Beyond the GUI in agriculture: a bibliographic review, challenges and opportunities

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ABSTRACT

Different reasons have lead to an increased interest in ICTs applications to the agriculture, like precision farming or agricultural robotics. However the GUI remains the most common interface today, a host of other interfaces are becoming increasingly prevalent, such as speech based, gestural, haptics, multimodal, etc. This work presents a bibliographic review about the inclusion of nontraditional interactions (named "beyond the GUI interfaces" after Kortum [17]) for different operations in the agricultural fields, a qualitative analysis and some challenges and opportunities found

CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**; **Interaction techniques**; *HCI design and evaluation methods*; Empirical studies in HCI;

KEYWORDS

HCI in agriculture, nontraditional interactions, user centered design

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1 INTRODUCTION

In 2008 Philip Kortum edited a book whose title is paraphrased by this article: "HCI beyond the GUI. Design for haptic, speech, olfactory and other nontraditional interfaces" [17]. In his introduction Kortum says: âĂIJwhile the GUI remains the most common interface today, a host of other interfaces are becoming increasingly prevalentâĂİ. Ten years after that book that prevalence has notably increased in areas such as entertainment, medicine and business with uneven extension. The intention of this article is to review the state of situation regarding agriculture and nontraditional interfaces.

The increasing food demands, the ageing population of agriculture work force, with younger generations opting for urban careers, the use of agriculture land for biofuel and alterative energy, among other reasons, have lead to an increased interest in ICT applications to the agriculture cycle of productions (precision farming, agro robots, etc). Just to mention that the global spending in agricultural robotics is estimated to raise from $817 million in 2013 to 16$ billion by 2020 [30].

On the other way, the development of mechanized agriculture has brought many new features to agricultural vehicles today. Considering more human limitations, such as situational awareness and the potential for mental overload, operator's mental workload seems to be a critical issue [15]. Researchers and practitioners in HCI and UX interactions design should have something to say in this context. New demands for holistic approaches are raised to our discipline, such as those that seek to relate HCI with sustainability in food production [25].

In this context, this work presents a bibliographic review about the inclusion of nontraditional interactions (beyond the GUI interfaces) for different operations in the agricultural fields, a qualitative analysis and some challenges and opportunities found.

This paper is organized as follows: first, we make a brief account about Beyond the GUI Interactions. The Section Method includes a full description of our review method, databases searched and classification criteria are introduced. Results from the survey are summarized in the following Section. Finally, the article discusses the results obtained and concludes with the challenges and opportunities that arise for the inclusion of Beyond the GUI interactions in agriculture.

2 BEYOND THE GUI INTERACTIONS

As Dourish and other authors have shown, the human interaction with Information and Communication Devices and Technologies (ICT) has evolved from the initial exclusive use of screens controlled by keyboards and pointers towards an increasing embodiment and socialization [9, 17].

The times of GUI (Graphical User Interfaces) based on visual metaphors such as direct manipulation, desktop on the screen, etc. have not ended. However HCI researchers and UX designers have been looking for ways to include in the user's final experience other dimensions of their corporality and social context, increasingly in recent years. Technological advances improved the easiness to detect and recognize hand gestures, the ability to inform location changes, machine understanding of natural language, possibilities of delivering information through haptic feedback, etc.

HCI researchers and practitioners are taking profit of those technologies and cultural processes of their diffusion and adoption for giving birth to âĂIJbeyond the GUIâĂİ interactions, as Kortum has called nontraditional interfaces, organized in eleven groups: haptic, gesture, locomotion, auditory, voice user, interactive voice response, olfactory, taste, small screen, multimode and multimodal interfaces [17].

Haptic interfaces are related to the human sense of touch. This sense is essentially twofold, including both cutaneous touch and kinesthetic touch. Cutaneous touch refers to the sensation of surface features and tactile perception and is usually conveyed through the skin. Kinesthetic touch sensations, which arise within the muscles and tendons, allow us to interpret where our limbs are in space and in relation to ourselves. The haptic interface consists of a real-time display of a virtual or remote environment and a manipulator, which serves as the interface between the human operator and the simulation. Haptic feedback, which is essentially force or touch feedback in a manâĂŞmachine interface, allows computer simulations of various tasks to relay realistic, tangible sensations to a user [19].

Gestures consist of movements of the body and face as nonverbal communication that complements verbal communication. This is the inspiration behind using gesture interfaces between man and machine. A gesture interface can be seen as an alternative or complement to existing interface techniques, such as the old desktop paradigm. Gesture interface systems seems very applicable in realms like agricultural work because they are naturally hands-off and hands-free interactions that can be done with any functional part of the body, giving alternative input modes to WIMP (windows, icons, mouse, pointers) applications, such as controlling the pointer with a hand movement [29].

Speech based interactions can be auditory, voice user or interactive voice response interfaces [17]. Auditory interfaces are bidirectional, communicative connections between two systemsâĂŤtypically a human user and a technical product. The side toward the machine involves machine listening, speech recognition, and dialog systems. The side toward the human uses auditory displays. A voice user interface (VUI) is the script to a conversation between an automated system and a user. This script contains all the utterances that the automated system will speak to the user and the logic to decide which utterances to speak in response to user input. Underlying the voice user interface is speech recognition technology that has the ability to capture and decode the userâĂŽs spoken input to allow the system to âĂIJunderstandâĂİ what the user has said. Interactive voice response (IVR) interfaces are chiefly telephony interfaces.

Multimodal user interfaces use two or more natural input modalities such as speech, handwriting, gestures, facial expressions, and other body movements. Using such systems, users may for example deal with a crisis management situation using speech and pen input over a map. An emergency response route can be established by sketching a line on a map along the desired route, using a digital pen, while speaking âĂIJCreate emergency route hereâĂİ [27]. Among the elements that define a MMUI we find that they allow an individual or a group to achieve a sequence of interrelated tasks using multiple devices and present features and information that behave the same cross platforms, even though each platform/device has its specific look and feel [26].

Kortum mentions as nontraditional interfaces the range of small screens from the ones seen on clocks, microwaves, alarm systems, and so on, to highly capable graphical displays as seen on mobile phones, medical devices, handheld gaming devices. Since his work was published in 2008, small screens have become so ubiquitous that we can take them out from nontraditional sets.

Of the remaining interactions mentioned by Kortum's work (Olfactory, Taste and Locomotion), we maintain as an analysis category the use of interfaces that include linking the user with a virtual model or an increase in the three-dimensional reality in which it moves (See [17] chapter 4).

Many fields, mainly entertainment, advertising and robotic manufacturing have already incorporated many of these interactions. Throughout the agricultural production cycle (sowing, cultivation, harvesting, fertilization, and fumigation) it could be expected that different types of interaction will be included as outdoor and indoor tasks are carried out combining scenarios with a variety of tasks and users. In many outdoor activities, the user has to keep focus on his specific task without accommodating their work to the technological requirements [12].

HCI, interaction design and specifically *Beyond the GUI* interaction technologies have promised, among other things, to solve this initial need for the user to adapt part of their work to the requirements of technology, and this is the one that deals with understanding and even anticipating the needs or user demands [28].

This review is aimed to review the literature to find out the extent these interactions have been applied to the agricultural process and to analyze the opportunities as challenges to the design of embodied interactions that remain open

3 METHOD

We performed a systematic literature review and a qualitative analysis about beyond the GUI interactions in agriculture.

Our analysis is mainly qualitative because our interest is oriented to discover some possible gaps and challenges for these interactions to be fully incorporated in the field of agriculture and many of the studies reviewed are so methodologically diverse (case studies, surveys, experimental works, etc.) as to make an eventual meta analytic aggregation impractical.

We try to answer two questions:

(1) What is the extension that *beyond the GUI*, nontraditional interactions movement has reached in domain agricultural?
(2) Is it possible to discover some challenges for these interactions make a greater contribution to this domain?

We performed searches on three online bibliographic databases: IEEE Xplore, ACM Digital Library and ElsevierâĂŹs Scopus. IEEE Xplore and ACM DL naturally contain work on ICTs while the objective of using Scopus was to extend the search range outside of technology-specific conferences or journals.

The process for selecting papers was carried out iteratively. Firstly a full text search was conducted to indentify the universe of potentially relevant publications. We collected studies on ICTs and agriculture with a search string containing keywords like âĂIJagricultureâĂİ or âĂIJprecision farmâĂİ or âĂIJagrobotsâĂİ or âĂIJagro robotsâĂİ, and filtered them to get the papers about interfaces and interactions used. First we queried IEEE Xplore and ACM DL for workings on agriculture and Scopus for agriculture and ICT (with search terms like âĂIJprecision farmingâĂİ, âĂIJagricultural roboticsâĂİ, âĂIJICTâĂİ).

No filters were applied regarding the source of publication or its date.

The resulting data set was filtered by using keywords related to HCI and Interaction Design: âĂIJinterfaceâĂİ, âĂIJinteractionâĂİ, âĂIJuser experienceâĂİ, âĂIJHCIâĂİ, âĂIJhuman computer interactionâĂİ, âĂIJHRIâĂİ, âĂIJHuman Robot InteractionâĂİ. Duplicates found were eliminated in this step.

After that title and abstract of each resulting paper were examined to get the ones related to nontraditional o beyond the GUI interaction. For a paper being included in the final selection the criteria was that it makes a proposal, describes use or perform an evaluation of any user interaction belonging to the chosen categories for replacing or complementing the GUI (in any device or platform). Finally, each of the selected papers was full read by at least one author.

The analyzed works were organized into six categories. Five of them directly related to the type of interactions presented: speech based, gesture recognition, haptic, multimodal and augmented or virtual reality interactions. Also sixth category âĂIJborderlineâĂİ was added. A paper was considered borderline when it doesnâĂŹt match the inclusion criteria but presents some processes (user centered or ethnography based) aimed to elicit requirements for using non-traditional interactions, to develop methods and specific usability guides to be considered in case of beyond the GUI interactions in agriculture.

In addition, we try to associate each work with one or more of the six stages of the agricultural value chain as stated by de Silva et al [32]: Deciding (where farmers decide on what crop to grow, how much land to allocate for each crop); Seeding (when farmers either purchase seeds or prepare their own seeds based on the crop they have earlier decided to grow); Preparing and planting (farmers prepare the land using own or hired labor or land preparation machinery and subsequently planting the seeds); Growing (where application of water, fertilizer and pesticides take place); Harvesting, packing and storing (farmers have to find labor for harvesting and locations for storage if at all); Selling (farmers check prices at markets, find a method of transporting and transport the packed produce to the selected market to sell).

4 RESULTS

The set of papers selected at the initial step is depicted in Table 1. After filtering the articles that include the relationship between agriculture and tics and selecting those that are specifically linked to HCI (interactions, interfaces, user experience, etc.) the set amounted to 996, of which 886 remained after removing the duplicates.

These 886 papers were subject to title and abstract inspection as stated above, and finally 58 papers where included in the selection for a complete reading.

Table 1: Papers set

Database	Agriculture AND ICT	Agriculture AND ICT AND user interaction	Without duplicates
Xplore	13619	75	75
Scopus	12866	866	776
Digital Library	763	35	35

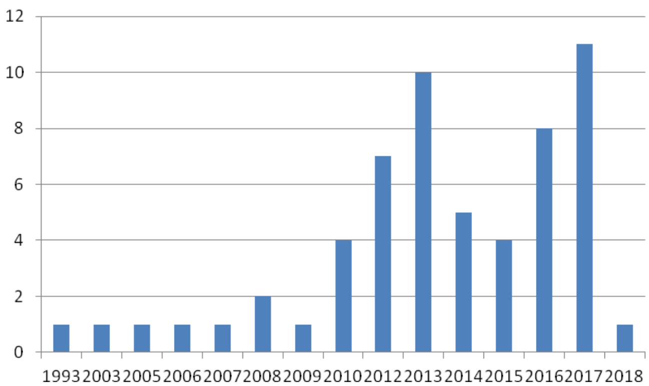

Figure 1: Papers by year of publication

Of these 58 articles, 46 explicitly refer to nontraditional interactions and 12 were considered borderline, as defined in the Method section.

As expected, there is a notable increasing of papers related to beyond the GUI interactions since 2010 (see Figure 1).

Works were found from 19 countries, with a clear predominance from the USA and India (see Table 2). Papers from USA were evenly distributed among different interactions, mainly oriented to agricultural robotics or design process organization, while Indian works are concentrated on speech based interactions, looking to lower the access threshold to technology for low-income farmers.

Taking apart the papers in the category Borderline, the percentage distribution of the different types of interactions found is the following: speech based (46%), hand gesture recognition (17%), several application of augmented/virtual reality using mounted displays and joysticks-like manipulanda (20%), multimodal interfaces (10%) and haptic interfaces (7%) (See Figure 3).

Regarding the agricultural value chain [32] works reviewed are devoted to first five links. Just a few were found on the Selling stage. The two first stages, Deciding and Seeding are mostly approached with speech based interactions. The other interactions are evenly distributed among Preparing and Planting, Growing and Harvesting, packing and storing. As expected, interactions more strongly embodied (gesture and haptics) are applied to soil work (See Figure 2).

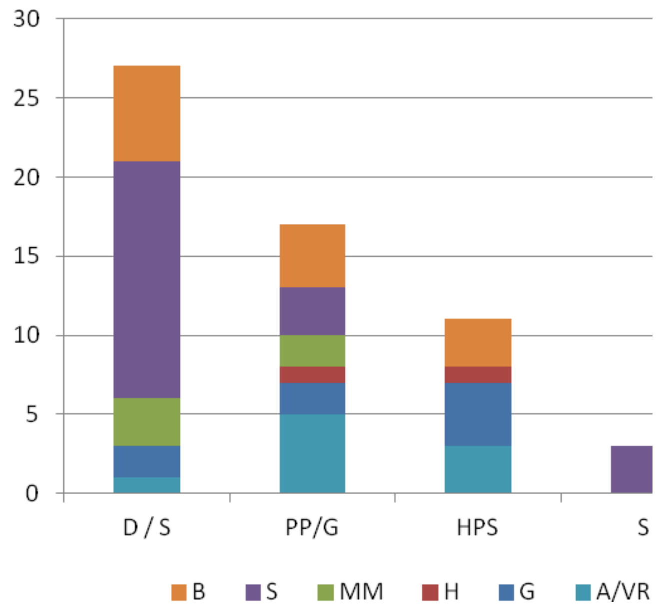

Figure 2: Distribution by stages of value chain (A/VR: Augmented or Virtual Reality, B: Borderline study, SB: Speech based, H: Haptic, GB: Gesture Based, MM: Multimodal)

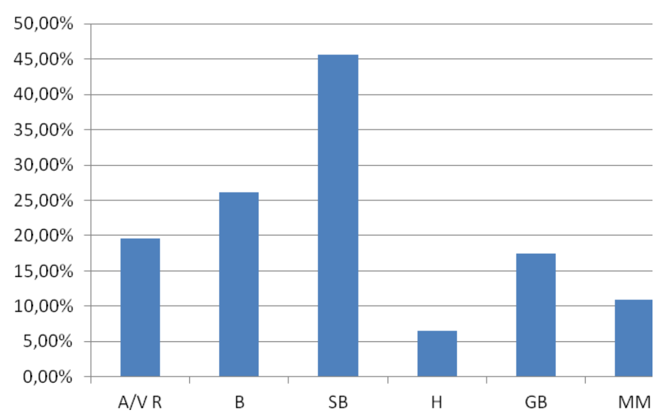

Figure 3: Percentage distribution found by interaction (A/VR: Augmented or Virtual Reality, B: Borderline study, SB: Speech based, H: Haptic, GB: Gesture Based, MM: Multimodal)

Table 2: Distribution by country and type of interaction (A/VR: Augmented or Virtual Reality, SB: Speech based, H: Haptic, GB: Gesture Based, MM: Multimodal, B: Borderline study)

Country	A/VR	S	H	G	MM	B	Total
Australia	1				1	1	3
Brazil						1	1
Chile/Argentina						1	1
Canada	1						1
China	1	1		2			4
Croatia		1					1
Cyprus				2		1	3
Czech Republic					1		1
Finland						1	1
France					2		2
Ghana		1					1
India	1	10	1	1		1	14
Japan	2	2	1	1		1	7
Malaysia						1	1
Netherlands		1					1
Pakistan		1					1
South Africa		1					1
Spain					1	1	2
United Kingdom						1	1
USA	3	3		2		3	11
Total	9	21	2	8	5	13	58

At the top of beyond the GUI interaction used are speech based interfaces, for example for Indian farmers [7, 10] (due to the low literacy found in the Indian agricultural work force) and also in the intent of freeing workers for using their others modalities during work [16].

Interfaces based on gestures recognition were used in remote controlled agro robots. Megalingam [22], for example, reports the application of manual gestures for the remote control of a robotic arm fixed on a rover roam for harvesting and Huang [14] poses the use of gestures as an intuitive form of interaction that lowers the barrier of use of computers in agricultural environments.

Heuristic evaluations have also been carried out comparing GUI interactions with embodied or tangible modes, such as the work of Adamides et al [4] that evaluates the usability of Head Mounted Display and controls with Joystick type PS3 versus traditional screen and keyboard controls. As well as experimenting with the use of joystick-style embodied controls, references were also found to the exploration of the use of Wiimote-like controls with promising advantages for some tasks on keyboard or mouse controls [3] for a semi-autonomous sprayer.

Very few haptic interactions were found, almost exclusively concentrated on giving feedback during the remote manipulation of agro robots. For example the work by Megalingam et al [23] that explores the inclusion of haptic feedback in harvesting coconuts robots.

We also find works that propose design guides for agricultural robots promoting nontraditional interactions. For example, Kohanbash [16] describe a layered safety architecture for autonomous agro robots that includes multimodal interfaces for workers to interact with the vehicles using natural language, gestures, and portable devices. The proposal advocates for using portable devices, voice, and gesture

A work from Chile (with some experimental work also carried out in Argentina) present the idea of service units as a flexible automation in agriculture [2]. A service unit is an automatic vehicle for main or secondary tasks in the agricultural environment. They have four important abilities: mapping the surrounding environment, navigation (how it deals with slippage, maneuverability constrains and how it plans its motion in order to fulfill the agricultural task while interacting with the environment) and action (a service unit can be used for primary -harvesting, seeding, fertilizing, spraying- and secondary tasks -grove supervision, weed detection, hauling, mowing). In this case, multimodal interactions are proposed.

Other works considered as borderline in this article focus on the use of interaction design techniques (such as user-centered design and the use of ethnographic methods) as tools to improve the inclusion of points of view, expectations and skill levels of farmers during the design of devices [1, 6].

5 DISCUSSION

It is clear that beyond the GUI interactions have walked different paths in these years regarding their application to agriculture. From the six categories used in this analysis, there is a clear majority of speech based works, some on gesture, augmented o virtual reality and multimodal interfaces and just a few on haptic.

It is not surprising that the largest participation of non-traditional interfaces for agriculture is in the category speech based systems, including natural language recognition. This feature is very valuable at least in two cases. It allows the operator to interact with the system while physically performing another task and when users have a low level of literacy (as is often the case in many phases of the agricultural cycle) it enable working with the system without the need to read or understand written instructions [1, 6].

Haptic interaction, on the other side, have come a long way in different application domains being surgical robots and exoskeletons perhaps the most advanced cases [13, 20, 24] but even haptics researchers themselves recognize that the tools necessary to adequately support the work of interaction designers are not yet available [31]. It also should be considered that this type of interaction requires a specific hardware, even in the case of vibrotactile feedback, that is not yet standard by default in many ICT devices.

There are many reasons that could explain the low incorporation of these new interaction technologies. For example, one might think of the idea that agricultural sectors are naturally conservative and resistant to technological change. However, empirical studies have shown that innovation adoption decisions of rural societies are rooted in their awareness, cost and benefit factors and applicability of introduced technology rather than the myth of adherence to socio-cultural heritage [1, 5].

Therefore, it is perhaps the community of researchers and practitioners of HCI and interaction design that should address how to raise awareness among farmers about the benefits that could be raised with new technologies applied to farming.

Almost all works reviewed argued that since the end users are in a crucial role User Centered Design methods can enhance the innovation process, help to choose the technological level of the product and enhance its acceptability [6, 12]. Works such as those by Readhead and her colleagues about farmer centered study of agro robots requirements or Brown ethnographic studio as input to design a computing solution for a vineyard [1, 8] should be a course of action for further exploration.

It seems that the role of human workers in agriculture would not be completely eliminated by the introduction of robots [2, 6]. Humans are still needed for supervision and collaborative tasks. In many cases, humans would still be needed to load/unload robots, help guide/reestablish robots, and generally work with robots. Also, operators monitoring the robots, be it from near or far, are surely needed to observe the robot while in action, perform online diagnostics and analysis, and so insure proper performance. Even the idea of a flexible automation, for example with the use of service units can be a solution in the absence of qualified human resources.

The fact that these workers share space and tasks with these service units can be seen as a process of human computer interaction with the challenge that entails to include the user-centered design process to achieve appropriate user experiences that contribute to closing the gap [2]. For example, when a field worker is collecting olives, the service units should be able to interpret his intention in order to optimize the agricultural task (e.g. approaching itself to him/her for a proper dispose of the olives within the deposit or avoiding collision when he/her is moving by the field). The perception that the worker has about the friendliness of the machinery with which he shares his work space is a key point in these scenarios. HCI and interaction design have already addressed such situations with a proxemics focus [11, 21] that has led to the emergence of new combinations of non-traditional interactions [18].

Perhaps one of the main challenges for human machine control in agro robots is the level of complexity across multiple systems and human skills that they need to cope with the technology. At the same time that studies show farmers using use multiple machine interfaces for office administration, weather stations, moisture probes and tractor operation [1], others complain about low literacy or poorly skilled workers [2, 6]. Multimodal, embodied interactions could be a good option to consider in those cases.

There is some evidence that there are still many challenges facing the inclusion of new interaction technologies and user experience in the agricultural process. Perhaps a holistic approach completely focused on users that considers their interactions with technological equipment but contemplates the complete vision of the food production and consumption cycle is the way to explore [25].

6 CONCLUSION

It has been shown that precision farming, agricultural robotics and others fields approaching the inclusion of ICTs in agriculture have begun to include nontraditional interactions but it has not reached a massive engagement on them yet despite the promises of improvements in productivity and user experiences that these new technologies offer. There are opportunities to make better use of the potential benefits of beyond the GUI interactions in agriculture. For example, with the support of user-centered design techniques it will be possible to improve the relationship between field workers and autonomous or semi-autonomous robots or facilitate the control and supervision of complex monitoring, irrigation, etc. systems. Finally, the main challenge for the inclusion of new technologies of interaction is to understand that this endeavor requires a joint work among computer scientists, product engineers and agricultural experts but also from other domains like design, sociology and psychology. To conclude, this work has presented a systematic bibliographic review about nontraditional or beyond the GUI interactions in agriculture. Some possible challenges and opportunities for research in this area have been pointed. Future works include further analysis in order to set some course of actions in each step of agriculture from soil works to food commercialization and some technical tool survey and comparative studies from the industry point of view (as suggested by a reviewer).

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