A Touchless Gestural System for Extended Information Access Within a Campus

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ABSTRACT

In the last two decades, we have witnessed a growing spread of touchless interfaces, facilitated by higher performances of computational systems, as well as the increased availability of cheaper sensors and devices. Putting the focus on gestural input, several researchers and designers used Kinect-like devices to implement touchless gestural interfaces. The latter extends the possible deployments and usage of public interactive displays. For example, wall-sized displays may become interactive even if they are unreachable by touch. Moreover, billboard-sized displays may be placed in safe cases to avoid vandalism, while still maintaining their interactivity. Finally, people with temporary or permanent physical impairment (e.g. wheelchair users) may still comfortably interact with the display. Here we describe an information provision system allowing for touchless gestural interactions, along with a trial implementation within our University campus to test its effectiveness in a real setting. Our system is intended for use by students, lecturers and staff members, providing a captivating way to access news, lectures information, videos and more. We also report the results of an ongoing user study, defining a set of guidelines for future designs.

CCS CONCEPTS

• **Human-centered computing → Field studies**; **Gestural input**; *Usability testing*; *Empirical studies in HCI*; *Empirical studies in interaction design*;

KEYWORDS

Touchless Interaction, Gestural Interaction, Natural Interfaces, Human-Computer Interaction, Information-provision Systems

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1 INTRODUCTION

Information provision systems in the form of interactive displays are increasingly available in several public contexts. They offer promising business opportunities and pose interesting research questions in different fields, due to their common physical features (spatial placement, deployment environment), and to their typical purposes (interactive advertising, information provision).

In the last two decades, there has been a growing interest in touchless gesture-based interaction with computer systems, both from the scientific and the commercial worlds [1]. Such interest, formerly driven by home gaming systems, recently had a boost due to the increased availability of interactive public displays of any size. In most cases, the touchless gestural interaction seems to be

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the most suitable one to address both technical, physical, social and effectiveness problems.

For wall-sized displays, such as the so-called *media façades* [2], the gestural input with no devices worn by the users is often the only feasible way to add interactivity. This is mainly due to the big size of the display, which results in a necessarily high interaction distance.

Concerning smaller interactive displays ranging from TV to billboard screens, such as the so-called *situated public displays*, they are typically placed at eye-level and within arm's reach [3]. These features naturally afford touch-based interaction, and possibly this is the main reason why touchless interaction has been rarely studied for such displays so far.

Currently, it seems there is a trend reversal, and touchless gestural interaction with situated public displays is gaining a growing interest for different reasons. Among them:

- simplify and encourage multiple parallel interactions, mainly due to the higher allowed interaction distance. In fact, the interaction distance defines the available space in front of the display for users to interact: the more the interaction distance, the more room for multiple users;
- increase the social acceptability of interactions with publicly accessible devices. Due to the growing diffusion of situated public displays in popular places, people could feel more comfortable to interact with no need to touch something that has been used by other people, for hygienic reasons;
- extend the number of prospective users, thus including people who, for some reason, temporary or permanent, may (or wish) not access a touch-based interface;
- place the display with no constraints related to the touch reachability;
- limit vandalism, as a direct consequence of the previous one.

Despite the undoubted usefulness of the touchless gestural input, there are several issues that must be taken into account when including it in general-purpose information provision systems available in public spaces. These issues are mostly related to the intended audience and the provided contents. Indeed, in the case of very specific applications, such as games or entertainment systems, they provide specific content to specific users, who are often aware of the interaction capabilities and media. On the other hand, in the case of information provision systems, a large and heterogeneous community access different kinds of information, presented in different media formats.

In this case, the design of a useful and intuitive visual interface requires the analysis of several context factors, both technical (size of the devices, place in which they are deployed, information they provide), and socio/psychological. One of these is the *legacy bias* [4]. According to this, users are affected by traditional interaction models (such as the well-known WIMP one [5]), also when interacting using completely different paradigms. Another human-related issue is the *display blindness* [6], according to which users do not look at the display, expecting uninteresting content (e.g. advertisements), or simply because it does not capture their attention.

Maybe the most relevant issue in the design of interfaces for situated public displays is the *interaction blindness* [7]. In this case, even if people are looking at the display, they may not understand neither that it is interactive nor the touchless nature of its interactivity.

All these issues are additionally influenced by other human factors, such as the personal profile of the intended users, the influence of the possible audience during the interaction [8], the culture-related acceptability of a gestural interaction in public, and many others. The discussion above means that the definition of general guidelines must undergo some statistical analysis over a sample of actual users. The more significant the sample, the more reliable the results.

Microsoft, who first provided access to the cheap and easy development of gesture-based systems, proposed its Human Interface Guidelines (HIG) for the development of Kinect-based applications [9]. Such guidelines are not mandatory, do not cover all related issues, and are not suitable for all situations (for example, for systems based on different devices). As a result, even if there are several implementations of information provision systems on situated public displays that are HIG-compliant [10] [11] (often only partially), there are no general rules to address all the interface design questions related to the touchless gestural interaction.

In this paper we present a possible layout for a visual interface to be used in a general-purpose information provision system allowing for touchless gestural interaction. In more detail, we implemented an *avatar-based* visual interface and deployed it in an actual information provision system as a public display within a building in our university campus. We then analyzed the people's behavior during their interactions with the display, in order to assess the overall usefulness of the system and, in particular, the effectiveness of a human-shape that replays the users' movements within a visual interface in conveying the interactivity capabilities and functions.

We conducted a three-months-long observation of such installation and carried out a longitudinal study in-the-wild on it. As a result, we assessed the effectiveness of the system, and we also deduced some basic general guidelines for the design of visual interfaces for gestural interaction. These guidelines should be useful for display or space managers, to better tune their setups and maximize their revenues.

2 RELATED WORKS

The research on public displays focuses on several different issues, such as audience behavior, privacy, software and hardware solutions, and the ability to communicate interactivity to passers-by and users [12]. Focusing on the last of these issues, researchers must take into account the need of overcoming the *display blindness* and - probably more complicated - the *interaction blindness*. The first problem occurs when people do not look at the display because of their prejudice about the content, which is expected to be an advertisement. Researchers must thus overcome this issue in order to study any aspect related to the interactions, especially in-the-wild, i.e. in uncontrolled environments where many external factors affect users' behaviors. Among the proposed solutions for attracting passers-by glances, visual animation effects and/or sounds have been demonstrated to be helpful. Other factors that can mitigate the display blindness are the colorfulness, the amount of time the display is potentially visible to passers-by, and the display size [13]. However, this problem is not simple to solve and can require applying some techniques from the persuasive computing area [14].

However, the display blindness is not the main issue, especially if we deal with interactive displays. Indeed, even when users look at the display, they often do not interact with it because they simply do not know that they can. This means that there is the need to communicate the interactivity and thus entice interactions. This is the *interaction blindness* phenomenon, and it generally refers to the inability of people to recognize the interactive capabilities of the display, also when looking at it [15]. Among the many solutions described in the literature, one of the most commonly adopted is the use of explicit visual clues that suggest users to perform some gestures. In [16], Walter et al. compared different presentation modes for such visual clues, i.e. integration, temporal division and spatial division. This study showed that spatial division results to be the most suitable solution for public displays, although it implies the need of allocating part of the screen to show such clues.

Ojala et al. suggest that one way to overcome interaction blindness and entice interaction is to make the interface more natural. Proxemic interactions are emerging as a potential paradigm for realizing natural interfaces, but simple visual proxemic cue (the *Touch me!* animation) did not noticeably increase user interaction [17]. *Proxemic interactions* were introduced by Ballendat et al. [18], and they are very related to (and actually based on) a previous work by Vogel and Balakrishnan [19]. In these works, authors propose systems that react on user's position and orientation, i.e. without any implicit interaction. Such idea seems promising in solving interaction blindness since users can easily understand the display interactivity if its contents change corresponding to their movements. Indeed, proxemic interactions allow for the implementation of more sophisticated solutions than a simple Touch me! animation, and there is the need for further investigations on how they can help to solve interaction blindness.

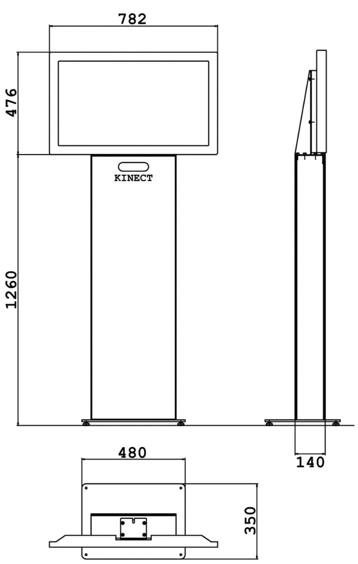

Figure 1: Physical layout of the hard case (size in mm)

Moreover, proxemic interactions can help users to understand the features of an interactive public display, by modeling it as a sort of mirror (i.e. one of the four mental models studied in [20]). The mirror mental model has been shown to have a strong potential in catching users' attention [21], which suggests using it also as a partial solution to the display blindness, as well as for communicating touchless interactivity. A successful application of the mirror mental model is MirrorTouch [22], where authors studied the use of touch-based interactions combined with mid-air gestures. In this application, a user interacted with her silhouette shown in a public display, and this showed how effectively the mirror model communicates the touchless interactivity. Indeed, authors underlined the need of explicit call-to-action as the only effective way to let users interact via touchscreen, instead of sticking on the gestural interaction modality only.

The use of users avatars in a visual interface can thus be seen as an implementation of the aforementioned mirror mental model, and MirrorTouch is not the only one solution that exploits this idea. For instance, Müller et al. showed that displaying the users' silhouette may help in communicating the display interactivity in MirrorTouch. Similarly, this idea has been explored in ShadowTouch [23] and Cuenesics [24], two touchless gestural application for public displays based on users' representations in the form of avatars.

According to this discussion, in order to evaluate the overall usefulness of a touchless-based information provision system, in this work we also assess the potential for an avatar in a visual interface to communicate the touchless gestural interactivity. To this end, we analyzed the people's behavior around an actual situated public display showing an avatar-based visual interface [25]. Our goal is to check whether the presence of the avatar may attract people, and if it may help them to easily understand the purposes of the system, thus maximizing its effectiveness and its communicative and informative goals.

3 SYSTEM DESCRIPTION

The information provision system we implemented is deployed as a public display in a 150 square-meters-large indoor space inside a building within the University campus in Palermo. The display is placed next to a couple of benches where students often sit while waiting for lectures starting times. Students of different disciplines

Figure 2: Main layout of the visual interface

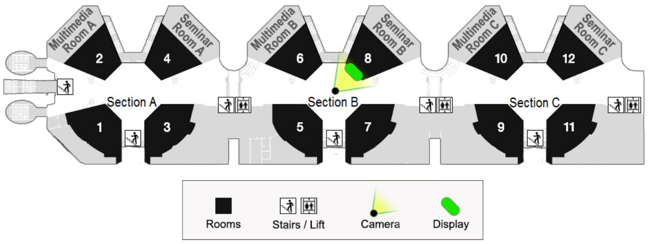

Figure 3: Map of the building and position of the display. The black dot shows the camera position; the yellow cone shows its field-of-view; the green shape represents the display

and ages (mostly from 19 to 35 years old), lecturers, and other University staff members usually frequent this area.

The hardware consists of a 40-inches LCD monitor placed at eye-level, with a Microsoft Kinect sensor placed right below it, and a suitable PC. A hard case encloses all the hardware for security, safety and aesthetic reasons (Figure 1).

The visual interface layout consists of a suitable number of interactive tiles arranged all around an avatar placed in the middle of the screen (Figure 2).

The avatar appears whenever a user approaches the display, and remains permanently present in the middle of the screen, continuously replaying user's movements. In particular, the avatar's arms end in two hand-shaped cursors, which represent and replay the user's hands movements. As stated in the previous Section, the presence of a predominant entity that continuously reproduces user movements should significantly contribute to reducing the interaction blindness. In other words, the main rationale behind the presence of an interactive avatar placed in the middle of the interface should be to help users in understanding both the interactivity of the system and its touchless nature.

As far the interaction is concerned, it takes place by means of in-air direct manipulations. In other words, users can mimic the direct manipulation of objects, as they would do in real life, without actually grabbing or touching them, with no need to learn specific activation gestures. The users can trigger the interaction events just by driving the avatar's hands and placing them on top of the available tile-shaped components.

For our study, we installed a Wi-Fi camera in front of the display, in a not-reachable position. This allowed us to observe the users' behavior in a quiet way, as well as to check the actual display status. Figure 3 shows the overall experimental set up, and Figure 4 shows a frame captured from the observation camera.

4 STUDY SETUP

The information system allows people to accomplish the following tasks:

- reading news;
- reading university information;
- displaying and navigating the building map;
- displaying lecture timetable;
- displaying weather data;
- displaying a video.

Figure 4: A view of the display and people around it from the observation camera

We conducted an exploratory study on people's behavior around the display following two different approaches. In the first one, we explicitly asked passers-by to interact with the display, and then submitted them a semi-structured interview. This study took about 20 hours across 40 days. In the second one, we quietly observed the users' behavior, for a total of about 30 hours, distributed across 40 days. During this time, we collected useful data both from our observations and from the video feeds from the camera. Also in this case, we submitted our semi-structured interview to users after we observed them, as described in the following section.

In both cases, we used the same scheme for the semi-structured interviews as follows:

- Q1) Did you already know that this system is based on touchless gestural input?
  - Q1.1) If no, have you guessed that it was gestural?
    - Q1.1.1) If yes, which hints have suggested you that the system was gestural? (e.g.: display size, presence of the Kinect sensor, the avatar on the screen, etc.)
- Q2) Have you ever had previous experiences in interacting with gestural systems?
- Q3) Did you miss the touchscreen or other more conventional interactive modalities?
- Q4) Are there some other tasks that you would like this system to accomplish?
- Q5) Do you have any other suggestions or ideas to improve this system?

We also asked users for some further information to sketch a personal profile, such as gender, age, current job, and if they were right-handed, left-handed or ambidextrous.

5 RESULTS AND DISCUSSION

Here we report the details of both approaches and a summary of their outcomes regarding the effectiveness of the avatar-based interface against the interaction blindness.

5.1 Explicit Experimenter Intervention

In this first approach, we explicitly asked people to interact with the display without revealing its touchless nature. In this case, the interactivity of the system was thus well known, and the main goal was to assess the capability of the avatar to convey the touchless gestural interactivity.

We asked 17 users (10 males, 7 females) to perform a 5-minutes-long interaction session, followed by a semi-structured individual interview. We directly observed users during their interactions, and they were aware of our presence. In order to obtain the most significant results, we have chosen a diversified users sample, with different levels of technology-related skills. In particular, we enrolled students attending various courses, from different disciplines.

In the interaction sessions, we asked each participant to carry out the following tasks:

(1) find and read a specific news;
(2) find and read university information;
(3) find the timetable for a specific class;
(4) play a video;
(5) find and read the weather forecast.

Users had to perform these tasks without any suggestions or hints on how to achieve such goals, especially in terms of interaction modality.

5.1.1 Outcomes. We analyzed the semi-structured interviews we conducted at the end of each interaction session, along with our observation reports. Such analysis allowed us to deduce some interesting results about the capability of the avatar to convey the touchless gestural nature of the interactivity. We also obtained useful clues on other aspects related to the presence of an avatar in a visual interface for touchless gestural interactions.

Concerning the ability to communicate gestural interactivity, none of the users we enrolled knew that the system was based on touchless gestural input. Moreover, 13 users out of 17 claimed that they guessed the touchless nature of the interactivity thanks to the presence of the avatar. Among the remaining four users, two claimed that the main clue for understanding the touchless gestural interactivity was the presence of the Kinect, and two did not understand it at all. It is worth noting that eight users already knew the Kinect sensor. Nevertheless, six of them recognized the nature of the interactivity from the presence of the avatar.

Concerning other aspects of interaction, we found that users often perceived the presence of the avatar as annoying, confusing and useless, especially during the reading of long texts. In such case, the avatar continued to be visible in the middle of the interface (despite it became semi-transparent to let users read and see the contents through it). Four users explicitly assessed that displaying only hand-shaped cursors would be preferred in such cases.

5.2 Quiet Experimenter Intervention

With this approach, we wanted to check if the presence of the avatar in the middle of the screen is useful to overcome the interaction blindness itself.

In this case, during the observations we were around the deployment place, blended in the crowd or sat on a bench next to the display, and quietly noted down the users' behaviors. We also asked users to undergo the semi-structured interview described before, only after each spontaneous interaction session, or after we observed someone staring at the system for a while. We observed 50 users, of which 29 accepted to answer the semi-structured interview.

5.2.1 Outcomes. The analysis of the local and remote observations, along with the collected interviews, allows us to infer again some interesting results, concerning both the interaction blindness and other interaction-related aspects influenced by the presence of the avatar. As far as the interaction blindness is concerned, we had 20 out of 29 interviewed users who stated that the avatar was the main hint to understand the interactivity of the system and its touchless nature. This comes out in favor of the avatar, especially if we consider that a group of 14 users out of that 20 already knew gestural systems. Among the remaining nine users, six claimed that the main clue for understanding the touchless gestural interactivity was the presence of the Kinect, and three did not understand it at all. 25 users stated that they would have preferred to interact with a touchscreen.

Our observations confirm this quantitative result. For example, we noted down that:

A user was attracted by the avatar, and he approaches the display. He observed the screen (and, in particular, the avatar) for several seconds, being clearly curious but without interacting. He explained that he had understood the interactivity and its touchless nature thanks to the avatar, but he did not interact because of his shyness.

We also noted that the recognition of the interaction device, due for instance to previous experiences with Kinect-based applications, is another common hint to understand the gestural interactive capabilities. This is the case of the user interaction described in the following note:

At the beginning of this observation session, I noticed a user who was using the interface. He seemed very skilled, so when he finished I approached him and asked some opinions about his experience. He told me that he had previous experiences with gestural systems (he used one abroad in the past), and he immediately noted the presence of the Kinect. He [...] was definitely satisfied with the currently supported features.

Not all the users were able to understand the gestural capabilities, and some of them did not understand them correctly. In many cases, the users' prejudice about the supported interaction modality was clear: the display size probably naturally affords more touch-based interactions than touchless ones. Moreover, using gestures in public seems to be something not easily acceptable for all. In our notes, several excerpts demonstrate both this prejudice and the low acceptability of gestural interactions:

Two users interacted with the interface. The first one approached the display and tried to use it as a touchscreen. After some attempts, she figured out that the system was not responding, so I tell her that it was touchless. She did not know any similar systems and stated that touchscreens are, in her opinion, more practical. The second user interacted by means of gestures (but after having understood how to interact by observing the first one). After a brief interaction session, she explained her embarrassment in using mid-air gestures, and that she would prefer to use a more traditional touchscreen.

An interesting observation confirmed the several attempts of using the screen by means of touch interactions:

[...] I noticed a really curious fact. The backlight showed me several fingerprints on the screen surface, and this can only mean one thing: during these days, several users guessed that the display was able to detect touches, so they used it as a traditional touchscreen.

These last observations let us believe that in some cases the avatar only conveyed the interactive capability of the display, and not its touchless gestural nature.

A possible and partial explanation of such issues may be found in the screen size and the previous experiences of users in interacting with situated public displays. As stated before, such displays are most commonly equipped with touchscreens. It is plausible to believe that users' expectations about the supported interactivity are more oriented on touch-based ones than on other alternatives. Obviously, such issue should disappear if the system is deployed with bigger and/or not reachable displays, where touch-based interaction can be neither afforded nor supported.

It is also important to note that some users approached the display from the left or right almost in parallel with the screen surface, entering in the Kinect field-of-view being 10-20 centimeters away. At this distance, the avatar is not shown at all, due to the sensor capabilities.

Anyway, the avatar turned out to be the main visual element that attracted people towards the system, mainly due to its dynamic shape that moves along with recognized bodies, thus disrupting the interface steadiness.

6 CONCLUSIONS AND FUTURE WORKS

In this paper, we presented our study on people's behavior while interacting with a situated public display showing an avatar-based interface. Our main goal was to assess the usefulness of the system and the effectiveness of the avatar in conveying the interactivity of the display and its touchless gestural nature.

Here we summarize the findings gathered from the study described above, that should be useful for the design of avatar-based touchless gestural interfaces for public displays. We also attach a short discussion and motivation to each finding.

(1) *Using an avatar-based interface helps to convey the touchless interactivity, but may not be enough.*
We observed that the presence of an avatar is often considered helpful to communicate the interactivity of a system and its touchless nature. However, it should also be taken into account that, in some situations, users may be wrongly recognized by the software (or not recognized at all, thus resulting in the avatar is not displayed). Designers should thus consider using some trick to guarantee a correct recognition. For example, placing a marker on the floor to indicate the optimal interaction distance, or adding explicit instructions on the screen or next to the display.

(2) *Always take into account the actual sensorial capabilities of the devices used for gesture recognition.*
If the gesture recognition capabilities are based on the use of Kinect-like devices [26], then designers should take into account the critical approach paths. If users may arrive from sides, then the avatar may not be displayed at all because of the limitations of the device. Using multiple cameras, pointing at different directions, may instead allow for a more robust avatar visualization.

(3) *Leave the touch interaction together with the touchless one when designing for reachable screens (i.e. touchable and placed at eye-level). Opt out for touchless gestural interactions only when it is not possible to interact via touchscreens.*
According to our observations, situated public displays seem to afford mainly touch-based interactions. While several users enjoyed touchless interactions, observations have shown that some of them were more attracted by the novel way of interaction rather than its usefulness. Users appeared to feel not comfortable while interacting with gestures in public settings. Both interaction modalities could allow most users to interact as they expect, and impaired users to exploit their residual capabilities to interact as they can. The visual interactive elements of our interface and their layout allow for both type of interactions at the same time.

(4) *Try to make a touchless gestural interactive display accessible regardless of the number of users in front of it.*
Single-user interfaces could be enough in several situations. However, this does not mean that the interface may not work when more than one user tries to interact with it. Moreover, it should be clear which user is recognized as active among the detected ones.

As a overall result, in systems that afford well-known input methods, such as the touch one, the gestural input should be suitably included to enrich the interaction channels. Such multimodal input should increase the number of prospective users, extending the access to those who for some reasons cannot use the touch input. The gestural input plays a relevant social role, and the resulting *honeypot effect* [27] can be successfully exploited by the display and space owners to increment their revenues.

For the near future, we are planning to apply the aforementioned hints to improve the visual interface studied in this paper. In particular, currently we are working to implement all the suggested hints, since they may dramatically increase the number of interacting users and, as a consequence, the space owners revenues.

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