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Participatory design for service robotics

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Beyond Participatory Design for Service Robotics

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Abstract
The spread of technologies as Cloud and Distributed Computing, the Internet of Things (IoT) and Machine Learning techniques comes with highly disruptive innovation potential and consequent design imperatives. High connectivity of devices and machines is shaping not only sensing and monitoring capabilities, but also describing ever more ubiquitous and diffuse computing capabilities, affecting decision-making with a wide range of assisting tools and methods. With the scaling potential of moving beyond its contemporary application such as industrial facilities monitoring, precision farming and agriculture, healthcare and risk management scenarios, RaaS is bound to involve an increasingly fluid and diverse range of users, shaping new socio-technical systems where practices, habits and relationships will evolve in respect to its adoption. On these premises, applied research at Polytechnic Interdepartmental Centre for Service Robotics in Turin, Italy, focuses on the development of a service robotics platform able to operate on the local scale and capable of adapting to evolving scenarios.

Keywords: service robotics, socio-technical, complex systems, making use, design

1. Introduction

Service Robotics is an emerging field in engineering design research and practice, that deals with recent advancements of technologies such *cloud services* and low-cost sensors, as enablers of the *automation* of activities beyond industrial applications. In consistency with Richard Normann's view of *service* (Normann, 2001)as value-creating systems with us inside, its progress is shaped by people's desire to augment human intellect, unlocking new levels of *productivity* and *creativity* by automating activities and evolving better programming paradigms.
Normann's description of services puts emphasis on the strong relationship that ties technology to its environment, as it influences habits and lifestyles in a perpetual process. Within this frame, anthropologist Tim Ingold's definition of *taskscape* is particularly useful to address the complementarity of the bond that ties human activity to the landscape (Ingold, T.,1993).

As described by Goodwin, the concept of landscape emphasizes form, as that the concept of *body* put emphasis on the form rather than on the function of a living system (Goodwin, B., 1988). Like organism and environment, body and landscape imply each other, alternately as figure and ground, generated and supported in and through the process of carrying out a total field of relationships that crosses the emerging interface between organism and environment.
Ingold proceeds in the description of this processual complementarity introducing the concept of *embodiment* as a "movement of incorporation" of the organism, in which its bodily form *emerges* from the life-cycle process, as being also pertinent in the description of the environment. To do so, the concept of *temporality* as experience of those who carry forward the process of social life in their activities, is introduced in his argument. He calls this ensemble of activities the '*taskscape'.*
Within this context 'tasks' are defined practical operations, carried out by skilled agents in their environment, as part of his or her normal business of life. In other words, tasks can be identified as the unit of dwelling activities. Tasks then take their meaning from their positions within an ensemble performed by many people working together in series or in parallel. Taking these considerations into account it becomes impossible to separate the technical dimension of a system from the social act of inhabiting a place, as every technological practice is embedded in the current of sociality, as people *attend to one another* when performing their tasks. Temporality is then intrinsic of a taskscape, emerging from the network of interrelationships between the multiple rhythms of the activities constituting it, lying the foundations of *sociality* in the resonance of movement and feeling deriving from the reciprocal and attentive commitment of people in a *context* of shared activities.

This anthropological framing of technological development is used in the following case studies analysis to include the social dimension in the development of Service Robotics applications, such as Precision Farming. By social dimension we then refer to the mutual engagement of organisms as sentient agents carrying out their activities in an environment. This definition helps us understand human as well as non-human (other animal and plant life forms) relationships between organisms themselves and their dwelling in the environment.
As Richard Tapper argues, farming activities shaped the notion of *domestication*, as involving a 'kind of mastery and control' similar of that entailed in slavery (Tapper R., 1988). By slavery, Ingold

describes a situation where the autonomy of the agent to act according to his own volition is compromised through the application of force with the specific intent to overwhelm his resistance. In the sense by which the use of force is based on the assumption that the slave is a being with the ability to act and suffer, and in that sense a person, domination and domestication are distinguished, starting from the assumption that one is a form of social control exercised over subject-people, and the other a form of mechanical control exercised over object-things.
Based on these premises, the domain in which human beings are involved as social beings with one another cannot be rigidly distinguished from the domain of their involvement with the non-human components of the environment. Therefore, any qualitative transformation in environmental relations manifests itself in a similar way both in the relations that man extends towards animals and in those that are established between them in society. It was, in fact, only with the advent of *industrial breeding and livestock management* that animals were reduced, in practice and not only in theory, to mere "objects" that the theorists of Western tradition had always assumed to be (Tapper 1988).Technical advances in adaptation strategies, such as those that led the advent of the agro-pastoral industry, marked the transition from a principle of *trust* towards the environment to one of *domination*, that extends beyond non-human relationships, directly into human social sphere.

In recent research, service robots have been described as a combination of a mobile platform and a manipulator which main function is to carry objects between locations. This kind of operation requires abilities such object detection, navigation, positioning and object manipulation (Kaloyan Y. et.al, 2016). The development of modular, more connected and versatile 'robots' enables the automation of more complex tasks that cannot be split into simple actions.
The recent broad diffusion of Internet of Things (IoT) paradigm in industrial development enables the use of automation well beyond production lines and well-structured and controllable manufacturing activities. High connectivity of devices and machines is shaping not only sensing and monitoring capabilities of different application fields, but also describing ever more ubiquitous and diffuse computing capabilities, affecting decision-making with a wide range of assisting tools and methods, like context-aware AI fuelled by a yet unmatched data flow. Digital Abundance is a shorthand that introduces us to the economy of information as a non-depletable resource, as it can be continuously copied, while exponentially increased due to "cheap and small" sensor technology. The high degree of connectivity that is going to characterize places irrorated with objects capable of 'talking' is bound to remove many physical constraints for social interaction.
These capabilities make fields of application such agriculture as favourable as industry, giving raise to new fields of research and development such Precision Agriculture (PA). Also known as Precision Farming, PA aims to manage spatial and temporal variability associated with all aspects of agricultural production, with the main goal of improving both *environmental quality* and *crop performance*.

2. Methodology

2.1. Beyond Participatory Design

As theorized in recent empirical studies of technology, philosophically recognized theoretical perspectives claim that the distinction between "designers" and "users" is symptomatic of culturally perpetuated social roles, as both designers and users perform inventive, creative and transformative acts in the same way. (Vardouli, 2015). From this argument, function theorist Beth Preston states that function is independent from isolated agents' purposes but grows from 'historical patterns of actual use and reproduction for that use' (Preston, 2016). Studying the phenomenon of use dissociated from design helps to correct some of the shortcomings of design-centric and communicative attitudes, which are based on the need to establish causal links between how an artefact was created and how it is used or between the human actor who created it and the one who uses it. Following Ingold's ecological approach, where the boundaries between subjects and objects do not exist before an active process, but emerge through the process itself and can only be recognized retrospectively, design theorist Theodora Vardouli argues that throwing these boundaries, in this case between users and artefacts, in advance is like reading the process backwards rather than forwards (Vardouli, 2015).

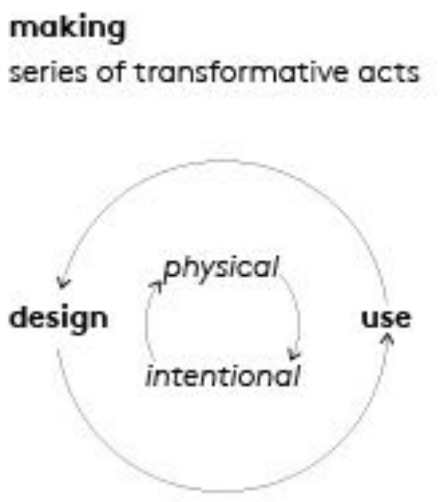

Figure 1. Transformations that occur when humans engage with things.

As Ingold's notion of 'taskscape' has been beforehand introduced as an ensemble of *tasks,* both as physical operations and acts of dwelling, it describes them a continuous, qualitative and heterogeneous, in opposition to isolated and quantifiable activities. They are driven by their own temporality, which causes the experience of the past and the perspective of the future to collapse into acts of present improvisation. Ingold's position shows visible traces of phenomenological philosophy, especially in his focus on the embodiment and construction of temporality as lived duration rather than quantifiable time. This shift from the intentions of a single human actor to a dynamic context of action, interwoven with material, social and cultural forces, is solidified in the keyword "making". 'Making', for this definition, shifts temporality and emergency to the centre of the scene by conceptualising the production and use of artefacts, opening new critical and productive possibilities for design research. The performative approach of man's engagement with artefacts, promoted by the conceptualizing of use as a sort of making, encourages designers to take a new perspective towards the products of their projects, not as a continuation of their author's intentions, but as constitutive parts of other people's niches. Consequently, users are no longer passive recipients of design activity, but active performers of improvisational, open-ended tasks as *makers of use* (Vardouli, 2015). The grammar of 'making' replaces the "identity operation" (application of rules on fixed entities) with an "embodying operation" (application of rules on any part of an entity that offers an opportunity for action to a subject)(Stiny, G., 2006), allowing emerging results.

In this sense *embedding* refers to the possibility in a particular situation that a subject recognizes for action, resulting in a concrete analogy with the initially proposed ecological meaning of *affordance* by American psychologist J.J. Gibson (1977)

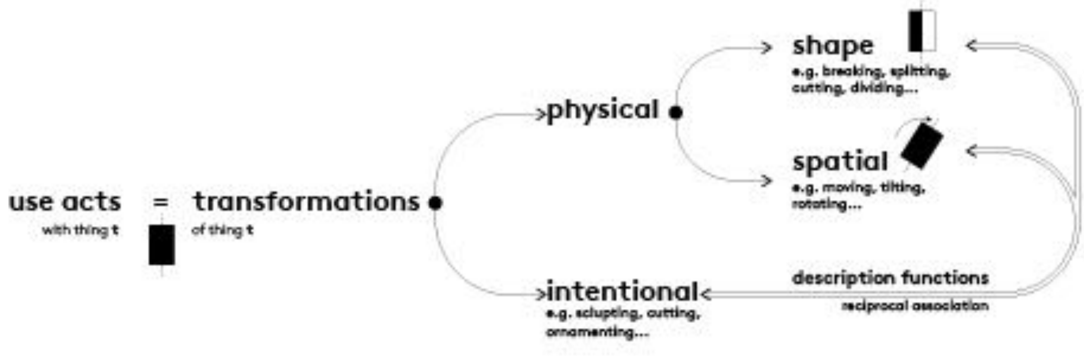

Figure 2. Vardouli's Sketch diagram of Use acts viewed as transformations (rules), which are divided into physical and intentional transformations, linked by reciprocal yet not necessarily deterministic relationship 'description functions' that occur in a human-artefact engagement.

3. Case Studies

To support heterogeneity of solutions fitting diverse use cases and even different application fields we investigate service robotics case studies looking for *modular* technological solution in relation to actors involved as users and more generally as stakeholders.

3.1. Modular Cloud Robotics Architecture

The management of agricultural activities requires intense and broad monitoring of multiple entities, such plants' health or soil humidity, resulting in the collection of large maps, images, video, real-time networks and financial transactions. The term "big data" is used in this context to describe amounts exceeding the processing capacity of a conventional database system. This condition makes it impossible to process the required information for an on-board memory of a single robot.

The main innovative technological feature of this project is a 'cloud approach' to data processing (collection and computation), which provides service robots with *access* to vast resources of data necessary to manage complex tasks. The working team proposes a high-level cloud platform to manage several unmanned robots, both aerial and terrestrial (UAVs, UGVs) with the goal of providing support through remote connection to the end users, both expert technicians and related to the application field. (Silvagni, et.al, 2016). In spite of the high degree of automation, this configuration requires a lot of interaction with diverse end users to carry out its tasks, from mission supervision to data management. End users are in fact required to produce mission requests to provide the constraints for automatic UAV/UGV path generation and other database and backup functions necessary to obtain a fully autonomous mission execution. Expert users have access to decentralize analysis capability thanks to real-time video deployment to control missions, while a more general data collection is used for *knowledge sharing* among robots, field agents and end users. The whole system is also built to adapt to local navigation authority rules through high-precision real-time localization features, guarantying safety avoiding costly systems such those used on commercial airplanes.
Further interaction is provided through APIs basic function blocks that can be used to build new services on top of the more open-ended "remote brain" that contains the main specific applications, opening the possibility of custom service applications, involving developer users.

3.2. RHEA project

A recent example of service robotics deployment in precision agriculture is the RHEA (Robot Fleets for Highly Effective Agricultural and Forestry Management) Project (Gonzalez-de-Santos P, Ribeiro A, Fernandez-Quintanilla C, Lopez-Granados F, Brandstoetter M, Tomic S, et al., 2016), concluded on 31 July 2014. The project was conducted under a work program of the European Commission that focused on the design, development and testing of robotic systems for physical and chemical management of weed in agriculture and forestry. In order to contrast the growth of the pest that subtracts vital nutrients form its surroundings, farmer usually apply pesticides with traditional sprayers, distributing them uniformly over the fields. The aim of this project was to provide support to the farmers to reduce the amount of applied pesticides without reducing the effectiveness of the treatment, by targeting local area of intervention such as wide row crops (processing tomato, maize among others), close row crops (winter wheat and winter barley) and forestry woody perennials (walnut trees, almond trees, olive groves and multi-purpose open woodland). with ground robots equipped with three different manipulators, once identified with high-quality cameras mounted on-board of flying robots hovering over the fields. To allow the control system to accurately steer the robots to work on wide-row crops (with 0.75 m-spaced rows) and ensure autonomous outdoor navigation, a high precision Global Navigation Satellite System (GNSS) was used. A graphical User Interface (GUI) on a ground station was provided to the farmers, allowing them to create and launch the missions. The interaction required the definition of the area by entering the limiting point of the field of action.

4. Conclusions and Discussion

The systematic design methods assist researchers in design choices, whereas the economic analysis considers allowable cost of a system. Only a few authors report design processes based in requirement engineering. For this product-service system we propose a *Socio-Technical Innovation* framework to balance the efficiency of simple stable technological systems with the capacity for resilience and adaptability of more complex, unstable social systems that surround them. A wider network of stakeholders, reaching out to growing community of users and producers, allows organizations to see more opportunities than those dependent on previous choices. Local decision-making made by a variety of actors with shared interests, is likely to be the most successful: though the larger system is complex and difficult to predict, its subunits are less so.

In order to increase cognitive ergonomics and affordance for the end user, each subsystem (component) shall have a self-sustaining life cycle, with explicit functions that make its purpose recognizable. A wheeled or winged structure will be regarded as responding to 'locomotion' functions, while a camera or a condensation hygrometer will cover 'sensory' functionalities and a robotic arm is responsible for 'grasping'. A great advantage given by this modularity is that improvements in the structure of a function can be integrated in the whole system without having to lose every other part.

To be part of a larger system, these components also need to be connected, which means they must interface with each other. This is made easily possible by standards of data transferring via wireless connection to internet services. Complex systems high connectivity leads to difficulties in centralized control and predicting causes and effects, driving the need of localizing decision-making when possible. Chances of identifying a single 'optimal' solution for the whole system width are low; great part of current information and implementation happen on a local scale, necessitating a decentralized approach. While in simple and stable systems homogeneity of input is favoured over a more problematic diversity, in complex social systems heterogeneity is incredibly more valuable, both increasing the range of current information and of solutions generated. The possibility to configure sequence or arrays of function to manage complex tasks in different and evolving scenario, along with the feedback provided by monitoring the conditions of the environment, gives users a much greater capability of engagement.
Faced with an ecological crisis that has its roots in this disengagement, in the separation of the human agency and social responsibility from the sphere of our direct involvement with the non-human environment, it is certainly necessary to reverse this order of priority.

A designed system of product components and services follows the purpose finding principle (Jones 2016). As Jones further explains in his paper on Systemic Design Principles, the purpose principle provides a whole-to-part view of problem space. The diversity of solutions provided by a modular configuration of functionalities, delivered in the form of services, guarantees a balance between fixed purposes and what Jones refers to as creative framing.
Useful to this purpose is Robotics-as-a-Service framework, a cloud computing service model that allows to seamlessly integrate robots and embedded devices into Web and cloud computing

environment. As a service-oriented architecture for robotic applications, a RaaS unit has the environmental potential of decoupling the production of economic value from energy and resources consumption. It includes services for performing functionalities, a service directory for discovery and publishing, and service clients for user's direct access. This platform allows to manage robotics components both as an increasingly granular integration of control over automated tasks and as part of a largely aware whole emerging from their connectivity.

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