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ARDUINO – EMANATION OF THE CULTURE OF PROSUMPTION AND PARTICIPATION. AN ANALYSIS OF THE RELATIONSHIPS AMONG USERS, OBJECTS AND TECHNOLOGY

The article aims at defining the specificity of Arduino technology from the perspective of the culture in which it has been developing, i.e. on the border of the culture of prosumption and participation. Arduino's development environment has been researched on the basis of existing data and source literature by analyzing the relationship between a user, an object and technology based on processes such as openness, adaptability, standardization, personalization, self-customization, democratization of technology, and peer cooperation.

Keywords: prosumption, participatory culture, Arduino, Do-It-Yourself, The Maker Movement

INTRODUCTION

Arduino is a microcontrollers' technology which enables one to add an interactive character to simple objects and, for instance, connect it to the internet. At the same time, Arduino is an open technology, an object of activity enabling potentially everybody to create a technological environment at low cost. As this technology gains more and more publicity, it is developing under specified cultural conditions resulting from social and economic changes which have taken place over the past few decades¹. The environment of its development consists of norms, principles and ideas originating from two interpenetrating practices: prosumption

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¹ As Massimo Banzi, one of the leading creators of Arduino, underlines, what makes this solution distinctive from others is that it is easy to use and to program, quick to produce, available with free license, and supported by a community of users who share their ideas and help each other (Banzi 2011: V and forward). The expansion of this technology also results from low-cost components (Williams, Gibb and Weekly 2012: 16). The size of Arduino is very difficult to gauge, as "every single month, 100,000 more people join" (Musto, 2015). There are other technologies similar to Arduino, e.g. BeagleBone, Raspberry Pi, LaunchPad, Nanode, Pinguino, STM32 Discovery, and Teensy 2.0.

and participation. What distinguishes them is the set of the defined relationships² which form between a person (a user), technologies, and the objects being transformed. The purpose of the analysis is to explain connections between Arduino, everyday objects and prosumers bringing about the transformation of objects. The specificity of relationships building the culture of Arduino development is explained through presenting examples on the basis of existing data and the source literature.

THE ESSENCE OF ARDUINO IN THE CONTEXT OF PROSUMPTION AND PARTICIPATION

Arduino is a programming platform based on a microcontroller (a small computer consisting of a processor, memory, inputs and outputs) used for purposes not requiring high levels of memory or power. It is available with a free license (open source and open hardware), facilitating and sometimes also enabling people without much technical experience to create a prototype (Waddington and Taylor 2007). It allows connecting sensors and executive devices (actuators) to objects. Sensors conduct measurements, for example of the temperature, and the collected data are processed by the software. The results are then transformed by executive devices into a specific response in the physical world, such as movement. In this manner, objects gain new functionalities. Many different measuring devices can be connected to Arduino, such as a thermometer, a humidity meter, a Geiger counter, a pH level meter, an oscilloscope, or a DNA analyzer. Moreover, there is a wide range of possibilities for connecting executive devices such as diodes, displays, etc. Arduino activates objects, endows them with a new dimension, and adds new application variants. It has very wide constructional powers and as the practice shows, the nature of this technology is innovative, just as the nature of innovation is democratic (Williams, Gibb and Weekly 2012: 16)³.

The relationship between Arduino and the objects connected to it is grounded in *openness and adaptability* (Waddington and Taylor 2007: 8). Openness means accessibility to tangible and intangible assets, the simplicity of the technology, a wide range of intermediary solutions (sensors and actuators), and constant development of these tools. This technological openness stems from the openness of intellectual property as well. The adaptability in turn means the potential capability to adjust to various needs: it can be connected to any object thanks to flexibility in choosing the software, a sensor, and an actuator. Through the endless possibilities of combining different elements and solutions, very diverse results may be obtained⁴. Arduino and objects form a symbiotic relationship. Connections between them are

² Relationships mean relations and connections between various elements. In the given case among users, technologies and objects.

³ Arduino operates in the field of physical computing, i.e. using computers to meet the needs of the physical world.

⁴ This is difficult to indicate the main Arduino applications because the spectrum of prototypes is very broad, from robotics and control systems, home and industry automation, and biotechnology to agriculture. The most-used sensors in Arduino projects are: temperature/humidity sensor, infrared emission sensor, photo light sensitive resistor, ultrasonic distance sensor, knock sensor and sound sensor (Top...). Pär Andersson (2015) presents a list

of a technologized nature: they become integrated and are supportive of each other. Arduino makes passive, non-interactive objects active, or expands the range of their interactive powers. Object transformation establishes a new object with completely different functions. Successively, the technology is constantly developing, owing to new applications. New components, ideas and implementation methods appear.

Arduino is developing on the border of, or rather at the intersection of, two cultures⁵: *prosumption*⁶ and *participation*⁷. The key term in understanding the prosumptive nature of Arduino is prototyping. It is the construction of an initial solution, whose capabilities are verified by tests. Building a prototype in the field of physical computing involves accepting two challenges: hardware development and software development (Conradi, Hommer and Kowalski 2010: 1). The first means the correct connection of sensors to actuators and joining them to a microcontroller in an electric circuit. In the latter case, a microcontroller needs to be programmed⁸ to be able to read and control the connected components. Arduino is a technology which facilitates and speeds up prototyping.

However, the development of Arduino has another, equally crucial basis. It is rightly perceived to have been the result of systematic evolution (Buechley 2010: 1) which can be described as technological and cultural. To begin with Web 2.0, which has changed internet user-receivers/consumers into user-creators/producers globally, through transforming market relations⁹, to opening of culture (Creative Commons) and software (open source). At the moment equipment, tools, hardware are being opened as well.

Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it. Ideally, open source hardware uses readily-available components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware. Open source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs (OSHA).

of various applications, including: Arduino called 'LilyPad' used for producing electronic textiles; Arduino with the temperature and humidity sensors, applied to monitor air quality in apartments; Arduino applied in medicine, for instance to construct peristaltic pumps; the combination of Arduino, biochips, micro-streams and craft in Indonesian shadow theatre; the use of Arduino, various sensors and smartphone applications for constructing a car accident detection system.

⁵ "Culture is defined as a social domain that emphasizes the practices, discourses, and material expressions, which, over time, express the continuities and discontinuities of social meaning of a life held in common" (James, Magee, Scerri and Steger 2015: 53).

⁶ According to Alvin Toffler's conception, prosumption means transferring by consumers some part of their activity in the exchange sector (sector B) to the own-use production sector (sector A) (Toffler 1997: 406).

⁷ The term participation refers to all forms of shaping value through cooperation of members of groups, communities, movements etc., both in non-commercial (artistic, civil) and commercial spheres. Find more in: Jenkins et al. 2005.

⁸ The Arduino programming language is merely a set of C/C++ (Arduino FAQ).

⁹ What was called and conceptualized in different ways as: e.g. Wikinomia (Tapscott and Williams 2008), crowd-sourcing (Howe 2006), knowledge brokering (Törrö 2007), wisdom of crowds (Surowiecki 2005).

The openness, free access to ideas and easy access to technology mean that Arduino is becoming more and more popular, applied and developed. Community participation, owing to which project resilience and autonomy is rising, plays a crucial role as well. Experts draw attention to the rich variety of illustrations completing project descriptions, which is great support in creating, and to the openness towards further rearrangements, improvements, etc. Not without importance is the ability to generate commercial value (Williams, Gibb and Weekly 2012: 16). Thanks to Arduino, ideas and visions that could not have been realized in the past can now be embodied, as they were once blocked by infrastructural, financial or competence limitations.

CULTURE OF PROSUMPTION: A USER AND AN OBJECT

The culture of prosumption is grounded in relationships of users with products, as they are produced or transformed. Transformed goods, enriched with the interactive dimension, become new objects. They change physically and most of all functionally (Weddington and Taylor 2007: 10). By the same token, relationships between an object and its creator/transformer are changed. Not only does a user consume, but s/he creates and produces as well. A user prosumes an object.

Arduino encourages beginning an adventure by transforming toys, combining easily available, spare or even already scrapped elements so that, among other things, work on a prototype would be pleasure, fun and an adventure (Banzi 2007: 15), even if this practice is useless and a creator does not know what s/he eventually wants to achieve. Not without reason is Arduino particularly dedicated to artists, people not necessarily aiming at a practical result in their work, and still less at its commercialization. Nevertheless, Arduino has highly targeted, specific, practical applications as well. The created projects sometimes become technological or social innovations.

In the case of Arduino, it is vital to restore the meaning of individual constructing grounded in tinkering. ‘Tinkering is what happens when you try something you don’t quite know how to do, guided by whim, imagination, and curiosity. When you tinker, there are no instructions – but there are also no failures, no right or wrong ways of doing things. It’s about figuring out how things work and reworking them. Contraptions, machines, wildly mismatched objects working in harmony – this is the stuff of tinkering. Tinkering is, at its most basic, a process that marries play and inquiry’ (*Tinkering* after Banzi 2007: VII). A contemporary user wants to (re)gain the capability to transform reality individually, based on what already exists. The basic mechanism here is trying and testing, therefore constructing initial solutions and searching for ultimate tools. As Massimo Banzi (2011: 14) claims: “We love junk”. Arduino has come to love junk, rubbish and scrap metal. The essence of tinkering and prototyping is patching: complementing elements, breaches, and lacks, which results from modularity of technology and a constructed solution. Application of Arduino as an intermediary technology for activating previously passive objects makes the relationship between Arduino and its user rest on the effort put into searching for solutions and performing tasks. First, one should become well familiar with the technology in order to be able to take

advantage of it and step into new relationships with transformed objects. Arduino is a tool and at the same time an element of tinkering and by the same token, a thing being modified is an object of transformation.

Prototyping with Arduino clearly fits into widely understood “*democratized technological practices*” (Tanenbaum et al. 2013: 2603). To a certain extent, these practices are standardized. *Standardization* mainly refers to materials and the infrastructure which facilitates sharing the knowledge (Tanenbaum et al. 2013: 2608). The user’s relationship with an object is based on the agreed principles of applying materials into construction and creation, but on the other hand completely defies the universal rules of effects. They are innovative and often surprising. The relationship between users and objects activated by Arduino is also built on *personalization*. A producer creates or transforms an object for specific needs or for pleasure, as s/he prefers, and makes such a transformation, whose result is tailored to one’s expectations. Taking advantage of standard possibilities, the user receives an individualized result. The meaning of standardization and personalization also refers to *reinforcement*, which is gained in terms of interoperability, cooperation and modularity (Tanenbaum et al. 2013: 2608). Taking advantage of someone else’s project while creating or transforming one’s own object places the user in a kind of relationship with other objects created by community members. Consequently, users’ relationships with objects are community relations, integrated with the practices, experiences and effects of many other users’ actions¹⁰.

However, most of all, the object-user relationship is a customer-product relationship, based on *self-customization*. A buyer has the right to do with a product whatever s/he wants within valid laws and rules, and so has the right to convert a product, transform it and combine it with anything else. ‘Hacking has always been a consumer right’ (Waddington and Taylor 2007: 10). This is the peculiar convergence of the commercial world and an alternative one, supported by the spreading hacker ethos, which means being involved in technology design, modification and sharing (Lindtner, Hertz and Dourish 2014: 2). Therefore, previously existing boundaries between a profit-oriented activity and a non-profit activity are becoming blurred.

What forms a contemporary user is DIY¹¹ culture, the culture of an individual creator and transformer. Its development stems from ‘people’s need to engage passionately with objects in ways that make them more than just consumers’ (Dougherty 2012: 11–14). A user becomes a ‘creative appropriator, hacker, tinkerer, artist, and even co-designer or co-engineer’ (Tanenbaum et al. 2013: 2609). In these communities the rule is ‘unflinching optimism’ and acting according to the motto ‘making is better than buying’ (Tanenbaum et al. 2013: 2604). This type of prosumption means consumers’ engagement and at the same time *democratization* of their activity. Free technologies make users-creators equal. The nature of Arduino is

¹⁰ It is enhanced by using the hackerspaces by tinkerers. Obviously, access to them is far more limited than to online resources. However, they play an important role in democratizing technology, because they eliminate one of the main barriers: the financial one. It takes place due to sharing hardware (e.g. 3D printers) and acting based on the ethos of sharing best practices, software sets, components and tools as well (Williams, Gibb, Weekly 2012: 19).

¹¹ DIY is understood as ‘any creation, modification or repair of objects without the aid of paid professionals’ (Kuznetsov and Paulos 2010: 1). Application of Arduino technology contributes to ‘the third wave of DIY’ (Fox 2014: 18–30).

particularly democratizing, because it is a technology adjusted to non-experts or so-called ‘expert amateurs’ (Kuznetsov and Paulos 2010: 295). At the same moment, the consequences of breaking passive consumerism are much wider. ‘This orientation toward personal fabrication rather than blind consumerism is also seen as the foundation for a new, more prosperous economy’ (Peppler and Bender 2012: 23).

PARTICIPATORY CULTURE – PEER USERS AND TECHNOLOGY

Participatory culture builds on specific relationships among technology users. Arduino fits into The Maker Movement, the culture of hand-making, creating, designing and implementing innovation based on cooperation. The hallmark of The Maker Movement is the set of ‘Do-It-Yourself’ or rather ‘Do-It-With-Others’ attitudes, which gathers individuals concentrated on activities including textile crafts, robotics, cooking, woodcraft, electronics, digital production, and mechanical repairs and creation. Despite its variety, the movement unites involvement in open exploration, shown interests and creative ideas shared by participants (Peppler and Bender 2013: 23). According to the researchers, it is characterized by three key features: manufacturers stimulate its development, it is participated in by representatives of various cultures and generations, and there are no limits to the manufacturing methods applied (Peppler and Bender 2013: 26–17). The Maker Movement has been developing effectively thanks to availability and accessibility of tools, and to new mechanisms of sharing (Kuznetsov and Paulos 2010: 1). The research proves that those in DIY culture become involved not as a search for employment, money or fame, but to ‘express themselves and be inspired by new ideas’¹² (Kuznetsov and Paulos 2010: 8).

The relationship is grounded in liberty, freedom, experimentation, and the discovery of new solutions. Thanks to Arduino a user is constantly learning and developing new capabilities, partly individually and partly along with other peer users. A user learns to search for the simplest, fastest and cheapest solutions, which means a particular ‘opportunistic prototyping’: the economic and ecological use of what already exists (Banzi 2011: 6). How do users who are not experts on electronics or computing produce their prototypes? Producers have a few opportunities for education and creation available. They take advantage of platforms and internet communities addressed to them, and they make use of rooms called hackerspaces¹³. There are also magazines dedicated to individual production at their disposal, such as *Make*. They also have the opportunity to participate in local and international events on such production, e.g. Maker Faires. Moreover, producers gain support from special organizations such as the

¹² Of course, there are differences in DIY culture development between the first world and the third world countries. However, according to the researchers, the geographical aspect is more complicated than the development level of a given region. Moreover, communities of manufacturers converge in a natural way (Tanenbaum et al. 2013: 2605).

¹³ ‘Hackerspaces are shared social studios that bring together people engaged in building creative technical projects through the free and open sharing of equipment, tools, software and hardware code. A typical hackerspace is equipped with computing tools that allow for experimenting with the physical/digital boundary – computer controlled laser cutters, 3D printers, and open microcontroller platforms such as the Arduino’ (Lindtner, Hertz and Doursih 2014: 3).

Maker Education. New models of business financing based on crowdfunding, best illustrated by the platform Kickstarter¹⁴, appear to have been of significant help as well.

There are plenty of internet platforms which bring together enthusiasts of so-called ‘personal fabrication’ (De Weyer et al. 2013: 1). Two internet services of a general nature are Instructables¹⁵ and Thingiverse¹⁶. The first presents amateurish step-by-step instructions for preparing various hardware, often including a list of necessary tools and materials, photo or video illustrations on the preparation, with comments, advice, and other users’ ratings. The last is strictly dedicated to digital projects. It facilitates the exchange of knowledge on design, in particular using 3D printers¹⁷ with free license.

Arduino users build communities sometimes dedicated to narrow specializations or topics. Micro-communities provide each other with support and instruction, building a peculiar ‘culture of sharing and helping each other’ (Banzi 2007: 16). Basic motives for participation in DIY communities include receiving feedback on projects, the chance to teach, the opportunity for presenting one’s own ideas and skills, sharing projects and knowledge,¹⁸ and meeting people with similar interests (Kuznetsov and Paulos 2010: 8). Arduino also has its own forum for information exchange¹⁹. Such places on the internet enable democratization of hardware, construction, prototyping and production processes (Buechley 2010). Everyone can try to make something individually and later rate it or improve it. You do not need anyone’s permission to do it: materials and instructions are available with free licenses. Potentially everybody can assess the proposals. The platform users remain equal. Relationships between users are grounded in the culture: the Free Open Source Software Movement where sharing one’s own output and production takes place in the form of the creative rhetoric of storytelling (Kuznetsov and Paulos 2010). Users take advantage of the videos, photographs and texts to tell the story of their project. They then continue the story through discussion, further adaptations, improvements, ratings, etc. Public results inspire further modifications, new ways of use and hacking. Amateurs have access to tools, materials and information, which until now have been difficult to obtain or reserved for professionals. In this way they are becoming Pro-Ams (Leadbeater and Miller 2004).

FINAL REMARKS

Arduino is a key example of *prosumptive and participatory design*. It sets a new direction for open and democratic software and hardware development. It is the next stage of technological evolution based on new relationships emerging among user, object and technology.

¹⁴ Kickstarter, <https://www.kickstarter.com/> [7.05.2018].

¹⁵ Instructables, <http://www.instructables.com/> [7.05.2018].

¹⁶ Thingiverse, <https://www.thingiverse.com/> [7.05.2018].

¹⁷ 3D printers play a specific role, because in many cases they significantly reduce costs and enable to produce disposable objects or small batches (Tanenbaum 2013: 2608).

¹⁸ Knowledge transfer and iterative feedback loop take place in the form of comments, asking questions and responding (Kuznetsov and Paulos 2010: 9).

¹⁹ Arduino, <http://www.arduino.cc> [7.05.2018].

Such properties as openness, adaptability, standardization, personalization, self-customization, democratization of technology and peer cooperation inform and shape those relations.

Open hardware means a new amateur design paradigm (Waddington and Taylor 2007: 10). Arduino personalizes not only consumption, but most of all, it revolutionizes production. Its practice is based on pleasure, usefulness and expressiveness (Tanenbaum et al. 2013: 2611). Arduino, fitting into DIY and the Maker Movement, manifests opposition to the existing relationships in the industrial world. ‘DIY practice is a form of nonviolent resistance: a collection of personal revolts against the hegemonic structures of mass production in the industrialized world’ (Tanenbaum et al. 2013: 2609). In the era of the third industrial revolution ‘making technology leads to individual empowerment that is essential in times of increased global economic uncertainty and social upheaval’ (Lindtner, Hertz and Dourish 2014: 4).

The community’s open nature means that resources and technological possibilities are becoming available to a still growing audience, making Arduino a better understood, applied and developed technology. Deep reflection on the results of relationships developing between the human and the digital environment includes a wide range of issues and is a current necessity²⁰.

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²⁰ The article was translated from Polish by Izabela Kaźmierczak.

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ARDUINO – EMANACJA KULTURY PROSUMPcji I UCZESTNICTWA.

ANALIZA RELACJI MIĘDZY UŻYTKOWNIKAMI, OBIEKTAMI I TECHNOLOGIĄ

Artykuł ma na celu określenie specyfiki technologii Arduino z perspektywy kultury, w której się rozwija, to jest na granicy kultury prosumpcji i kultury uczestnictwa. Środowisko programistyczne Arduino zostało poddane analizie w oparciu o istniejące dane i literaturę źródłową, pod kątem relacji kształtujących się między użytkownikiem, obiektem i technologią, opartych na otwartości, adaptacyjności, standaryzacji, personalizacji, samodoskonaleniu, demokratyzacji technologii i współpracy *peer-to-peer*.

Słowa kluczowe: prosumpcja, kultura uczestnictwa, Arduino, Kultura Zrób-To-Sam, Ruch Twórcy (The Maker Movement)