Design for sustainability and ICT: a household prototype for waste water recycling

Fiammetta Costa
Department of Design, Politecnico di Milano, Milan, Italy, fiammetta.costa@polimi.it
Marco Aureggi
Department of Design, Politecnico di Milano, Milan, Italy, marco.aureggi@cybergraphics.it
Luciana Migliore
Department of Biology, Tor Vergata University, Rome, Italy, luciana.migliore@uniroma2.it
Paolo Perego
Department of Design, Politecnico di Milano, Milan, Italy, paolo.perego@polimi.it
Margherita Pillan
Department of Design, Politecnico di Milano, Milan, Italy, margherita.pillan@polimi.it
Carlo Emilio Standoli
Department of Design, Politecnico di Milano, Milan, Italy, carloemilio.standoli@polimi.it
Giorgio Vignati
Department of Design, Politecnico di Milano, Milan, Italy, giorgio.vignati@polimi.it

ABSTRACT

ICT can play a role in environment preservation, to face degradation of the ecosystem, and innovation, to satisfy emerging needs. This research focuses on experimental application of interaction design methodologies and digital technologies to foster the transition towards sustainability in the framework of a wider interdisciplinary research about the development of a system for recycling water at home to grow edible plants.
An iterative design process, articulated in prototyping-evaluating-improving cycles, has been implemented, with the involvement of different stakeholders, to develop the interaction system applied to manage waste water and information flows needed to control water decontamination, plant irrigation and lighting. The paper reports the main features of the system and the main outcomes of the user studies.

Key Words: Interaction Design, Internet of Things, User Centred Design, Environmental design.

1. INTRODUCTION

The paper presents a research project aimed to experiment the application of interaction design methodologies and digital technologies to foster the transition toward sustainability. To this purpose, we developed an interactive prototype based on a domestic water recycling system drawn up with life science experts. The system consists of a dishwasher integrated with an indoor planting device, where the wastewater is treated to make it available for the cultivation of vegetables or for the reuse in following washing cycles (Costa, 2018).
The potential of ICT is exploited in an ecosystem approach, overcoming the current application, often reduced to the restyling of old-fashioned products. In fact, a new user centred interactive product typology is designed to create a living space fulfilling the requests of a society focused on environmental needs and quality of life.
This new product will stimulate the development of healthier eating behaviours in users. In fact, the in situ production of edible plants will increase their contribution to the diet, reducing simultaneously the environmental impact due to the transport of food, produced and marketed in a standard way (Bhamra, 2008). In addition to aesthetic perception and indoor air purification, broader sustainability is achieved in a circular economy meaning, since what is left from an application (washing water) will become a resource for another (irrigation).

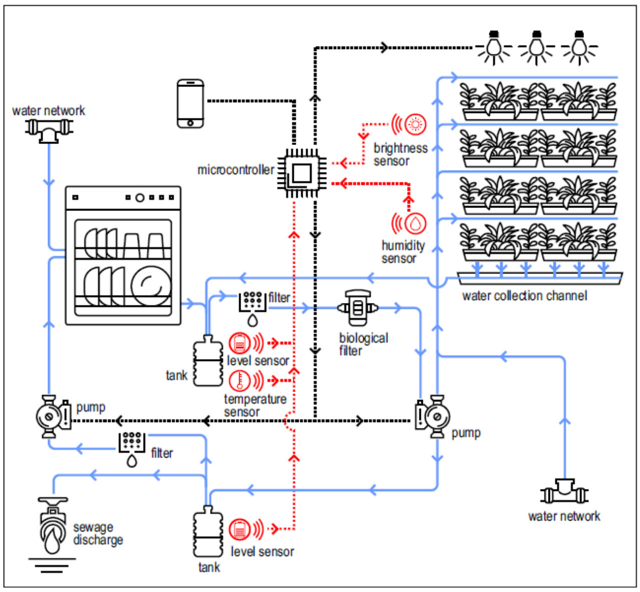
2. RESEARCH BACKGROUND

The theoretical background of the presented research is manifold comprehending natural science, socio-cultural matters and technological issues.
Zero-mile food production is gaining popularity worldwide. Beside healthy eating habits trends, this renewed interest is due also to the environmental benefits it can provide. These benefits include increased urban and architectural greening, reduction of food transport, and recycling of nutrient in wastewater. Innovative forms of green urban architecture include rooftop gardens, rooftop greenhouses, indoor farms, and other building-related forms, defined as “ZFarming” (Walk, 2014). Domestic Wastewater streams are often nutrient-rich, and urban agriculture could absorb these nutrients and has historically done so. However, the reuse of kitchen wastewater is no more practiced in modern society despite the high nutrient content and the low presence of pathogens, heavy metals and pharmaceuticals. The integration of domestic edible plants production in homes with the exploiting of kitchen wastewater for irrigation represents a promising strategy to reduce water consumption in households, to decrease the amount of wastewater to discharge, to produce healthy plant food and to enhances the environmental awareness of citizens.
Regarding socio-technical aspects, the success of the system relies on customer acceptance. As Norman states, technological innovation is simple; on the contrary, social, cultural and organizational changes are difficult. To this end, household appliances must turn into "info-appliances” to support users controlling energy and water consumption (Norman, 1999). According to User Center Design guidelines, involving the end-user in all phases of the design process, from the requirement analysis to final evaluation, is needed to achieve a high level of usability efficiency and pleasantness.
Following an Interaction Design approach, the development of innovative product/services requires user studies since the very first phases of the design process (Benion, 2013), so to orient the design toward a solution capable to produce value and satisfaction. The investigation of the context is even more important in the creation of solutions for the domestic environment, since most people see home as a personal territory, a place of intimacy, wellbeing, safety, and expression of self (Pillan, 2017). Authors such as Claire Rowland (Rowland, 2015), introduce four different ways to look at a context: operational, behavioral, ecological, and socio-cultural. The *operational context* refers to the characteristics of the physical world where the product/service will be located (thermal factors, presence of wet/dust, spatial arrangements, ...). The behavioral context includes time and space factors related to the interactions of users with the product itself and its surroundings. The sociocultural factors are related to the motivations, expectations, value, psychological and relational needs of users. Finally, the ecological context concerns the products ecosystem and involves the organization model between stakeholders related to the solution, also including the economical and transactional factors. For this reason, the research presented in this paper includes several activities aimed at investigating attitudes, needs, expectations and constraints of users, with respect to planting at home, re-use water and to the availability of adopt such a system.

3. SYSTEM DESCRIPTION

The system represented in Fig.1 consists of a dishwasher integrated with an indoor planting device, to recycle wastewater from dishwasher for two parallel purposes: (i) making available the organic nutrients present in waste

water for the cultivation of vegetables in home environment; (ii) reusing the recycled water for following washing cycles.
Wastewater is treated by a biological filtration, taking advantage of bioremediation techniques: selected algae and microorganisms mineralize nutrients from the wastewater, enriching the filtered effluent, 'fertilizing' water and, therefore, supporting zero-mile plant cultivation.
IoT technologies are applied to support the interactions between user, functions and surrounding environment.
An experimental in balance prototype as shown in Fig.2 was built considering: a) the mean Italian dishwasher uses around 4 times a week; b) the amount of wastewater discharged, approximately 12 lt. per washing cycle; c) the daily water consumption per plant, around 40 ml for salad.

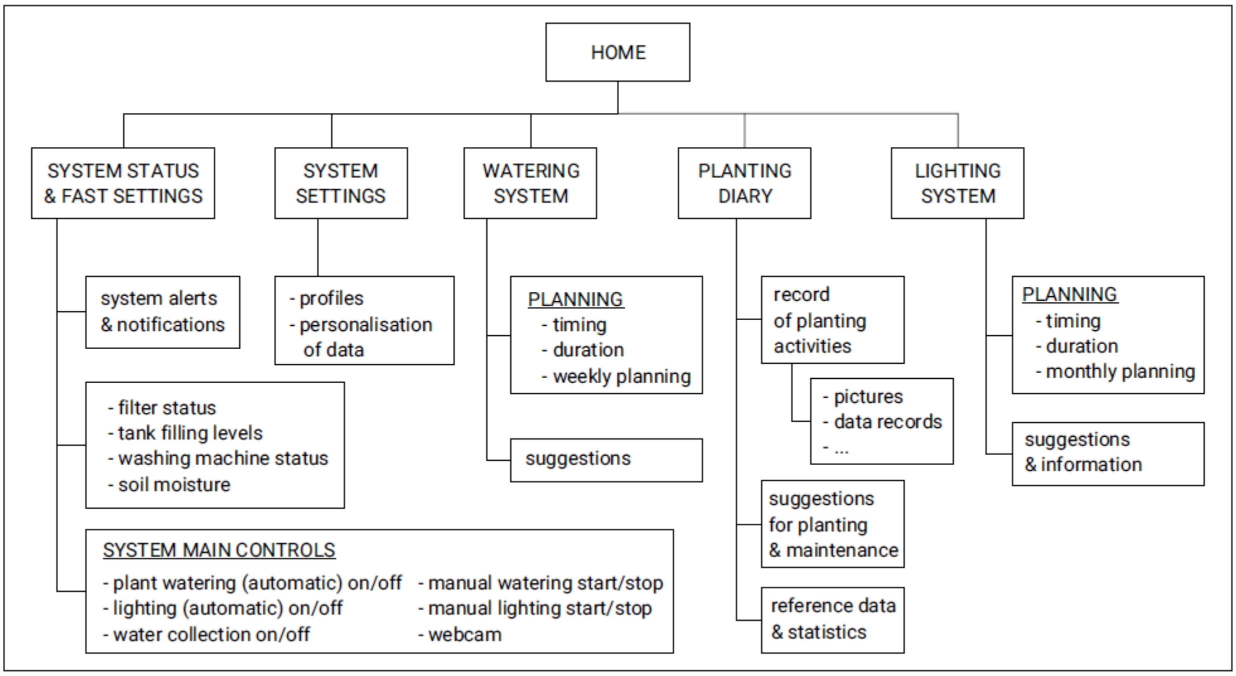


[Figure 1] System

[Figure 2] Prototype

4. RESEARCH METHOD

The methodological process consisted in 6 main steps.
At the beginning, we conducted benchmarking through an internet-based research using key-words (such as: green wall, growing plants appliance, cultivation system indoor, green kitchen) and performed field-research during Eurocucina, Milan Design Week 2018.
A mixed methodology, including secondary analysis of quantitative data and focus groups with consumers and stakeholders, has been applied to understand consumer habits regarding water recycling, home cultivation and eating preferences.
On the base of the results of the previous steps and the biological experimentation, that was conducted in parallel, we organised a co-design workshop to generate the system concept.
The final user interface was developed according to the workflow represented in Fig. 3.
An experimental prototype was then built to test plants growth and interaction modalities through an iterative process, articulated in prototyping-evaluation-modification cycles, with the collaboration among different professionals and the involvement of expert users.
The collaborative development of the interaction system is in progress thanks to the use of software and prototyping platforms such as MIT App Inventor and Arduino.
User trials are planned to test the prototype's interface usability.



[Figure 3] Workflow of the final user interface for system control

5. USER NEEDS

People representative of possible final users have been involved up to now through a questionnaire, a focus group and interviews to investigate attitudes and opinions about the *system*. The research involved people, of different age and personal disposition toward environment issues, none of which had a preliminary knowledge of the concept.
The focus-group (7 people), reported the motivation of users toward a better use of water and a diffused awareness of the advantages of using domestic appliances selecting the ecological program. The core phase of the focus-group was based on the presentation of the concept with the support of some images reporting the scheme of the system and the experimental apparatus. The impact of the presentation was positive, and it created a fertile conversation between the participants about potential and critical factors of the concept. We schematically condense the outcomes in terms of critical, positive features and other relevant issues.
To begin with criticalities, the discussion evidenced space constraints (dimensions, encumbrance and positioning); maintenance and hygiene (management of leaves and organic wastes, insects, smells); safety regarding breakdown of the electric or water system and risks related to behaviors (as an instance, kids climbing on the plant-shelf); consumptions and economic impact (initial costs, consumption of electricity for lighting and for feeding the watering system).
The list of positive factors includes elements of gratification related to the adoption of behaviors giving a convenient contribution to environmental issues; the pleasure of gardening at home; availability of pot herbs; the flexibility of the system with respect to different uses of recycled water; the opportunity to distribute the components of the system (e.g. locating the planting shelter out of the kitchen); the symbolic impact of hosting the system at home.
The focus-group revealed also a trusty attitude of users toward recycled water: while the research team is paying much attention on the possible impacts on health and is dedicating several research activities to the monitoring of the quality of the veggies, users showed a positive attitude with respect to the safety of the process and positive expectations about the impacts of plant facilities in domestic environments. Users consider positively the requirement of using only eco-friendly detergents.
Target interviews with professionals were dedicated to the discussion of technical and maintenance requirements of the system and to its potentials with respect to other contexts, such as restaurants and canteens.
The conversation with users pointed out also the importance of a suitable communication apt to better explain the potentials and the 'reasons why' of the system: while the attitudes of the people involved in the survey showed interest and curiosity, it is also evident that innovation as such is not considered as a value in its own, and it is important to accompany the development of the new domestic solution with a broad conversation about its potentials and criticalities. This result is of general importance and it is coherent with a general principle of Interaction Design, i.e. that innovation requires social engagement to discuss the impacts and verify consensus. (Erwin, 2013).

6. CONCLUSIONS AND FUTURE DEVELOPMENTS

The experimental development of the integrated system reported in this paper was conducted following a research method based on a design driven creation of a scenario and concept that were shared with the project partners since the very first phases of the concept generation, through the design/experiment cycles, so to enable co-design and progressive improvements based on independent contributions of researchers from different disciplines and collection of hints from potential users. The research is still going on and the next steps will focus on the iterative prototyping and refinements of the digital interfaces for control, on the investigation of the quality of the final organic products and on the technical characteristics of the system.

BIBLIOGRAPHY

Benion, D. (2013), Designing Interactive Systems: A Comprehensive Guide to Hci, Ux & Interaction Design, Pearson.

Bhamra, T., Lilley D., Tang T. (2008), Sustainable use: Changing Consumer Behavior Through Product Design, in Changing the Change: Design Visions, Proposals and Tools.

Costa, F., Amati A., Antonelli M., Cocetta G., Di Mauro M., Ferrante A., Krasojevic K., Mangiarotti R., Erwin, Meraviglia M., Nebulon A.i, Perego P., Sironi R., Spanu F., Standoli C.E., Vignati G., Volonté P., Ziyaee M., Migliore L. (2018), *Designing the Future: An Intelligent System for Zero-Mile Food Production by Upcycling Wastewater*, MPDI, Proceedings 2018, 2, 1367; doi:10.3390/proceedings2221367.

Erwin, K. (2013), Communicating the new. Methods to shape and accelerate innovation, Wiley.

Norman, D., (1999), The Invisible Computer, MIT Press.

Pillan, M., Colombo, S. (2017),.*Will smart homes improve our lives? A design perspective towards effective wellbeing at home.* 12th EAD-European Academy of Design, Design for Next.

Rowland, C., et al (2015),. Designing connected products, O'Reilly.

Walk, H., Dierich, A. (2014), Urban agriculture of the future: An overview of sustainability aspects of food production in and on buildings. Agric. Human Values 2014, 31, 33–51.