comprises the following elements:

- Central Server.
- Home Server.
- External hardware systems (robot, sensors, interaction and parameter collecting devices).
- Webcam.
- Smartphone and tablet (Android-based).

The webcam is connected to the Internet through a Wi-Fi router. Operators and therapists can use it to monitor the local environment and to support patients and caregivers by working on the system themselves, through the Central and Home Servers. This is an optional feature that can be disabled by the end user for privacy reasons.

The Central Server (CS) is the main element of the system. User profiles, device configurations and all system data reside on the CS. The CS also provides the web interface that operators and therapists use to interact with the system, in order to customize exercises and therapy for pupils. Configurations can be done on the CS by the tutors only, to avoid unauthorized modifications by the users or caregivers. The Home Server and the hand-held device periodically synchronize data and download configurations from and to the CS. The CS has been built on eResult's OMNIAPLACE software development platform, and it inherits its inner characteristics:

- Hierarchical data structure.
- Web-based user interface.
- Advanced data navigation, display and search.
- Extensive data export functionalities.
- Granular user privilege management.
- Structured system event management.
- Information traceability.

The Home Server (HS) acts as a gateway that interfaces with detection sensors and external devices managing all of the diverse communication protocols. The HS collects data from the devices and also provides configuration data exchange to proper manage them. The HS also consolidates and conditions data and sends them to the CS, according to the established rules and timing, while at the same time providing warning or alerts in case of a detected anomaly. As concerns the LMS system, the HS also contains the software engine used for exercise administration and the user interface module to display such exercises to the pupil, along with the interaction control dashboard for the therapist/teacher to manage behaviors of the NAO^{TM} robot. Different access to information and functions can be granted on the HS- based LMS platform to different users, according to their needs and competences, by a web interface present on the CS configuration page.

RESULTS

As far as the ASTRO Project is concerned, 63% of involved children positively reacted to the robot's presence, showing curiosity, happiness, interest; 18.5% showed negative reactions; 18.5% of children showed an alternate behaviour, sometimes afraid or indifferent, sometimes curious. In some cases, negative expressions depended on technical problems interfering with, or blocking, the experimentation session. 48.1% of children satisfactorily responded also to direct interaction with the robot. It was important for the experimentation to note how easily children would physically approach the robot, spontaneously approached and touched in most cases.

As to families, parents were actively involved in the ASTRO co-design and experimentation phases. 81.5% of families declared themselves satisfied by the experimentation, in some cases expressing amazement for "the progress obtained [by their children]". Even those who were doubtful in the beginning of the project, progressively gained confidence during the course of experimentation, due to the gradual successful improvement in their children's interaction. In 90 sessions, parents participated in exercise execution, using the system and stimulating children to establish a direct contact with the robot, by singing and dancing with it and giving expressions of encouragement. This allowed the robot to play a role of "functional game" and raising interest and curiosity in autistic children, unlike the "stereotyped games" they typically use in a solitary manner. Thus, the robot facilitated the relation between child and parents. Parents, on their side, discovered a new way of living a joyful and playful moment with their children, at the same time useful to stimulate their cognitive and behavioral abilities.

In a limited number of cases, intensive intervention and help by the therapist was necessary, because the parent was not able to properly use the PC and thus easily discouraged; or, for the fact that the parent, while desiring to cooperate, was not able to oversee the child and use the system at the same time. Some families decided to leave the project because the exercises from the system were too simple for the chronological age of the children. This criticality emerged as a side effect of the need to experiment the possibilities offered by the system as a mediator in the parent / child relation. In fact, the proposed exercises were rather simple, in order to ensure the active involvement of parents allowing them to carry out the session autonomously, with the simple supervision of the therapist. This prevented the system to adapt to the need of the single patient. From the experimentation, it nonetheless emerged how the preparation and behavior of therapists are critical to the success of the session. It is important that they invest time in preparing the setting before the session itself, eliminating any distractors and arranging preliminary plans along with required procedures.

The ASTRO project led to the conclusion that the realized intervention, designed to make parents protagonists in their children's treatment, makes a step in the right direction towards the awareness of the possibilities they have to make a difference with their own kids. Parents were all available to further experiment and gave suggestions for improvement.

As concerns the assessment phase that followed the experimentation, evaluation is still in course to verify whether, and how, the interaction between children and parents mediated by the robot has had a positive effect in terms of quality of and wellness of families. Results will be made available at the end of the study, at the beginning of 2016.

As regards the ROBIN project, the system was tested by children in different locations. At the end of the sessions an evaluation was made, involving teachers specialized in treating children with specific learning disabilities. The evaluation was carried out by means of questionnaires in Likert scale, after a demonstration session of the system, with and without interaction with the NAO^{TM} robot. The questionnaire proposed 28 open and closed questions and open, designed to identify:

1. The level of acceptance of the proposed activities
2. The level of appropriateness to users
3. The level of usability in the context of a class
4. The usability, the synthesis of the interfaces, the overall appearance of the system

The total score of the four areas was 140 points (28 questions with a score from a minimum of 1 to a maximum of 5). The analysis of the questionnaires showed an average score of 66.41. In general, the responses and comments received in the open questions showed a positive response from teachers towards technological tools to support students with dyslexia but that may also be used extensively in the activities of the classes, and that can be integrated into their curriculum. In fact, despite the wide availability of specific software, the views of teachers highlight the need for products whose use can be extended to all students. Such tools can help avoid the stigma arising from employment of "special" media while on the other side reduce the slowdown of the teaching activities. The need expressed by teachers, therefore, is perfectly in line with the culture of inclusion and special normality, and with the proposal of the model of Universal Design for Learning.

As concerns the overall system, composed by the LMS OMNIACARE integrated with the interaction with NAO^{TM}, a particularly positive response was given to the use of a robot in human form. The development of automated agents to support the learning process showed results in line with the literature: a positive effect is experienced on the response and on the involvement of the students when given the opportunity to interact with the robot, through some functionality available on the technological devices, or, better, by the implemented interaction model. Specifically as regards this latter, facial expression, movements and lights of the robot associated with emotional expressions phrases, adverbs, adjectives of encouragement used as feedback in the execution of the exercises are welcome among the students.

DISCUSSION AND CONCLUSION

The Living Labs methodology with its emphasis on "user involvement" and the "co-creation" process makes it different from other testing and evaluation methods. In the Living Labs approach for user-driven open innovation the sharing with end users and other stakeholders into development projects remains a difficult task but it is the most important step of the overall process. We addressed this weakness of the Living Lab approach by organizing regular focus groups among the end users and the SMEs and research laboratories, since the requirements phase through design and development, test and experimentation, evaluation of market perspectives, and by monitoring the projects every four months. The main strength of the Living Labs approach, i.e. the users' involvement, is strategic in ASTRO and ROBIN Living Labs in terms of co-design of services/products to be realized as solution for user needs, test and validation of services/products, market design for business model developments. Methods and tools adopted for the active involvement of users are also operative meetings, interviews and surveys aimed to share problems and objective, to design solution perspectives, to suggest strategies for the development of results, further stakeholder involvement, networking actions, workshop for dissemination, and communication plans. Another strong point of the described model is the possibility of Living Labs to build interdisciplinary projects that allowed the dialogue between knowledge and operating skills.

The computer is an important tool because it can both motivate and because it allows more elaborate and sophisticated exercises than those with paper and pencil. One of the conclusions that have been reached through the experience made with the ROBIN project, is highlighting the role that ICT can play in the global care dyslexic student, not only from a technical learning reading (phono-syllabic, and visuospatial tasks), but also on the emotional and relational aspects.

Acknowledgements

Authors thank all the partners of ASTRO and ROBIN projects, and InnovaPuglia for the technical and scientific monitoring and evaluation of the projects above. This work has been funded by Apulia Region, under Regional Operational Programme ERDF 2007-2013 Action 1.4.2 supporting the growth and the development of SMEs specialised in the delivery of digital contents and services. We thank Adriana Agrimi, Apulia Region, Innovation and Industrial Research Service, Director, for fostering the Living Labs approach in the European Research and Devlopment Funds (ERDF) projects.

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