Interfaces of the Agriculture 4.0

Letizia Bollini[1][a], Alessio Caccamo[2][b] and Carlo Martino[2][c]
[1]*Department of Psychology, University of Milano-Bicocca, Piazza dell'Ateneo Nuovo 1, Milan, Italy*
[2]*Department of Planning, Design, Technology of Architecture, Sapienza University of Rome, Via Flaminia 72, Rome, Italy*

Keywords: Agriculture 4.0, Agritech and Design, Human-Decentered Design, Conversational Interfaces, Multimodal User Interfaces.

Abstract: The introduction of information technologies in the environmental field is impacting and changing even a traditional sector like agriculture. Nevertheless, Agriculture 4.0 and data-driven decisions should meet user needs and expectations. The paper presents a broad theoretical overview, discussing both the strategic role of design applied to Agri-tech and the issue of User Interface and Interaction as enabling tools in the field. In particular, the paper suggests to rethink the HCD approach, moving on a *Human-Decentered Design* approach that put together user-technology-environment and the importance of the role of calm technologies as a way to place the farmer, not as a final target and passive spectator, but as an active part of the process to aim the process of mitigation, appropriation from a traditional cultivation method to the 4.0 one.

1 INTRODUCTION

Today, we live in an immaterial society, based on the so-called *fifth dimension* (Cosenza, 2012), an information dimension in which knowledge passes through the analysis and communication of data: the pervasive information society (Resmini, Rosati, 2011), or Society 4.0. Today more than ever, contexts of use and digital technologies should be investigated in order to understand the perspective of the future world.

Historically influenced by HCI, Computer Science and cognitive ergonomics (Drucker, 2014), the interface design takes today's cultural connotations and socio-political influences to question not only on the functional aspect, but the communicative and expressive, aesthetic and educational. Borrowing the term from the theatre, the novelty of the new interfaces is the ability to break the *fourth wall*, since they go beyond the screen (Kortum, 2007) and, far from being just and exclusively invisible windows of connection between the data and the user, are today more than ever a pervasive reality that - from the screen to the AR - take on the characteristics of the new media. The interface leaves the frame of monitors, moving into the world becoming a structure that is architecturally grafted onto existing reality. Going beyond the interface as a tool for help and support - seeing it instead as a partner with whom to live - means affirming the pervasiveness of the same and its repercussions in its social, political, cultural and therefore educational aspects.

Today, the interface effectively becomes a hybrid environment between the physical and virtual. A mixed reality that assumes architectural features and spatial qualities. For this reason, the future of the interface requires investigation to understand what we should borrow from the design physical spaces to create mixed ones, in terms of methods and approaches. Starting from this theoretical framework, the paper presents a broad theoretical overview – part of an on-going research - discussing both the strategic role of design applied to Agriculture 4.0 and the User Interface and Interaction as enabling tools in the field.

Paragraph 2 presents the shifting role of Design in the field of Agriculture, from product to service, suggesting the cultural approach that design could give in the transmission of knowledge in the agricultural and ethno-botanical fields.

[a] https://orcid.org/0000-0001-6491-4838
[b] https://orcid.org/0000-0002-2045-6385
[c] https://orcid.org/0000-0002-0664-0549

Bollini, L., Caccamo, A. and Martino, C.
Interfaces of the Agriculture 4.0.
DOI: 10.5220/0008164802730280
In *Proceedings of the 15th International Conference on Web Information Systems and Technologies (WEBIST 2019)*, pages 273-280
ISBN: 978-989-758-386-5

Paragraph 3 explores, firstly, the definition and the possible skills of the farmer of the future, secondly, the importance of calm technologies as a mediated tool to aid the passage from traditional cultivation method to the 4.0 one.

Paragraph 4 suggests a new approach to the interaction design project that from a human centered point of view, shifts to a human de-centered one, involving the environment. At the end, an international case study shows one of the possible applications of non-traditional interface in home-made farming.

2 DESIGN- INNOVATION-AGRICULTURE 4.0

Until the late 70s, in the mechanization age, the contribution of Design for Agriculture was limited to the design of material artefacts, tools and means for working in the field or, at the end of the chain, in the arena of corporate graphics, the branch that studies and create the packaging for agricultural products or to the visual communication of agribusiness brands.

Excluding intensive, extensive and advanced cultivations in the USA, in the rest of the world cultivation processes were the prerogative of agricultural traditions reiterated through the generational transfer of knowledge (Ison and Russell, 2000). In the most advanced cases, they were integrated by the consultancy of technical-scientific figures, agronomists, well trained on the so-called hard sciences – chemistry, botany, biology – but poorly trained on the entrepreneurial and managerial aspects of agricultural production on an industrial scale. Technological innovation applied to artefacts for agriculture – as the central theme on which design was focused for a long time – has always been pursued to free mankind from physical fatigue (Maldonado, 1987; Boni, 2014) and to increase the productivity of cultivation processes.

The digital revolution and the innovations developed over the last 30 years within Computer Science, Robotics and AI, applied to agriculture first with precision farming (Auernhammer, 2001) and then with [...] "*the transposition of the paradigm of Industry 4.0 in the agricultural sector, that is the tendency towards automation and the interconnection of agricultural activities and all supply chain processes [...]*" (Osservatorio SmartAgrifood, 2018). This paradigm today defines Agriculture 4.0 or digital farming, and it has opened up new problems and new areas of experimentation to which Design, as a "plastic" discipline, is called to give answers.

In the 90s, we witness the first forms of technology and process innovation in Agriculture, thanks to the development of Precision Agriculture (Auernhammer, 2001). Today, these innovation - as a result of Agriculture 4.0 - extends to the monitoring of crops, to the traceability of the entire supply chain, up to the Supply Chain. The introduction of technological elements - on one hand has clear and noble goals - on the other brings out new and more complex problems. In fact, if this application responds to a growing demand for "food" connected to the increase in the world population or seeks new solutions to adapt the cultivation processes to climate change (Howden, SM et al, 2007), it also raises questions related to the dissemination and integration of the same in the traditional cultivation processes as well as open a debate about the role that the farmer has and will have to have in hybridised contexts. The farmer could, in fact, evolve into a professional agronomist / farmer with digital knowledge and skills – digital farmer – with a wealth of expertise resulting from the combination of ICT and agronomic skills, expressly dedicated to the implementation of the so-called Smart & Precision agriculture and automation processes. Design can continue to contribute to the production of artefacts for cultivation processes, even in an "increased" performance logic deriving from ergonomic innovations or from the integration of new technologies – *Smart Farming* – the relationship between Design and Agriculture 4.0 shifts the application centre of gravity, investing in mainly intangible areas, ranging from the transfer of Intelligent Environments to the agricultural environment, to the design of the "services" defined by new processes, to the definition of new Users, and to the design of functional interfaces in a HCD approach, useful for the management of new systems and new technological devices. In the scenario of Agriculture 4.0 the spaces for *Design-Driven Innovation* (Verganti, 2009) seem to be unlimited and on very different scales. In fact, they can be approached according to the logic of Strategic Design, Social Innovation, Systemic Design or according to the Human Centred Design modality. The research that our team is carrying out is part of the latter, positioning it in a scenario that strongly integrates scientific research in the context of the IoT, the UX and the UI design.

Design-driven innovation in agriculture can now, focus on the relationship between new devices and their usability, for the construction of interfaces capable of facilitating the use of the former ones by

more advanced farmers, characterized by a different technological and cultural imagination.

The challenge for the new interfaces that go beyond the screen to reach the environment – becoming pervasive – seems to be the translation of the different ethno-botany – as stated by Treccani Encyclopaedia - into an interface that becomes a medium of agri-*culture* – in the meaning of culture of cultivation – according to a logic of customization that can lead to an empathic and natural fruition, which does not deny it flattens as it settles in previous peasant cultures. Added to this point, there is the need for dynamic-responsive, customizable and interoperable tools – able not just to "make people read" and/or transmit information but also to suggest actions and solutions to be adopted in a DSS logic – Decision Support Systems – or "machine learning".

3 CALM TECHNOLOGIES FOR SMART FARMERS IN HYPER-LOCAL PRODUCTIONS

As stated by Nielsen back in 2004, internet and digital technologies are undoing the industrial revolution balancing a mass and centralized vision of the production, media and social organization with a more holistic eco-systemic and dispersed life-way (Nielsen, 2004). Moreover, the dramatic ecological crisis and climate changes we are facing are a vast and compelling motivation to rethink our economic model. We can define it as a sort of digital *eco-nomic* paradigm that claims a social innovation move from an XVII-XX century way of life to a post-industrial, post-modern post-capitalist era in which the development of technology is no more a promise of infinite growth, but rather a commodity to improve a decentralized individual and collective lifestyle. Something in between the *décroissance sereine* theorized by Latouche (2004, 2007) ad a *glocal* approach to a sustainable and ecological transition of the *post* society (Klein, 2014).

The new organizational paradigms that, at times, seem to emerge, develop according to centrifugal and contrasting tendencies. In some cases we can see the concentration of large parts of the production and distribution systems centralized in a few hands, as is happening in Silicon Valley with the *Gang of four* as Gallow (2015) defined them and where some players, instead of dis-intermediating people's access to information and resources have simply replaced the old intermediaries (as in the case of Amazon, even in the food distribution sector) (Bauman, 2013). Beside these realities, however, root-grass phenomena and bottom-up economies, fragmented, local have been developing according to the model of the *long tail* theorized by Anderson (2006) in the world of media, music, books, contents, and integrated platforms Amazon and iTunes *in primis*.

In this scenario, even a traditional production sectors such as agriculture is invested by technological innovation at a different scale. On the one hand, there are big business players able to introduce and adopt a vast range of technological devices and systems. It is the field of *agritech* and *smart-farming* where drones, Artificial Intelligence, machine learning, automation, sensors, IoT, and other data-driven and science-driven information technologies are applied to farming and agriculture. However, this cultural shifting also allows small realities, to adopt a smart approach with a high level of IT and added-value innovation to sustainable micro-cultures or local experiences to improve harvesting and food productions (Bollini & Cerletti, 2009). It is the case of the MIT Media Lab project headed by Caleb Harper: *The open agriculture initiative* intended to offer a digital framework, an open and accessible ecosystem that is raising and growing a community of nerdfarmers and aims to "builds open resources to enable a global community to accelerate digital agricultural innovation […] that enable and promote transparency, networked experimentation, education, and hyper-local production […] creating collaborative tools and communities to explore future agricultural systems" (OpenAg, 2015).

Nevertheless, the transformation between a global and industrial approach to a local and digital dimension implies further cultural changes. The passage of scale from large estate-owned productions to the possibility of self-production involves two fundamental factors in the relationship with applied technologies: the territory and the people. It questions the ancestral value of this relationship. The tech infrastructure, in fact, overlays on the spatial surface, both physically and metaphorically, as a sort of second overlapping eco-system (Bollini, 2016). At the same time, it should be able to create an accessible interface for people interacting with sensors, data, and environment in an engaging and friendly way. The technologies, in this case, are enabling tools in automating natural processes and supporting what could be defined as user-generated *products*, where the products are harvests of agricultural crops at local or hyperlocal scale and self-production of food.

But who are the new farmers? Are they real technology "geeks" and nerds well trained and skilled in Computer Science? Or only people with a strong concern for sustainability and affordable living willing to respect the environment and to embrace the de-growth or a different growth culture? Or, again, small entrepreneurs willing to change the relationships of production and distribution reducing the production chain and using eco-compatible practices in the agricultural sector, ready to revitalise marginal rural areas or to protect and recover traditional crops and biodiversity? Above all: what is their relationship, their need for technology?

Within this varied world there are experiences such as the one developed by the artistic collective *Futurefarmers* founded and animated since 1995 by personalities of the technological scene of the Bay Area such as Amy Franceschini. The multidisciplinary group explores issues concerning the role of urban agriculture and citizenship participation – e.g. the *Victory Gardens* project in 2006 then became *The Urban Garden Registry* and exhibited at the 13th Venice Architecture Biennale in 2012 – or the relationship between tradition and technologies. In the *Ethnobotanical Station* – a workshop and an online tool developed in 2012 (futurefarmers.com/ebotanical) – *"a mobile module [drawn] upon a diverse lineage of knowledge to study the complex relations between plants and humans. It brings in the question our faith in modern quantitative science as compared to the long tradition of qualitative indigenous knowledge. An inventory of distinctive tools, hands-on workshops and mappings are the vehicle for research and sharing new configurations of knowledge."* (Franceschini, 2012). Alongside this *neo-rural* culture, which has a powerful connection with the world of technology, there are, however, realities where the potential of agriculture 4.0 is grasped not as a goal in itself or as a meta-project discourse, but as a tool to support concrete results, *in the field*.

In the latter case, the people involved therefore need distributed systems in the environment, Industrial Internet of Things and smart technologies that offer systems of interaction and *calm* interface. If we extend the concept proposed by Weiser and Brown (1995) the *agritech* applications must not engage the peripheral attention of users, they must not absorb energies, cognitive or not, in their learning, decoding and monitoring process. The flow of information from the territory, the environmental conditions and the data collected in real time are used to supervise the crops and to make informed decisions that are optimized in relation to the context. User research, user experience, and interface design, multimodal and distributed are therefore key tools to make the digital ecosystem accessible and useful (Bollini, 2001). About the user interactions of the OpenAg Ecosystem Harper claims: "as *affective* as it is effective, and as *desirable* as it is accessible by exploring how to incorporate the principles of human-centered design, behaviour design, and calm technology into user experience/user interaction. We want to create emotionally-, socially-, and culturally-intelligent food production technologies that respond to and support folks who want to grow their own food" (Harper, 2017).

4 APPROACHING THE INTERFACE PROJECT IN AGRICULTURE

Innovation in the agricultural sector is today one of the greatest issues put in place also by the European Union, as demonstrated within the specific objectives of Horizon 2020, as necessary in order to respond to problems (European and global), in the field reduction of resources, increase in production costs, and lowering of sales, environmental pollution and climate change. According to the United Nations' Food and Agriculture Organization (2018), *food production is expected to increase by at least 60% by 2050 in order to compensate for the increase in the world population, which is expected to reach 9 billion people*. Technological innovation plays a key role in the resolution of these issues. *Precision agriculture*, as stated by Godwin (2003), is an example of increasing crop performance through the rationalization of inputs and the reduction of crop and environmental costs. Nowadays, the integration between precision agriculture and ICT has allowed the definition of the so-called Agriculture 4.0 (De Clercq, Vats, Biel, 2018) and Internet of Farming or the application of different technological systems aimed at improving agricultural production in terms of yield and environmental sustainability, quality and safety of the product along the whole supply chain and transformation, as well as within the working conditions.

HCI, interaction design and non-traditional interface forms can provide solutions to the initial difficulties of integrating technology with traditional work as well as becoming an instrument for anticipating emerging needs and demands from the user (Harper, Rodden, Rogers, and Sellen, 2007). Considering therefore the difficulties in approaching

new methods and techniques, in agreement with Rodriguez, Fernandez, and Hormazabal (2018), the role of HCI and User Interfaces in agriculture can and must be decisive, going beyond the interaction for GUI – Graphic Human Interface – linked to a screen, but going further rethinking the concept of interface in a broader sense and integrating the normal GUI into non-traditional interface forms that Kortum (2007) divides into 11 groups: *haptic, gestures, movements, hearing, vocal action, interactive voice response, smell, taste, interfaces on small screens, bimodal and multimodal*. It is clear that the big question is not in itself generating new ICT tools but rather defining the relationship between farmers/data in order to mitigate and make the use of technology efficient, making it easy to access and understand, breaking the cultural barrier that sees agriculture as an activity goes beyond the technology, offering a non-traditional farmer-friendly interface based on a new concept of HCD – Human Centered Design – (Cooley, 1989) that it could be called *Human-Decentered Design* (Bottà, 2018), a new and contemporary approach to UI and UX design that moves from the service experience thinking to the ecological experience system. In this approach, the design of the interface is not framed into the screen and its relationship with the user, but focus on a triangular relation based on user-technology-environment. The design of the new interface could work on this new paradigm, trying to understand the real effect of what you could do thanks to Smart Farming. It's not a game as FarmVille, it is the real environment – therein lies the innovation. For this reason, the role of interface designer – and also of the other form of that – must be considered as a strategic role, from a systemic point of view.

4.1 A Human Decentered Approach to UI

Nowadays we are living in a pervasive information society (Resmini, Rosati, 2011), in which data are all around us, move by the internet and envelop us totally - Internet of Things - changing many aspects of our lives. Despite a wide range of information, without a structure they end up becoming just "noise" - destructive and disinterested information. In agreement with Tufte (1997), it is possible to understand the management role of a designer who manages data by visualization. In the agricultural field – for example – data are shown as charts mostly. All the data generated by the different sensors are visualized in these simple ways. Because of that, into an architecture of contents, information began interface (Tufte, 1997). The definition of interactive is not linked in itself to the sense of digital but to the level of affordance as theorized by J. J. Gibson (Norman, 2013), or as the property to facilitate use and effectively respond to user actions.

The changing contexts of application of the interface design – moving historically from teletype, punched cards, keyboard, mouse and touch screen and beyond (Billinghurst, 2019) - poses the key question on how designers should approach the interaction project that goes beyond the screen and envelops the environment (Billinghurst, 2019). The inputs, outputs and even the scenarios are different.

In the past, technologies allowed us to see in an imaginary world made of windows and icons (Laurel, 2013). Today, digital and physical world seems to collide each other. Digital technologies and the internet of things can generate the most from the trans-disciplinary nature of interaction design discipline in which visual contents, elements of cognitive psychology, behavioural, contest history and place are mixed together, and today, thanks to the pervasive technologies involved, architectural aspects too. Who is the interface designer today and in the future? From a methodological point of view, what are the professional skills that a designer must have? Taking up a famous passage by Giovanni Anceschi (2006), about the theme of the project compared to the new digital media, he replied that the role of the designer is comparable to Content DJ, who selects, samples, and re-combines the elements of a project to design a better solution despite the context of use. The importance of the educational and communication factor in the interaction process, if applied to a sector such as that of agriculture, needs a total re-definition of its paradigms and its language, having to deal with the socio-cultural context (Meroni, 2016).

The art of the mixite is one of the hardest skills of the design approach, but the method is changing. In agreement with Martino (2012, 2011, 2010), the way in which the contamination of [different] cultures with other artistic traditions and with different knowledge is being implemented today is certainly new: A modality based on a "mutual recognition" and with a consequent "support of otherness". This approach could be clearly transferred to the contemporary UI design discipline where interface is not yet a screen, but it could be anything and applied everywhere. Maybe it's time to go beyond the UI guidelines in order to achieve the different and new context in which the designer could be asked to put their skills. How can a UI designer in the ubiquitous information society do this without losing their

nature? In this scenario, big/small Data and Farmer are not so far from each other if there is the presence of a director who manages, structures and designs the information in a living context: this is the director UI designer who designs – by a Human Decentered Approach – for a multimodal environment, according to an intertextual scheme of the various modes of expression, which are activated in the presence of the co-authorial figure of the user (Bollini, 2004). The new reality brings with it the need to no longer see the end user as a generalized target of the project, but to make it a "designer" in all the phases of the project in a Co-Design perspective view (Rizzo, 2018) and in the desire to offer an interface/product in which information and data empowers the collaborative remixability of Dybward (Manovich, 2005) – i.e. the customization of the data visualization – by graphics, or sounds - that come closest to the user's mental pattern.

This approach could clearly help the digital metabolization of people with lower IT skills or to ease the technological transfer from analogical practices to digital ones. For the best possible result, the involvement of farmers becomes instrumental for the purposes of technological metabolization; to place the farmer not as a final target and passive spectator, but as an active part of the process so as to aim the process of mitigation, appropriation (Preece, et al., 2002) and passage from a "traditional" cultivation method to the 4.0 method.

4.2 A Conversational Interface for Agriculture

In 2015, IKEA founded *Space 10* – innovation hub – to extend its concept of creative freedom to a global network of collaborators, allowing them to freely explore topics such as food security, urbanization, health and well-being and other macro-trends (Le Pluart, 2016). Inside the hub, multidisciplinary teams come together to imagine and design the world of the future with an emphasis on sustainability and total accessibility. One major topic is urban farming and home-grown vegetables using the hydroponic technique and to do this, the Space10 team re-create an indoor cultivation totally monitored by sensors.

The aim of Space10 was not only to put the already existing sensors and technologies in the field of hydroponic cultivation into a system – but also to offer in a single simple and accessible interface – a whole series of data necessary for the improvement of the cultivation, through a totally spontaneous mode: the voice. This is Sprout: a conversational interface. It is possible to ask questions about the plants and it "talks" back via Google Home's small speaker (Ikea Space10, 2018). The importance of the Space10 project can be linked to two key concepts in the development of contemporary interfaces: the design of a non-traditional Human Computer Interface (Kortum, 2007) in terms of accessibility to a large amount of data to farmers or not, and the importance of the interoperability between different sensors in order to achieve a better solution to grow plants and to resolve possible diseases. As we said, Sprout is a conversational interface designed with the aim of creating a natural link between people - who want to explore hydroponic agriculture - and "plants".

Cultivation, in general, is a demanding task for farmers, who usually "understand" the plants' behaviour just by experience and simple tools. Time and crop selection are critical to product quality and resource use, logistics and disease/pest control requirements are high. Thanks to a conversational interface, a natural language is used to interact, allowing normal people or the new Digital Farmer a better and easier understanding of what plants need and make the right choice. For home-made farming, there's no necessity – even if it would be always right – to have high agricultural skills because all the information you should know are processed and available just with a voice. If we consider Sprout as an educational tool, we can clearly notice a bridge between past and future. In ancient times, techniques and knowledge – based on hands-on experience - were handed down by oral transmission, by voice, father to son and so on. A Conversational Interface uses the same approach, going beyond the screen and going back to the "voice" – even if it's an artificial one – remixing past and future.

From an interoperability point of view, Sprout takes another step forward to the current state of the art of sensors in agriculture. The data generated by the different sensors – soil pH control, nitrate level, humidity, water and temperature – are processed by an algorithm based on machine learning that can thus offer real-time data and forecasts on the possible actions to be taken for the development of cultivation. All the information is processed through the Google Home's voice-assistant platform, thus offering a clear and accessible unified non-traditional interface.

Sprout represents one of the possible applications of the contemporary approach to UI. In this new scenario, the interface is the key point in which computer science, biology, heritage and behaviour are completely mixed and re-mixed in order to achieve a new way of living.

5 CONCLUSIONS

Information technologies have a huge and pervasive impact on many aspects of our present and future lives. In particular, IT applied to traditional sectors like agriculture are changing it on very different scales: they impact the production process and the supply chain both at the massive and the micro level, they improve strategic decisions and controls thanks to the use of big and local data collected from the environment, and furthermore, they provide companies and individuals with tools to directly connect them with the physical space.

Nevertheless, Agriculture 4.0 and data-driven decisions should meet user needs and expectations: design, therefore, serves as a mediator and an enabler both in a functional and cognitive way, between the potentiality of the digital revolution and the real demands of the people involved. Moreover, it is fundamental when users are asked to interact with a complex system without necessarily being expert in the digital domain. If the data is never neutral and needs interpretation, as a designer who *de-signs*, selects, re-elaborates the contents how will we design information in terms of accessibility, usability, consistency and language? Today, should the visual grammar of interaction with information be rewritten in light of the expansion of contexts of use and subjects?

According to Drucker (2014), technological development has meant that the interface design was dominated by a rationalist and functionalist attitude, deriving from *Computer Science and Information Architecture*. The interface is not an object but an environment (Drucker, 2014) that through its language favours a specific activity, mediating between the computer patterns and the mental ones of the subject. How and what does the designer translate (Baule, Carratti, 2016) in terms of visual grammar, signs and behaviour? What will remain of the visual apparatus of individual knowledge? Designing with the user (Rizzo, 2018) how can it absorb and integrate the historical-visual anamnesis of the subject and its activities, thus creating a bridge between tradition and process innovation?

Interface design thus becomes the place where the role and success of Agriculture 4.0 is strategically played; a field in which the cultural and ethical role of design, as a tool for *preserving - enhancing - increasing* the cultural heritage of the traditional professions currently invested by the digital revolution, becomes "*conditio sine qua non*" of the interface design project: towards an *ecology* of the man-information-context system.

ACKNOWLEDGEMENTS

Although the paper is a result of the joint work of all the authors, Carlo Martino is in particular author of paragraphs 2, Letizia Bollini of paragraph 3 and Alessio Caccamo of paragraph 4.

REFERENCES

Auernhammer, H. 2001. Precision farming-the enviromental challenge. Computer & electronics in agriculture, Boni, S. 2014. *Homo Faber*. Edizioni Eleuthera. Milan.

Anceschi G., Botta, M., Garrito, G., 2006. *L'ambiente dell'apprendimento. Web design e processi cognitivi.* McGraw Hill. Milan.

Anderson, C., 2006. *The Long Tail: Why the Future of Business is Selling Less of More.* Hyperion. New York

Baule, G., Carratti, E., 2016. *Design è traduzione. Il paradigma traduttivo per la cultura del progetto. «Design e traduzione»: un manifesto*. Franco Angeli. Milan.

Bauman, Z., 2013. *La ricchezza di pochi avvantaggia tutti. Falso!*. Laterza. Bari.

Billinghurst, M., 2019. What is AR?. In Fink, C.. *Convergence: How The World Will Be Painted With Data.* Convergence Press. New York

Fink, Charlie. Convergence: How The World Will Be Painted With Data (p.11). Edizione del Kindle.

Bollini, L., 2001. Multimedialità vs. Multimodalità. *Il Verri*, 16: 144-148

Bollini, L., 2004. *Registica Multimodale: il design dei New Media*. CLUP. Milan.

Bollini, L. and Cerletti, V., 2009. Knowledge sharing and management for local community: logical and visual georeferenced information access. In *International Conference on Enterprise Information Systems and Web Technologies (EISWT-09)*. ISRST

Bollini, L., 2016. *Large, small, medium. Progettare la comunicazione nell'ecosistema digitale*. Maggioli Editore. Rimini.

Bongiovanni, R., Lowenberg-Deboer, J. 2004. Precision Agriculture and Sustainability, in *Precision Agriculture Journal*, n° 5, Kluwer Academic Publishers. Netherlands.

Brenda, L., 2013. *Computer as Theatre(2nd edition).* Addison-Wesley Professional. Boston.

Bottà, D., 2018. *User eXperience design. Progettare esperienze di valore per utenti e aziende.* Hoepli. Milan

Cosenza, V. 2012. *La società dei dati*. 40K Unofficial. Milan.

Cooley, M., 1989. Human-Centred System. In *Designing Human-centred Technology*. The Springer Series on Artificial Intelligence and Society. London.

De Clerq, M., Vats, A., Biel, A., 2018. *Agriculture 4.0 : the future of farming technology.* World Government Summit 2018.

URL:
https://www.worldgovernmentsummit.org/api/publications/document?id=95df8ac4-e97c-6578-b2f8-ff0000a7ddb6

Dionisi, T., 2016. Interview to Prof. Anna Meroni [Interview by T. Dionisi]. *Design e Agricoltura. Strumenti e metodi per il trasferimento dell'innovazione in agricoltura.* (PhD Thesis, Sapienza – University of Rome, Rome).

Drucker, J., 2014. *Graphesis: Visual Forms of Knowledge Production.* Harvard Univ Pr. Boston.

Ethno-Botany, encyclopaedia entry - Lessico del XXI secolo, Vol. I. Edizione Istituto della Enciclopedia Italiana fondata da Giovanni Treccani. Rome.

Franceschini, A., 2012. Ethnobotanical Station. In *Futurefarmers.*

URL:
http://www.futurefarmers.com/projects/ethnobotanical

Gallow, S., 2015. The Four Horsemen: Amazon/ Apple/ Facebook & Google. Who Wins/Loses. In *DLD Conference*

URL:
https://www.youtube.com/watch?v=XCvwCcEP74Q&feature=youtu.be

Godwin, R. J., 2003. *An economic analysis of the potential for precision farming in UK cereal production* in Biosystems Engineering. 84(4): 533-545

Harper, C., 2017. *2017: The OpenAg Ecosystem Expands - Research, Non-Profit, Ventures, Medium*

URL: https://medium.com/@calebgrowsfood/2017-the-openag-ecosystem-expands-research-non-profit-ventures-b5762beed64b

Horizon 2020.

URL:http://ec.europa.eu/programmes/horizon2020/en/h2020-section/food-security-sustainable-agriculture-and-forestry-marine-maritime-and-inland-water

Howden, S.M., Soussana, J., Tubiello, F., Chhetri, N., Dunlop, M. Meinke, H. 2007. Adapting agriculture to climate change in *PNAS*. Wiliam Esaterlin. Pennsylvania State University.

Klein, N., 2014. *This Changes Everything: Capitalism vs. the Climate.* Simon & Schuster. New York.

Kortum, P., 2007. *HCI Beyond the GUI: Design for Haptic, Speech, Olfactory, and Other Nontraditional Interfaces*. Morgan Kaufmann. Burlington.

Krishna, K.R., 2013. *Agroecosystems. Soils, Climate, Crops, Nutrient Dynamics and Productivity*. Apple Academic Press. NY.

Ison, R., Russell, D., 2000. *Agricultural Extension and Rural Development: Breaking out of Knowledge Transfer Traditions*. Cambridge University Press. Boston.

IKEA Space10, 2018. *Sprout: Talk with your plants* URL: https://space10.io/project/sprout/

Latouche, S., 2004. *Survivre au développement. De la décolonisation de l'imaginaire économique à la construction d'une société alternative.* Mille et une nuits. Paris.

Latouche, S. 2007. *Petit traité de la décroissance sereine.* Mille et une nuits. Paris

Le Pluart, Joanna, 2016. *Secret Innovation Lab Revealed*, in IKEA Highlights 2016. URL: https://www.ikea.com/ms/en_US/this-is-ikea/ikea-highlights/IKEA-secret-innovation-lab/index.html

Maldonado, T. (1987) *Il Futuro della Modernità*. Feltrinelli. Milan.

Manovich, L., 2005. *Remixability and Modularity*. URL: http://manovich.net/content/04-projects/046-remixability-and-modularity/43_article_2005.pdf

Martino, C., 2012. Design, verso una riscoperta della cultura materiale, in *Op.Cit*., selezione della critica contemporanea, 143. Edizioni Electa, Naples.

Martino, C., 2011. Territorio come facilitatore di processo A helping hand from the local area. In *Design for made in Italy. Sistema design nelle imprese di Roma e del Lazio* 12.

Martino, C., 2010. *Orienti Mitici*, in MIXDESIGN, web magazine – www.mixdesign.it,

URL:www.mixdesign.it/Orienti-mitici_think_x_4186.html

Meroni, A., 2005. *Strategic design for the food sector. Food-system innovation. Agrindustrial Design. Ist Product and service design symposium and exhibition olive oil, wine and design.* Izmir

Nielsen, J., 2004. Undoing the Industrial Revolution in *Nielsen Norman Group.*

URL: https://www.nngroup.com/articles/undoing-the-industrial-revolution/

Norman, D., 2013. *The Design of Everyday things.* Basic Books. New York.

OpenAG Initiative, 2015.

URL: https://www.media.mit.edu/groups/open-agriculture-openag/overview/

OSSERVATORIO STAMRT AGRIFOOD. URL: https://www.osservatori.net/it_it/glossario-agricoltura-4-0

Preece, J., Rogers, Y., & Sharp, H., 2002. *Interaction design: Beyond human-computer.* John Wiley & Sons Inc. Hoboken.

Resmini, A., Rosati, L., 2011. *Pervasive Information Architecture: Designing Cross-Channel User Experiences.* Morgan Kaufmann. Burlington.

Rizzo, F., 2018. *Strategie di co-design. Teorie, metodi e strumenti per progettare con gli utenti.* Franco Angeli. Milan.

Rodríguez, A., Fernández, A., Hormazábal, J. H., 2018. *Beyond the GUI in agriculture: a bibliographic review, challenges and opportunities* in *Interacción 2018.* 35(18).

Tufte, E., 1997. *Visual explanations.* Graphic Press. Cheshire.

Verganti, R., 2009. *Design-driven Innovation: cambiare le regole della competizione innovando radicalmente il significato dei prodotti e dei servizi*. Rizzoli Etas. Milan.

Weiser, M. and Brown, JS., 1995. *Designing Calm Technology*. In *Xerox PARC.*