ICAT 2002
December 4-6, Tokyo, JAPAN

i-trace: An Interactive System Drawing One's Traces and Illuminating the Area

Yasuaki Kakehi[1], Keita Ushida[2], Takeshi Naemura[1] and Hiroshi Harashima[1]

1) Interfaculty Initiative in Information Studies Graduate School of the University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
{kakehi, naemura, hiro}@hc.t.u-tokyo.ac.jp

2) Graduate School of Information Science and Technology, The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
ushida@hc.t.u-tokyo.ac.jp

Abstract

"Walking" is the inevitable action in our daily life. In the lobby of an office building, a lot of people pass by and no one seem to care about the other people who happen to be there. The authors have been proposing and developing an interactive system that generates an illuminated area caused by behaviors of participants (perhaps they are unintentional). In our system, you are tracked by computer vision technique and the image of their traces are synthesized and projected to the floor. These traces would change the area into a colorful and attractive space. When they've crossed someone else's trace, the system will attract them again by providing some fantastic video and sound. We call the system "i-trace" (interactive trace).

In this paper we propose the concept and design of i-trace system and demonescribe seven examples of applications implemented on the system. We will also report about exhibitions of i-trace.

Key Words: Interactive System, Spatially Augmented Reality, Human-Tracking, Projection, Traces

1. Introduction

Spatially Augmented Reality (SAR)[1] is thought to be a key technology to make our daily life more informative and attractive. In SAR, the user's physical environment is augmented with images that are integrated directly in the user's environment, not merely in their visual field*. Based on this technology, we have been developing an interactive system that can be attached to our daily life space. The system generates an illuminated area caused by either intentional or unintentional behaviors of participants who happen to be walking there.

For example, let us imagine that we are in the lobby of an office building. Here a lot of people pass by, while some are walking around or having a talk. We focus on people "walking" and their "traces" they leave behind. The traces are visualized by our system and would change the area into a colorful and attractive space. We call this system i-trace as an abbreviation for "interactive trace". In this paper, we report:

- Design of i-trace mona
- Applications of i-trace
- Exhibitions of i-trace suguita

2. i-trace

2.1. Concept of i-trace

The authors are aiming to attach interactive system to our daily life space. Anyone could enter the system without any particular equipment (such as sensors and HMDs) and enjoy the fantastic world produced in the system. The i-trace system is proposed as one of such interactive system. Moreover, this system has an aspect that the interaction is emerging from an unintentional action: "Walking". As mentioning below, projecting images from the ceiling to the floor is the basis of the system. On the floor, a trace is created representing the presence of a participant and the accumulation of time of motion (walking). The traces crossed by the other participants would activate some interactive performances (See Fig. 1). The following two interactions are planned in i-trace:

* For example, "PingPongPlus"[2] is visually and aurally augmented table tennis which is enjoyable literally with "whole body".

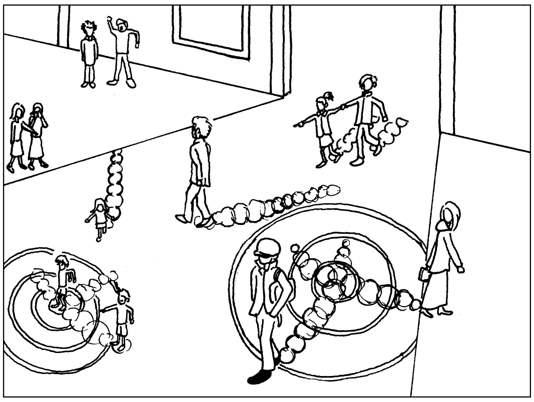


Fig. 1: A trace is created representing the presence of a participant. The traces crossed by the other participants would activate some interactive performances.

Interaction between People and Space: Traces made by people walking around the area either intentionally or unintentionally make the space colorful and attractive.

Interaction between People: Various events that happen when you cross someone else's trace would make "loose connection" between her/him who passed by the spot a moment ago and you (stepping on there right now).

You may find a similarity between i-trace and Boundary Functions[3], since both utilize a projection system from above to the floor. But there is a key difference. Our system focuses on the flow of time and displays the dynamics of the traces, while Boundary Functions copes with the present position of participants. This feature is effective for enhancing the interaction between people in the system.

2.2. Technological Design of i-trace

Process of i-trace system:

- Capturing images by a camera attached on the ceiling,
- Estimating and tracking human position using the captured images,
- Recording the histories of each participants' position and creating traces from them,
- Detecting the crossing of traces,
- Synthesizing images and projecting them to them to the floor

Fig. 2 shows the system outline and Fig. 3 describes the complete view of the system. The system is installed in an open area with high ceiling. On the ceiling, a camera and a projector are attached (Fig. 4).

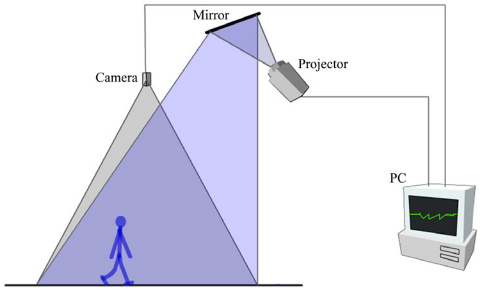


Fig. 2: Outline of the i-trace system

Fig. 3: Complete view of the system

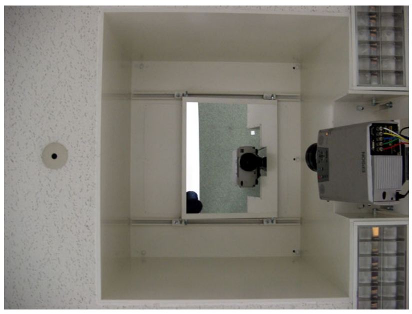


Fig. 4: The camera and the projector (using a mirror because the ceiling is not high enough)

In the calibration process, we need to achieve the various transforms between the camera, projector, and the floor screen coordinates. Therefore, we can convert the human position in the camera frame correctly to the screen (floor) coordinate and the synthesized images of the traces can be projected onto that very position.

The process consists of three steps as described below.

Human Tracking

There are many studies concerning human tracking. In

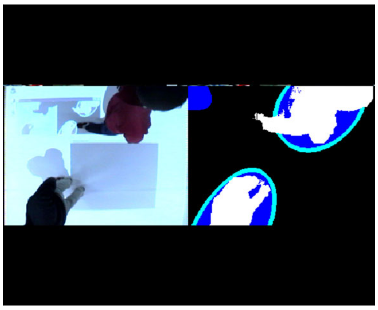


Fig. 5: Current camera image (left)
Human regions are tracked based on background subtraction and ellipsoid models (right)

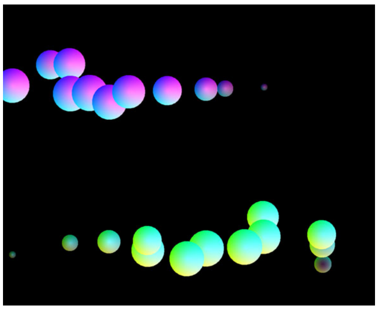


Fig. 6: Trace images are synthesized along with the path of each participant

this system, we use Nakazawa's algorithm[4] for human tracking that is based on background subtraction and ellipsoid models. The algorithm matches to this system in the following respects: The process needs to run on real-time, We need to acquire the participants' "position" (not his/her posture), Users could enter the system without any special equipments.

In this algorithm, the PC captures images taken by the camera and estimates human regions based on background subtraction and ellipsoid models. Fig. 5 shows the result of human tracking. The elliptical part corresponds to the human position. The current implementation of i-trace system can track 5 people at a time, because of the computational power limits (now we use 2.2 GHz Pentium 4 PC). This means up to 5 people can enjoy the interaction in this space (The sixth person in the system would not be tracked and his/her trace would not be drawn).

Drawing Traces
Position data of each participant, which is acquired through the human tracking process, have been accumulated for a fixed time. Traces are visualized by

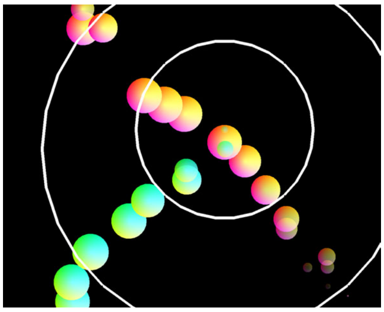


Fig. 7: An event will occur if a crossing is detected

Fig. 8: Synthesized traces projected onto the floor

computer graphics techniques with the use of these data (Fig. 6). The forms to illuminate the traces are programmable and various applications can be implemented in this system. The system attaches trace information such as color and shape to the ellipsoid models individually. People in the environment would be able to identify the traces corresponding to each participant in the system. At the same time, the process checks whether one's trace crossed the other's trace. If crossing is detected, various types of fantastic visual and auditory applications will be performed (See Fig. 7).

Projection
Finally, the synthetic images for the interaction are projected onto the floor (See Fig. 8).

Other Notices
All of these processes run on real-time. Referring to the system environment, the floor surface should not be reflective and is preferred to be white or light gray, so as to make it easy to track human regions (image subtraction) and project synthesized images clearly. Illumination conditions are set to the same level as you have in your room with the lights on. This is because there should be enough light so that the system can detect the participant's image accurately without detecting the projected images (traces) as a participant

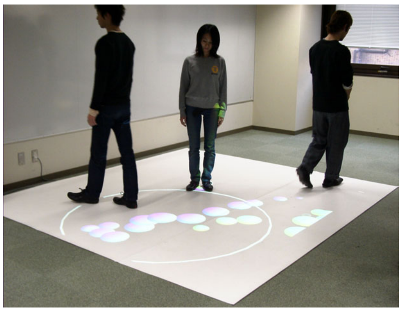


Fig. 9: The sparkling trace would create rings and let everybody in the system notice the event of crossing and your presence

(a) Texture of night sky with glittering stars on traces

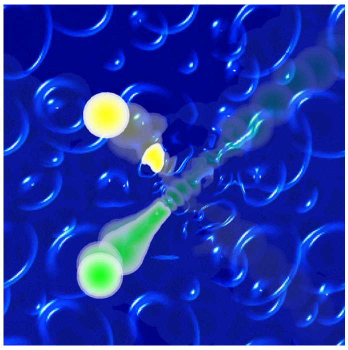
(b) Shooting stars sparkle when traces are crossed

Fig. 10: Shooting Stars

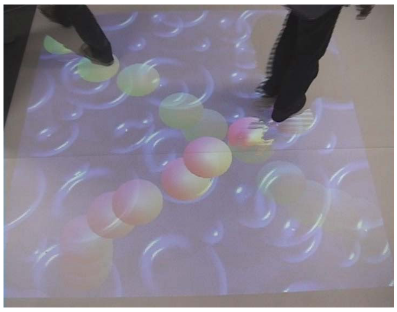
(Dark conditions make the human detection hard, and the projectors images become too obvious from the back-ground). Also the illumination condition should not change much, since our system is based on background subtraction.

3. Applications of i-trace

We have designed and implemented seven different application modes on the i-trace system. In this section, we illustrate and discuss these seven applications.



(a) Footprints are floating on “virtual water”



(b) The virtual water makes ripples triggered by the crossing of traces

Fig. 11: Walking on Virtual Water

3.1. People Linked with Traces

The first application is simple. When you step into the i-trace system, the trace will be visualized along the path you were tracked by the system. For each participant in the space, a different color of trace is drawn. These traces would make the space colorful and attractive (see Fig. 9). When one crosses the trace someone else has drawn in the system, the trace sparkles, letting you know the participation to this emerging interaction. The sparkle would create rings and let everybody in the system notice the event of crossing and the your presence.

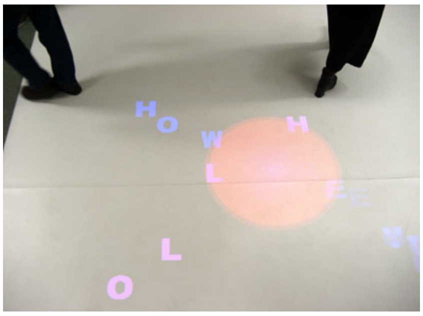
3.2. Shooting Stars

Fig. 10 illustrates an application that is an advanced implementation of 3.1. The system covers the floor with texture of a night sky. Glittering stars appear and disappear on the traces. When you cross someone else’s trace, the shooting stars would sparkle from the very point you have crossed it.

3.3. Walking on Virtual Water

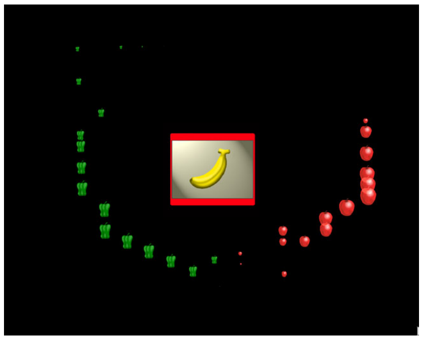
In this application, the floor is filled with a kind of “virtual water”. When a participant just walks on it, the i-trace gradually displays her/his footprints floating on

(a) Greeting words following the participants

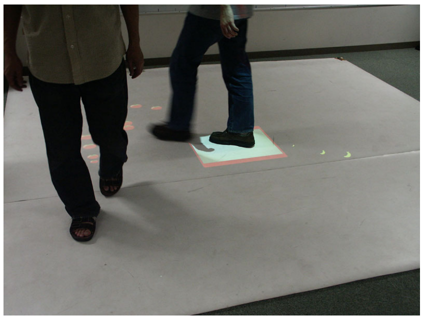


(b) You will hear the voice of greeting when the words are crossed

Fig. 12: Space of Greetings



(a) There is a spot imitating a "display". Various images of objects appear in it



(b) You could change the image of your trace by stepping over the spot

Fig. 13: Trace Changer

the water (Fig. 11 (a)). When you cross someone else's trace, the virtual water would then create ripples spreading from the crossing point (Fig. 11 (b)). The traces left on the water would sway and the whole space would be filled with fantasy. Participants would feel as if the "freezing water" melted all at once creating ripples, and experience interactions emerging from un/intentional actions.

3.4. Space of Greetings

In "Space of Greetings", traces will act as greeting words. People in the system are walking around with the words like "Hello" or "How are you?" following them (Fig. 12 (a)). Just like other applications, when someone crosses the other's trace, an event will occur. The area around the crossing point will glow red, with the voices of greetings (Fig. 12 (b)). This application is very humorous since several effects are added both visually and aurally.

3.5. Trace Changer

"Trace Changer" (Fig. 13) was designed to explore the amusement aspect of i-trace. In this application, participants can change the image of their traces by themselves. There is a spot imitating a "display" on the floor. Various images of objects (e.g. Apple, Banana) appear in the "display".

When a participant steps over the display, his/her trace would be replaced with the object in the display with a switching sound.

Participants can enjoy choosing their traces to whatever texture they like and they will experience an exciting space with varying ambiance.

3.6. Peephole Traces

In this application, an image like Fig. 14 is "hidden under the floor". When participants step into the system, small peepholes would appear along the path they walk. These peepholes would show up only for a short time revealing a small portion of the image hidden under the floor. Users may catch a glimpse of the image as they walk.

When a user crosses the other's trace, a large peephole would emerge on the crossing point for a moment. It enables the user to take a larger look of the image. In order to see the image thoroughly, users would have to

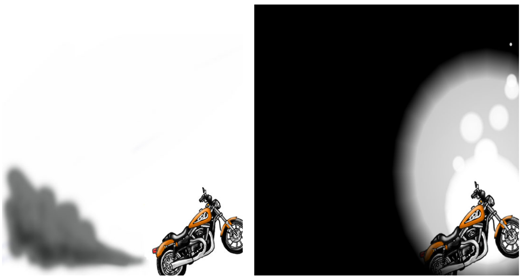


Fig. 14: Peephole Traces (left: the image hidden under the floor, right: peepholes reveal a potion of the image)

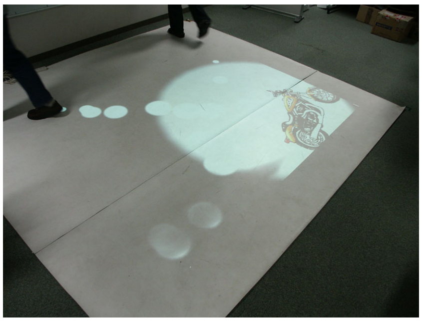
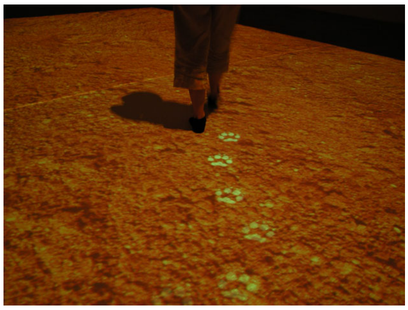
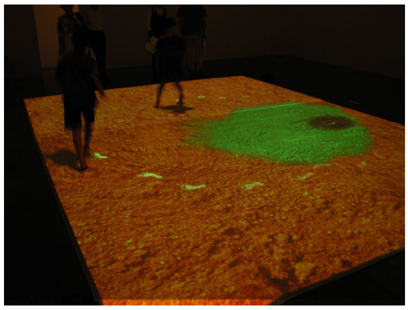


Fig. 15: Users cooperating to make a large peephole and reveal the hidden image



(a) Footprints of various animals follow participants with a voice of them



(b) Various scenes appear when the footprints are crossed

Fig. 16: at ‹case sandbox›

cooperate making many large peepholes (See Fig. 15).

3.7. at ‹case sandbox›

We intended this application to be implemented as a work of technology art, which participants could enjoy with their whole body. When users step in the system, footprints of various animals (e.g. cat, dog and horse) follow them with a voice of the animals (Fig. 16). They would feel as if they were the animals or the animals chasing them. When someone crosses the other's footprints, people in the environment could catch a glimpse of a part of various scenes (e.g. sea, plain, flower garden) that are associated with the animals (See Fig. 16). Furthermore, when a user steps on the footprints of some specific animals, the animal would sometimes appear and run off from the point.

4. Exhibitions of i-trace

The authors exhibited the i-trace system in some places. In this section, we report about these exhibitions.

4.1. InfoComm Japan 2002

We installed and exhibited i-trace in InfoComm Japan 2002 that was held at Tokyo Big Sight in July 2002.

Fig. 17: The installation of i-trace system in InfoComm Japan 2002

Fig. 17 shows the overview of the system. The size of the projection area was about 200 cm × 150 cm, according to the size of the booth where the system was installed. Because there were some poles in the booth, participants could enter the system from limited direction (see Fig. 17). In this exhibition, we implemented applications that are introduced in 3.1-3.6 on i-trace. Applications changes in sequentially. A snapshot of the exhibition is shown in Fig. 18.

Fig. 18: Scenes of the exhibition in InfoComm Japan 2002

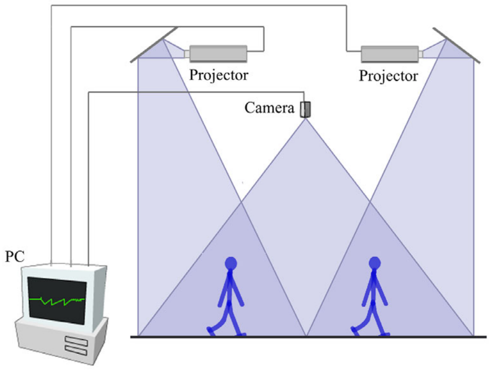


Fig. 19: System outline of the i-trace in "CAFE IN MITO". We used two projectors in this case. The projection areas are aligned side-by-side.

In this exhibition, we found that some people pass by the system without being aware of the traces displayed behind them. Some people will realize the illuminous event when the traces are crossed, and learn that the traces are left behind them while they walk around. Seeing the space illuminate by people's traces, some by stander found i-trace interesting and stepped into the system. Some found out how the trace-crossing event triggers and tried to follow or step someone else's trace who happen to be there. We found some people collaborate (although they are strangers) to activate the event. Many participants joined the interactions either intentionally or unintentionally.

4.2. CAFE IN MITO

We exhibited the i-trace system as a work of technology art in CAFE IN MITO that was held in Mito Museum from August to September in 2002.

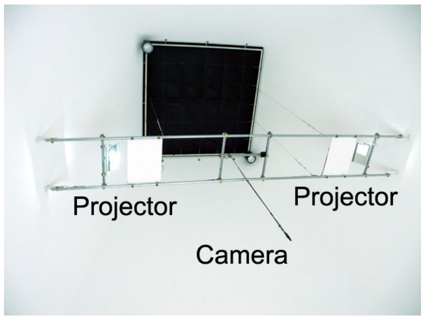


Fig. 20: The camera and two projectors are attached on the ceiling

Fig. 21: Scenes of the exhibition in CAFE IN MITO. Participants are enjoying the interaction.

Fig. 19 and Fig. 20 show the overview of the system in CAFE IN MITO. In this exhibition, we used a PC, a camera and two projectors. The two display channels from the PC are connected to the two projectors. By installing the projectors so that their projection areas are aligned side-by-side, we achieved about 410 cm × 600 cm of projection screen.

For our future work, we are planning to analyze the behaviors of people interacting in the system, and examine the results to improve the system.

5. Conclusion

We have presented the concept and design of i-trace: an interactive system using human tracking technology. Two directions could be considered for our future work.

- Installing the system as "informative/interactive street furniture"[5] to a common place like the lobby of an office building, and performing an attractive space with interactions emerging from unintentional actions.
- Making multi-modal performances so that users can enjoy the media space with their whole body.

Through various exhibitions, we plan to improve the system design and implement new applications (i.e. location/context-aware).

Even if they are not aware of the system, the traces will fill the space with fascinating performance. Hopefully, we expect the system that makes chances to tell the people that they had shared the same spot.

Acknowledgements
We thank Dr. Atsushi Nakazawa for helpful instruction on human-tracking technique. Audio Visual Communications Ltd., Mr. Motoshi Chikamori and Ms. Kyoko Kuno kindly supported us in exhibiting the i-trace system. Mr. Hiroshi Kato and Ms. Kumiko Morimura gave helpful comments for the paper. A part of this work has been supported by CREST of JST (Japan Science and Technology Corporation).

References

[1] Ramesh Raskar, Gref Welch and Henry Fuchs: “Spatially Augmented Reality”, Proceedings of the First IEEE Workshop on Augmented Reality, pp. 63-72, 1998

[2] Hiroshi Ishii, Craig Wisneski, Julian Orbanes, Ben Chun and Joe Paradiso: “PingPongPlus: Design of an Athletic-Tangible Interface for Computer-supported Cooperative Play”, Proceedings of Conference on Human Factors in Computing Systems, ACM Press, pp. 394-401, 1999

[3] Snibbe S. Scott: “Boundary Functions”, (online) http://www.snibbe.com/scott/bf, 1998

[4] Atsushi Nakazawa, Hirokazu Kato and Seiji Inokuchi: “Human Tracking using Distributed Vision Systems”, 14th International Conference on Pattern Recognition (ICPR ‘98), pp. 593-596, 1998

[5] Hiroshi Harashima, Keita Ushida, Yu Tanaka and Takeshi Naemura: “A vision for Informatized Cities —Designing Information Environments for ‘Now, Here’—“, Keynote Speech of IEICE Human Communication Group Conference, pp. 1-9, 2002 (in Japanese)