Particle Display System: A Real World Display with Physically Distributable Pixels

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CHI 2008, April 5 – April 10, 2008, Florence, Italy
ACM 978-1-60558-012-8/08/04.

Abstract
In this paper, the author designs and implements a new display system called *Particle Display System*, which can be installed on the non-planar surface of any objects. It consists of hundreds of full-color and wireless Light Emitting Diode (LED) nodes with a PC and video camera. The wireless capability makes the each node freely movable without distant limitation of the use of wire cables. By processing the images from the camera, the system calculates the positioning information of the each node and performs the timing control of the LED in the each node in real time. Therefore, the author is able to design a uniquely arranged pattern in full-color in the real world, by distributing and controlling the smart nodes. This paper describes the design and implementation of the prototype of *Particle Display System*.

Keywords
Display, Intuitive Interaction, Pervasive Computing, Intelligent Space, RFID, Tangible Display, Augmented Reality

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

Introduction

The innovation in display technology in recent years has enabled presenting information effectively in the real world. Users are intuitively able to understand the information that relates to their physical environment. For example, imagine an arrow sign displayed on a flat-panel screen hung on a wall navigates passengers. However, if the arrow sign is shown on the floor, and its pattern is dynamically changed in corresponding to the movement of the passengers, it will be more effective way to navigate people.

Currently, video projectors and portable devices are widely used to present information in spatially but their physical problems regulate the use of them. "The office of the future" [1] is a well known display technology to present information on every surface from video projectors. However, its use is limited only indoor. Even worse, people are serious obstacles off which the projected images are blocked. The portable devices, portable video projector [2], Head Mounted Display (HMD) [3] and Head Mounted Projectors (HMP) [4], provide users images without optical occlusions but requires them to carry the device all of the time.

Particle Display System (Figure 1) consists of physically distributable pixels, which can be installed on the non-planar surface of any objects. The users are able to perceive images without carrying devices. The author discusses about the implementation of the *Particle Display System* and the software optimization to increase the perceivable resolution of the illuminated graphics.

Approach

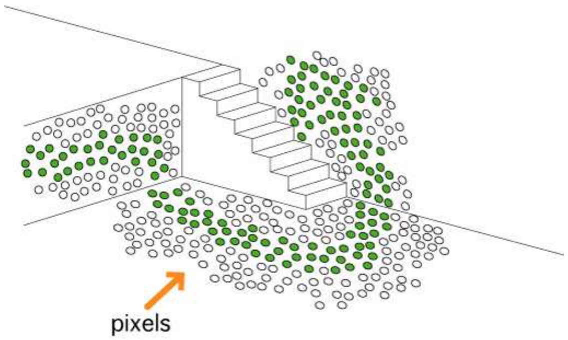

Figure 1. Physically distributed pixels are displaying an arrow.

The characteristics of *Particle Display System* are defined.

- No Physical Boundaries
- Three-Dimensional Images
- On-demand resolution

Particle Display System is physically distributable in a lager area. Each pixel can be installed on every surface in a room, on the wall, floor, every step of stairs and ceiling. The use of the wireless controllability breaks though the distant limitation of the use of wire cables.

Poupyrev discussed the relation of the shape of a display and the displayed information [5]; "By designing a certain display shape we can influence how the information will be structured." We can design the shape of the display so that it fits to the displayed information.

Particle Display System can modify its resolution on the illuminated graphics by changing the number and the density distribution of the distributed pixels. The users are able to change the number of pixels, depending on desirable images. For instance, displaying a single arrow requires small number of nodes. By adding extra nodes, it is able to display more complex characters.

Related Works

"Smart Dust [6]" project has built a smart network of tiny wireless micro electro mechanical systems (MEMS) devices for monitoring spatial information in a large area. *Particle Display System* is capable to illuminate the LED on the each node in real time.

"Throwie [7]" project has built a small and simple device to emit light though a 10mm diffused LED powered by a lithium battery. It is wildly distributable in a large area for artistic use. However, Throwie is designed to emit light until its battery discharges. *Particle Display System* is capable to control the lighting sequence of the LED on the each node in real time.

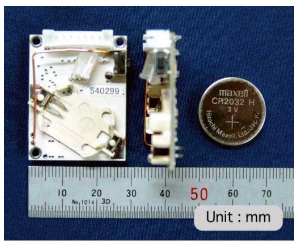

Figure 3. "S-Node" RFID nodes (LED nodes) and a CR2032 button lithium battery.

The Particle Display System

Particle Display System consists of three sub units, **Display (LED)**, **Location** and **Communication,** units in Figure2.

(1) Distribute the **Display (LED)** unit in a place.

(2) **Location** unit calculates the positioning information of the each node of **Display (LED)** unit.

(3) **Communication unit** controls **the Display (LED)** unit by sending a lighting sequence to each of the **Display (LED)** node.

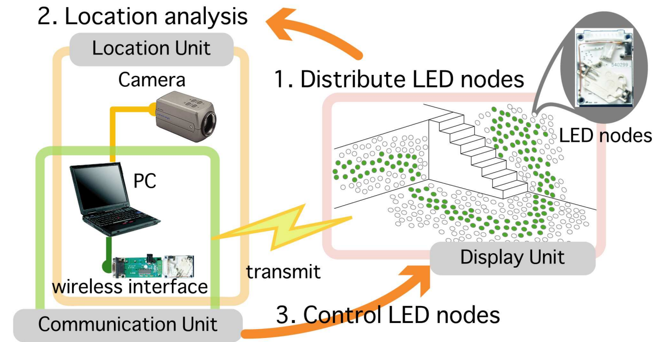

Figure 2. System diagram of the Particle Display System.

Display unit

Display unit consists of hundreds of wireless Light Emitting Diode (LED) nodes. The author uses products of "S-Node," (Figure 3) from YMATIC Corp [8]. It contains a full-color LED, and it can be controlled via wireless communication. It is 38* 28 * 5mm in size and 5.2g in weight.

Location unit

Location unit consist of a PC and video camera. It calculates the position information of the each node of the distributed Display (LED) unit. (1) It sends a message to the each LED node and turns the LED on. (2) It captures a video stream by the camera. (3) It calculates the position of the lighting LED node from the captured image.

Communication unit

Communication unit sends a message to control the lighting pattern of the Display unit. It communicates with the nodes via wireless communication at the rate of 4800bps. Sending and displaying real-time animation

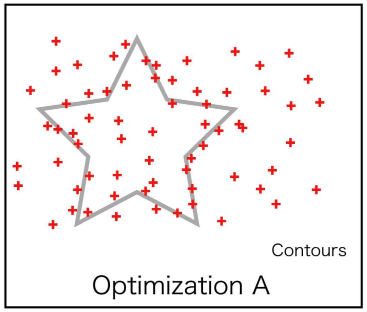

Figure5.a

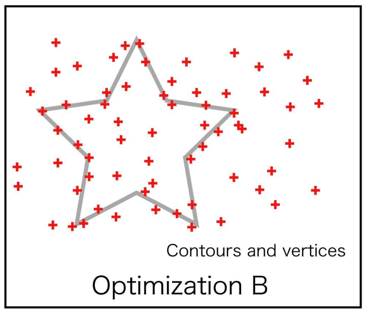

Figure5.b

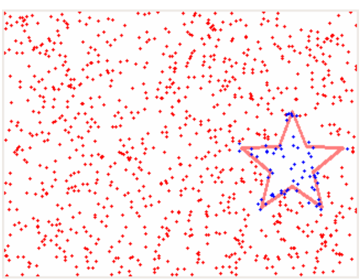

Figure6. An optimized location by optimization B with 1000 nodes.

is technically difficult because of the low baud rate of the wireless communication.

Results

The author conducted experiments on displaying an animation of moving arrows "->" (in 32 frames) with 100 LED nodes under the following conditions:1) LED nodes were distributed in a rectangle area of 700* 600mm on a flat surface on the floor; 2)the camera was set 800mm above of the surface. Figure 4 shows pictures of the moving arrows, taken by a camera. Each frame displays its frame number at the lower left. At the lower right, grading scale of one to four indicates "How well the figure is represented". This grading evaluation is conducted by a group of nine ordinary students.

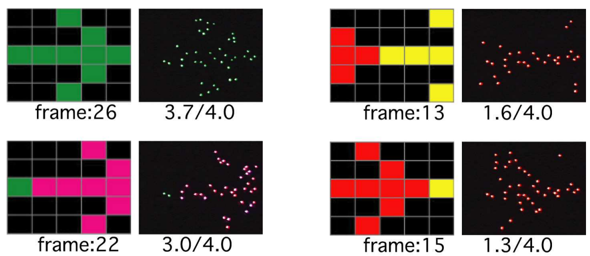

Figure 4. Pictures of moving arrows with two best grading (left) and two worst (right.)

Optimization of Displaying Position

The perceivable resolution on the displayed figure by the *Particle Display System* is very low in Figure 4. To improve the resolution, the author evaluated the result in Figure 4 and came up with two questions.

By increasing the number of the distributed pixels, how much does the perceivable resolution on a simple figure increase?

By what method, is the system able to display a clear and perceivable simple figure with the randomly distributed pixels?

To answers the two question, the author performed two computer based simulations and one real world experiment (Figure7, 8.) The compute based simulations use large numbers of virtual nodes (100, 500, 1000, 2000, 5000, 10000 nodes) with 320 * 240 (pixels) field. The virtual nodes are randomly distributed on a computer and works as the same as the actual system.

Optimization A: Search for a position on the virtual nodes where *the contours* of the character of a star contain the greatest large number of the virtual nodes within. (Figure 5.a)

Optimization B: Search for a position on the virtual nodes where *the contours and vertices* of the character of a star contain the greatest large number of the virtual nodes within. (Figure 5.b)

Real World Experiment: Based on the result from simulations with optimization A and B, the author performed a real world experiment with the better method, optimization B.

	Simulation	Real World
pixel field	320 x 240	320 x 240
character	star	star
pixel size of character	92 x 87	184 x 174
number of nodes	100 - 10000	100

Figure 7. Conditions for simulation and real world experiments.

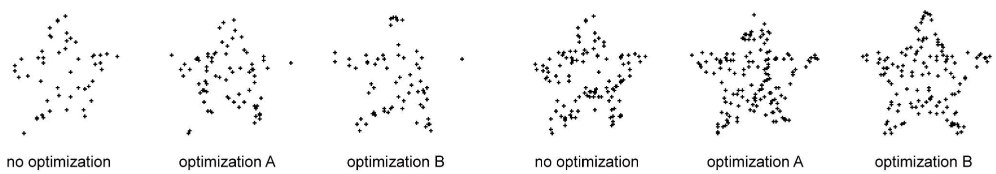

Figure 8. Representation of a star with 1000 nodes (left) and 2000 nodes (right)

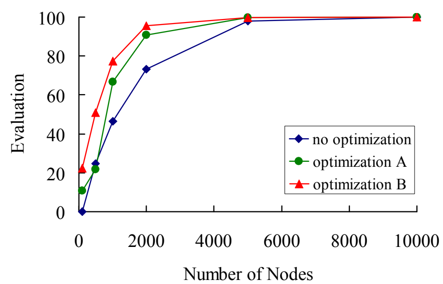

Figure 9. Averages of evaluation of each optimization method

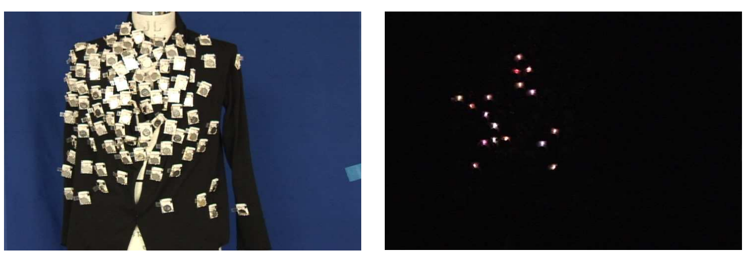

Figure 10. Distributed pixels (LED nodes) (left), and the displayed star (right.)

The author conducted an evaluation of two optimization methods. Eleven ordinary students answered "How well the figure is represented" in grading scale of zero to one hundred. (Figure 9)

Discussion

Application of the optimization method is making it easy to understand the original figure. Both of the optimizations improved the score in most cases, and optimization B scored more than A did, in most cases. This result leads to the conclusion that conditioning the displaying position so that there are more nodes on the contours of the figure and especially on the vertices provides better representation of the figure.

The representation in the real environment (Figure 10) didn’t work out as the author had expected, and there are couples of possible causes. One hundred pixels are not enough to represent a complicated figure like a star. In addition, there are some other possibilities that the system did not work properly. Failure in wireless communication is considered to reducing functional pixels.

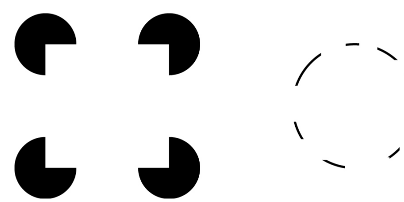

Figure 11. "Closure" of Gestalt Principles.

People do recognize shapes which are not fully illustrated in the image (Figure 11) [5]. Poupyrev discussed to introduce this principle to a display. This approach is a possible method to overcome the problems of representations on a display with very small number of pixels.

Conclusion

In this paper, the author has described *Particle Display System*, a physically distributable visual display for representations and annotations in the real world. The system enables objects to be associated with information, and users to *wear* visual. The physically distributable pixels allow users to construct a display anywhere they want, and even the shape and resolution are not restricted. Optimization of the displaying position has the possibility to conquer the drawback of *Particle Display System*, randomly distributed pixels.

Further development may extend to three-dimensional representation and also to integrations with an acceleration sensor or a photo transistor. In addition, with three-dimensionally distributed pixels, users can see images vary with the direction of the viewpoints, enabling showing specific information to more than one user. The implementation of an acceleration sensor would make the pixels work also as input devices so that users can tap them as they usually click with mice on graphical user interface (GUI).

Acknowledgements

The author would like to thank his supervisors, Dr. Hirose, Dr. Tanikawa and Dr. Hiyama at the University of Tokyo. Thanks to Dr. Ueoka, Mr. Kobayashi and Mr. Sidharta for their helpful guidance and support. This work was supported by Grants-in-Aid for Scientific Research, Japan.

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