



## [EVA] agent table

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## **Abstract**

The purpose of the EVA agent table project is to develop the tool for supporting architectural and urban design by providing pedestrian feedback information. Although there are many pedestrian simulation programs, none of them is applied to the physical interface for interaction with designers whilst they are designing. Thus, this project employs sketching interface by pen and paper, interacting with pedestrian simulations. As designers are familiar with this traditional interface, therefore they can naturally sketch the design interaction with pedestrian simulations. In addition, the advantage of adding this simulation is certainly to reduce time and cost invested in design process because designers can adjust their design immediately. However, sketch is a thinking process that designers communicate with themselves. Accordingly, if this feedback information of pedestrian movement interferes with designers' thinking while sketching, it will be not useful at all to include this information. Hence, the hypothesis has to be tested to confirm that the movement of pedestrian simulation will not interfere with designers' thinking but will help designers to evaluate their design. The test in this project will be investigated by using EVA agent table to design. From the experiment, it is also shown how designers sketch interacts with real time pedestrian simulation. Consequently, adding this feedback information to sketch has a beneficial effect on designers because it facilitates the design process.

Keywords: Sketch, Agent pedestrian simulation, physical interface, augmented reality, reflection-in-action

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## **1. Introduction**

The pedestrian simulation program is a part of a multi-agent system. It is an analysis tool which provides feed-back information in architectural and urban design. However it is used specifically for analysis by designers who having completed the conceptual design then test their design using the pedestrian movement program. After that they return to adapt their design again. This iterative process slows down the design process. Though there is some agent software which provides the interaction in real-time, using mouse is the only way to input the information into the software. The limitation of the system is certain because built environments are composed of complex shape which is difficult to be drawn by mouse. In stead of using mouse, Sketch, using pen and paper, is a method in design process which designer like using to explore their idea. If we add feedback information like pedestrian movement into this stage of design, it will be easier to change as it spends least time and cost in design process. Therefore in EVA agent table project, it is used pen and paper interface to interact with pedestrian simulation.

### **1.1 Why adding pedestrian simulation**

There is no regular collective of pedestrian data because behaviour of pedestrian movement is complex. In addition, to collect pedestrian data is complicate. Therefore pedestrian simulation has received attention in many contexts, such as evacuation, traffic operations, which including architecture and urban planning.

### **1.2 Design Process**

In architecture, the design process can be divided into seven parts; program, schematic design, preliminary design, design development, contract documents, shop drawing and construction [Laseau, 2001]. Most analysis programs are used after the schematic design or after the preliminary design such as in energy performance or evacuation. Then designers have to adjust their design again. This process is in iterative loop which continues until the design meets the requirements. This can waste cost and a

lot of time in design process. Therefore this project is provided pedestrian feedback information to interactively during the design process. Designers can adjust their design according to the simulated pedestrian movement. The method used to interact with the pedestrian movement simulation is the sketch. The sketch in this project refers to a floor plan spatial configuration sketch in schematic design due to the concept of agent and configuration. This concept will be described in section 2.

### **1.3 Why Sketch**

Although most CAD applications are useful, it takes time to learn and operate. Moreover using the mouse breaks down the flow of thinking, designers have to push the button or type to select commands. Using the paper and pencil method is more flexible and easier to use. By sketching designers explore their ideas more freely and quickly. As Verstijnen [1997] stated “idea-sketches are important in the early stages of design.”

In the early stages of design, designers always use sketches to explore their ideas. Designers naturally use pen and paper to think or solve problem in design. In addition designers, especially architects, are trained to use pen and paper in developing designs. Lawson [1994] interviewed designers about their design process. He reported that the act of freehand drawing played an important role for designers: “They find it hard to think without a pencil in their hand.”

### **1.4 Thesis Statement**

Sketching plays an important role in the early design stage and it would be useful to add feedback information at this stage. If feedback information makes designers refine their ideas at this stage, it will increase efficiency in the design process. The iterative process of sketch by putting the visual image, refining function and meaning of form, find and adapt new form is a loop from mind, hand, and eye to image on paper then feedback to the mind. From this process it can be seen that designers sketch visual images to communicate with their mind [Laseau, 2001]. This raises the question that the agent simulation, which interacts with designer in real time, might interfere with the thinking process of designers. My hypothesis is that the real time interaction agent will not interfere with designers’ thinking but will help designers to re-evaluate and refine their

design. Designer will like to design with real time interaction agent. In addition, the agent might give unexpected solutions which will be different from what designer think without it.

In the next section, principle of this project in agent simulation and sketch will be explained. Then follows by the related work that build up this project in section three. Section 4 and 5 will be described the EVA agent table system and technical overview. Section 6 is methodology. Conclusion is in section 7. The last section is future development.



## 2. Theory background

### 2.1 Sketch as a thinking process

The sketch refers to the freehand drawing which designers do in the early phase of design process. Designers draw to think and acknowledge sketch as a part of design process. While designers are thinking, they always sketch to explore their idea or to find a solution. Several studies in cognitive and the interviewing with designers show the relationship between the sketch and the thinking process. This section supposes that sketch is a method that designers use to communicate within their mind [Do, 2002].

#### 2.1.1 Sketch & Cognitive science

Cognitive science has also paid attention to the studies of design drawings as drawing relates to the cognition process in a designers' mind. Their studies show the relationship between sketch and the cognitive process. One of the reasons for sketches is to extend the limitation of our memory to think. We use sketching to compensate short term memory to communicate with our thinking. As Norman [1993] argued that human cognitive resources are highly overestimated; without external aids humans have only a limited memory and reasoning capacity. Larkin and Simon [1987] also explained that people are limited by the amount of information they can keep in their mind and the mental operations they can apply to that information. Memory limitation can be extended by external displays to help them inspect and reinspect. In addition, many researchers in cognitive science and protocol analysis studies believe that drawings relate to design thinking.

For example, Donald [1991]; Kirsh [1995]; Larkin and Simon [1987] discuss that drawings are a kind of external representation, one of many cognitive tools invented to facilitate memory and thinking.

Fish in "How Sketches Work" reviewed many literatures in cognitive science, art history and design to argue that sketches are representations of "visual thought" that help facilitate perception and the translation of ideas. Furthermore, sketches aid designers attend to thought and stimulate short term memory. Mezughi [1996] argues that sketching

is “the principal means of visualizing design solutions and crystallizing the thinking process.

It can be seen that sketches come from the mind to support the cognitive load in information processing. By sketching, we can take advantage of visual perception by putting visual image in the mind externally and explicitly on paper. Designers can interact with their thinking while they are sketching. As Verstijnen [1997] states that sketches make the designer interact with their mental imagery and Tversky [1999] “Drawings are an integral part of the dialogue a designer conducts with him or herself during design.

### **2.1.2 Sketch & Architects**

Many architects also reveal that the significance of the relationship between sketches and thinking are similar to those of the cognitive scientist. Opinions gathered from interviews with architects show that they use sketching to communicate with their mind.

From Lawson’s book, “Design in Mind”, he interviewed ten famous architects. He reported from the interviews with these designers who talked about their design process. For example, Herman Hertzberger argued that “drawing is a communication of my brain and paper” so it is precious in his design process. Denis Scott Brown pointed out that although Robert Venturi’s sketches are beautiful and expressive; they are drawn to communicate with self not just for a work of art. In addition Herbert in “Architectural Study Drawings” [Herbert, 1993] explained that drawings are not only a convenient strategy for solving problems but they are also the designers’ principle means of thinking”. He argues that the designer must interact with the drawing. Even the famous architect, Renzo Piano, also claimed that “drawing is a pure instrument of circular process between thinking and doing” [Robbin, 1994]. Like Piano, Louis Kahn state that” designers need to interact and work with a sketch, not just crystallize thoughts on paper[Kahn, 1931]. The same as Piano and Kahn, Michael Graves argued that drawings are language that play back to mind and bring forth to elaborate. They are speculative so they play an important role between action and designers’ mind [Graves,1977].

Laseau [2001] described that the process of sketch is an iterative process. The ability to modify information in sketch is come from the communication loop of paper, eye,

brain and hand. He explained that “the process of graphic thinking can be seen as a conversation with ourselves in which we communicate with sketches.”

In brief, sketches play an important role in the thinking process. The advantage of sketching makes a designer's observations and thoughts about a design problem become more easily accessible through the act of making drawings. We extend our thinking in mind onto paper and interact with it. Therefore sketching can be seen as a thinking process that designers communicate with themselves.

### **2.1.3 Sketch and Reflection**

As we see designers employ a sketch in the thinking process. In order to understand how they think while they are sketching, the term “reflection” will be explained. Dewey [1933] defined reflection as an active persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusion to which it tends. Later Schön [1983] whose idea is influenced by Dewey bring the word reflection into the centre of an understanding how professional think. He identifies reflection into two categories which are reflection-on-action and reflection-in-action.

The former is described as the process of reflection which occurs after the event when practitioners pause to deliberate their theory in action (what they do) and evaluate it. While reflection-in-action can be described as the interaction with a live problem as it unfolds. It might be happened when intuitive performance gives surprises, please or unwanted result. Reflection-in-action involves looking to our experiences, linking to our feelings and applying to theories in use. This leads to building new understandings to inform our action on the situation which is unfolding [Smith, 2001].

“The practitioner allows himself to experience surprise, puzzlement, or confusion in a situation which he finds uncertain or unique. He reflects on the phenomena before him, and on the prior understandings which have been implicit in his behaviour. He carries out an experiment which serves to generate both a new understanding of the phenomena and a change in the situation.” [Schön, 1983]

Practitioners test out their theory to develop further respond and move. In order to do this, they cannot directly apply principle from textbook. They have to treat each situation as a unique case. This is similar to the design tasks. Designers have to deal with the unique of each case in design and ambiguous problems in which there is no exactly problem. To solve the task, designers or practitioners have to construct their collection of knowledge, such as images, examples and action, which they can draw upon. This notion of repertoire is the key aspect of reflection. Schön, like Dewey, saw this as a key aspect of reflection thought.

When a practitioner makes sense of a situation he perceives to be unique, he sees it as something already present in his repertoire. To see this site as that one is not to subsume the first under a familiar category or rule. It is, rather, to see the unfamiliar, unique situation as both similar to and different from the familiar one, without at first being able to say similar or different with respect to what. The familiar situation functions as a precedent, or a metaphor, or, in Thomas Kuhn's phrase, an exemplar for the unfamiliar one [Schön 1983: 138].

Schön [1983] also described that design is a reflective conversation with the materials of a situation. Designers interact with materials, such as a sketch, which talks back to them. While they are sketching, the changing and emerging representation of the sketch "talk back" to designers allowing them to reflection-in-action. After that the reflection-on-action may happen when designers see the result of the representation [Nakakoji *et al.*, 2000]. Therefore they use such representation not as a solution but as a means for reflection. Designers act and reflect almost simultaneously; acting, interpreting and reacting to the evolving design.

While designers are communicating with his material, it reveals to them the unanticipated problems and potentials. As they appreciate the new unexpected phenomena, they also evaluate the moves that have created it. In addition, they can perform learning sequences in which they correct their errors and takes account of previously unanticipated results of their moves.

Sketching can be seen as a virtual world which functions as a context for experiment. It enables designers to eliminate the complexes and confounds of the real world which might disrupt their experiment. Therefore in this world they can easily conduct their

experiment by exploration, move testing and hypothesis testing at once. This is the distinctive character of experimenting in practice.

In conclusion, design is a unique and ambiguous case. Designers have to do their experiment in practice to succeed in the design task. In order to set up his experiment, designers employ sketching as a media to talk back to them and trigger the reflection process. This process, in turn, is necessary to serve his experiment in exploration, move testing and hypothesis testing.

## **2.2 Agent**

An autonomous agent is a unit which interacts and responds to its environment independently from all other agents. It has no idea about the global plan which it should follow and does not get any command from seen or unseen leaders. The process through which the autonomous agent interacts with its environment to create a global plan is called self-organization. There are many examples of this phenomenon such as collective animals, chemical soup, gene regulation systems and also the movement of pedestrian [Flake, 1998].

### **2.2.1 Agent base simulation**

Agent base simulation has been applied to many fields such as engineer, biology, architecture and urban design. In this system, agent interaction with each other and their environment is modelled and simulated as a multi-agent system. Agents, which can be animals, human or software systems, perceive their environment and perform to act and react to change it. To compare with traditional methods, such as mathematical equations, cellular automata, and discrete event simulation, agent based simulations are more abstract than reality as it focuses on modelling specific behaviours of individuals. Many methods apply to different types of agent. However, in this project, we will focus on agent based pedestrian simulation, which is normally used in architectural and urban design. The type of agent based simulation can be divided into three main categories. First is the macro simulation level which is based on transportation modelling. This level simulates pedestrian flow by using differential equations. It analogizes pedestrian flow as a gas or fluid. Second is the mesoscopic level which does not focus on individual agents

but it focuses on group of agents in an identical environment for instance vehicles' speed is the same in the same section of road. Although the mesoscopic level is improved in agent simulation, it is suitable for traffic modelling. The system of cell transmission model of Daganzo [1994] and TRANSIMS are also in this class. TRANSIMS is a cellular automata based system which can model 20,000 agents. Finally, the micro simulation level focus on the granular physics models of flow which uses predetermined directional paths to simulate crowds. This led to the emergence of life-like phenomena that is based on simple rules. This category is therefore suitable to model pedestrian movement and is used in this project.

### **2.2.2 Agent navigation and Spatial Configuration**

This project uses the EVA (exosomatic visual architecture) which is an agent simulation program [Turner&Penn, 2002]. Its behaviour models come from movement rules which are based on Gibson's principle of affordance [Gibson, 1979]. The authors apply large number of agents with these rules in building context and adapt parameters such as field of view, number of steps before decisions, and destination selection by associated with building configuration alone. The result of the agent pedestrian movement is similar to that found in real life.

Socioeconomic factors also affect human behaviour. Human activities are regarded as Cost benefit behaviour. However when looking at crowds, individual humans can be seen as particles driven in a certain direction, pushing through the other and forming lanes. This can be coded in an agent-based system and are usually used ,for instance, in this following works: Hoogendoorn *et al.*, Helbing and Molnár [Turner&Penn, 2002]. Nevertheless the lack of sight makes agents seem to be particles pushing each other in the dark. The ability to see makes it differ from particle and led to an intuitively attractive behaviour. Human will move to the direction which provides the potential of further movement. Gibson calls this situation "natural vision". According to this theory, agents recognize the environment just to explore in order to move. Hillier *et al.* [1993] also shows that the majority of human-pedestrian movement occurs along lines of sight which can be interpreted that there are more areas in which to move. In these theories of

movement, human movement is generated by configuration. Configuration and walkable surface are equal in providing the possibility to move of agent [Turner & Penn, 2002].

Microscopic human movement from spatial cognition also shows the importance of configuration. Golledge [1995] conducted an experiment by asking participants to walk in a campus. He found that people do not necessary take the shortest route and there are different paths taken between original to destination and destination to origin. “Perceptions of the configuration of the environment itself... may influence route choice. Thus, a route that seems shorter or quicker or straighter from one end may not be so perceived from the other end...”

Another experiment by Peponis *et al.* [1990] to study people’s movement in hospital is also interesting. He observed pilots who move in hospital. From his experiment, he defined the rules for navigation as followings.

- (1) Avoid backtracking
- (2) If all else is equal, continue in the same direction.
- (3) Divert from the current heading when a new view allows you to see more space and/or activity.

### **2.2.3 Is the movement of agent similar to the real pedestrian?**

Turner and Penn [2002] used the EVA-based system to compare with real pedestrian data in Tate Britain Gallery, Millbank, in London. The agent decision process was tested according to two variables which are the number of step and the field of view. There were three types of agents to be compared in this experiment. The first is particle agents which take an average of  $n$  steps before moving at random to the new direction. The second is unsighted agents which walk an average of  $n$  steps and change the heading  $\pm\theta/2$  from the current heading. The last is sighted agents. Each type of agent was applied to the layout separately.

The authors used correlation with observed movement for calculated data by taking the linear  $R^2$  correlation coefficient of log-log data of the observed room movement [Hillier *et al.*, 1996] against the simulated room movement. They discovered that the sighted agents who take an average 3 steps and field of view  $170^\circ$  will give the correlation coefficient about 0.76 compared with real observed human movement.

Although this system still does not apply to other buildings, the good correlation result in this case shows that it is possible to generate pedestrian movement in which the only movement strategy is dependent on the configuration of a space.



### **3. Related Work**

Many researches use the computer augmented to reality with a tangible interface to provide feedback information to designers. The significant advantages of these systems are that designers act naturally and do not necessarily need to learn how to use the systems because systems provide traditional interface which designers are familiar with and they have the ability to predict the result of their design through the computational simulation. Similar to these works, “Eva agent table” aims to create a design which visualizes the pedestrian movement information and interacts with designers’ sketch. In this chapter, existing projects which have a similar approach will be briefly reviewed in order to show the background and principles of this project.

#### **3.1 ARTHUR Multi User Augmented Reality System**

Arthur round table [Bartlett School, 2004] is a three dimension augmented reality system. This project uses a physical interface to interact with virtual objects by using HMD and camera. By using shape recognition, physical objects can be used to interact with users to move virtual objects and cameras are used to track orientation and position of users to update the view point. This system also includes agents which simulate pedestrian movement in the environment. In this experiment, pilots are tasked to arrange objects in environments. The task is divided into a single user and multi users. At first pilots will do task only in physical object. Then they use ARTHUR system for 3D augmented reality interacts with agents.

#### **3.2 MouseHaus Table**

MouseHaus Table is a tool for urban design which uses a physical interface with pedestrian simulation program [Huang *et al.*, 2003]. The authors described that hardware system is composed of a custom-made table, a rear projector with a rear projector screen and a video camera. The principle of this system is the agent simulation software which is mouse.class. The programming language of this agent system is Java. Users use scissor and paper to interact with the system. This physical interface is done by an image

processing program employing Java Media Framework to capture and analyze images. The image processing can be divided into two parts, which are the physical Object Register and the Object Detector. The Physical Object Register uses colour to detect that agent can pass this object or not. Users have to put the object which will be used under the camera to register. After that the Object Detector will scan the image and get the colour of objects. The camera will scan position of the image from top left to the bottom right for the system to get the size and position of object. Agents receive this information and interpret objects into urban elements. For example in Figure 3, the red object represents the building so agents cannot pass through it. On the other hand, the green object represents the urban leisure area, such as a park or plaza, so agents can pass through it.



Figure 1. MouseHaus Table



Figure 2. Interface of System



Figure 3. Agents using color to detect

### 3.3 Illuminating Clay:

#### A 3-D Tangible Interface for Landscape Analysis

Illuminating clay [Piper *et al.*, 2002] is novel system for real time computation to analysis landscape model using augmented reality and a tangible interface. Landscape design and engineering need great numbers of specialists to cooperate in their work. In addition, it is difficult to communicate with each other. It therefore needs this tool to efficiently represent physical structure with physical tangible media to display complex geometries and physical relationships which are complicated to describe. This system uses plastacine with steel to be a physical model as an interface which is detected by using the ceiling-mounted laser scanner. By writing a control script, the system is able to capture changing geometry in real time. Information from the scan will be converted into

x, y, z coordinates, and then converted to digital elevation. The display of the analysis will be cast back to the physical model by a LCD projector. Two sides of the interface have thumbnails from library of landscape analysis function which is update with the model. The other two edges are used to convey section. The display of quantitative information; such as slope 60°, shadowing: Yes, “Aspect: South, etc; are on the corners. During the interaction with illuminating clay, the system conveys various real-time landscape functions, presenting information such as slopes, shadows, solar radiation, land erosion and water flow by projection.



Figure 4. Illuminating Clay

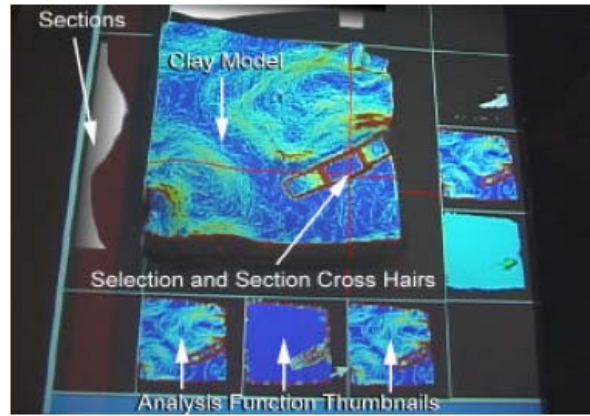


Figure 5. Interface of Illuminating Clay

The fusion between output and input makes it easy for users ease to understand mapping. The clay model captures the complex appearance of the landscape and makes users easy to explore the task using the physical model.

### 3.4 Augmented Urban Planning Workbench: Overlaying Drawings, Physical Models and Digital Simulation



Figure 6. Augmented Urban Planning Workbench

Augmented Urban Planning Workbench is combined various forms of representation which are 2D drawing, physical models and digital simulation [Ishii *et al.*, 2002]. Users can sketch 2D for lying below the physical model. The hardware system is composed of two video projectors, two video cameras hanging from the ceiling and a 4.0 m by 1.4m work table surface. The software system is based on a URP luminous table project which employs tangible interfaces to interact with digital simulations such as shadow cast, glare, wind patterns, simple traffic simulation and proximity constraints. However the software in the Augmented Urban Planning Workbench is extended from the URP in four main parts.

1. Sun and shadow computation

When buildings are put in this system, the system will cast shadow and reflect glare depending on the position of sun, date, time and latitude. In URP, system cannot change latitude and time can adjust in discrete increments of one hour.

2. Architecture geometries

Only small groups of buildings and lattice structures can be used in URP. For digital, we can use only polygon descriptions in a simple geometry description format. In contrast, the original software was developed to meet the requirement of using large and complex architectural structures. Furthermore it supports buildings that were

created in shape file format the same as GIS which works well with the other GIS specific elements such as topology and waterways.

### 3. Save and Load

URP lacks the ability to save and restore work. On the other hand this system allows the user to save the entire state to written out or continue to work later.

### 4. Traffic Simulation

Traffic simulation in URP was fixed. Unlike this system, users are allowed to set parameter for width of road(number of lane) , length of road, vehicle density and traffic cycle time at each road in an intersection.

URP has interface limitations by using a wand to touch for the wind or glare. It will be difficult to touch, if a group of buildings are close together. Moreover it is impossible to change a small parameter such as to change time by one minute. This system therefore changes the features to use a mixed interface between TUI and GUI. By combining all features this project brings a more realistic sense of site and enriches the urban design process.

## 3.5 Summary

All of these projects provide feedback information to users. However their projects are focused on collaboration. Therefore they do not intend to make their interface to be compatible to adjust the design. For instance, the interface of Augmented Urban Planning Workbench which is lattice model is difficult to change. They have to adapt 2D sketch below, before changing the model. Similar to Augmented Urban Planning Workbench, the MousHaus table which uses paper and scissor is difficult when it is used to design. In addition, objects in this project can only be rectangle because the limitation of this image processing will scan and recognize parameters from top corner to bottom corner. This limitation will be developed in the EVA agent table to make it suitable for designing.

The aim of “EVA agent table” differs from above projects. This project focuses on creating tool for supporting architectural and urban design which is based on feedback information of pedestrian movement. The interface of this system is by pen and paper which is the traditional interface that designers are familiar with. Designers

therefore naturally use this system as in the physical world. However, as a nature of thinking by visual image, designers sketch to communicate and explore with image in their mind. Kubie [1961] asserts that “Thinking processes actually are automatic, swift and spontaneous when allowed to proceed undisturbed by other influences. Therefore, what we need is to be educated in how not to interfere with the inherent capacity of the human mind to think”. According to this reasoning, adding a real time interaction agent whilst sketching may not be useful at all if it interfere with the thinking process. The assumption is that the agent which is feeding back information can be added in the early stage of design and will not interfere with the interaction between sketch and designers but it will help designers to focus on their task will be proven. The installation is set up for the test which will be done by designing with real time interaction agent. If the agent does not disturb the designers’ thinking, then this can lead to an enriched design process by providing feedback information to the early stage of design.

## 4. System Architecture

In order to make a tool for designing, I constructed the installation to make agent interact with users' sketch [Figure 7]. This system has two significant parts: hardware and software.

### 4.1 Hardware Setting

The advantage of the hardware system is ordinary equipment to set up which is easy to be acquired and not expensive. The hardware for this tool comprises a custom-made table for supporting transparent plastic. The display surface is transparent plastic combining with paper which cast display from projector. The mirror reflects the light from the projector to the top surface of table. The web cam will capture the display as an input to the software.

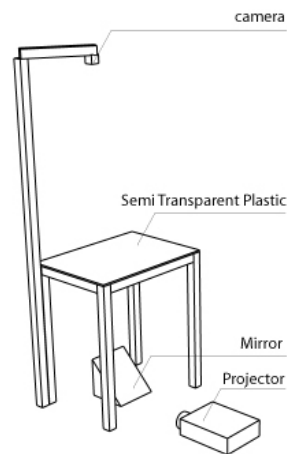


Figure 7. Hardware System

## 4.2 Software System

The EVA agent simulation software [Turner&Penn, 2002] is used in this project. The concept of the agent in this software follows the Gibson's theory of natural movement. EVA (Exosomatic visual architecture) is the principle component of this project. This software follows the concept of natural movement [Gibson, 1979]. EVA composes a visibility graph by overlaying two dimensional grids with plan view layout. EVA computes the probability to see in each point of the grid. Then the set of visible locations for each point are stored so a visibility graph can calculate the approximate viewable area from each point on the grid. The set of visible can be subdivided into 32 bins, thus set of viewable location from each point has field of view  $11.25^\circ$ .

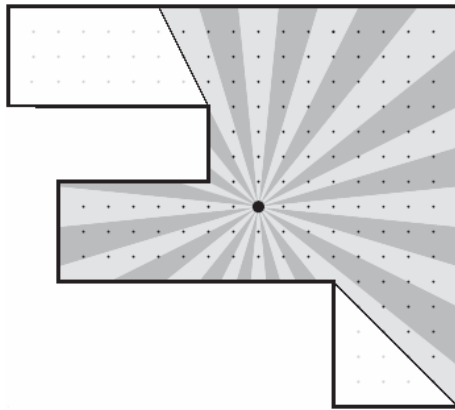


Figure 8. Visible locations are divided to 32 angular bins.

The position of each agent will round to the nearest grid and round the heading of each agent to the nearest bin. The agent will then choose the new direction from the set of visible which have more viewable area. These sequences occur in loops every  $n$  steps.

Mottram developed EVA software to be compatible with the concept of this project. The agent in his method can detect configuration by bitmap rather than using vectors. The system calculates the walkable surface by using pixels. Agents explore the different intensity colours of the bitmap in each pixel and decide how to walk. The high intensity will be defined as a configuration which the agent cannot walk through.



### 4.2.1 Agent everywhere

To make the agent see the physical world, Mottram made the program to load the video image from web cam into the software. By capturing the video image and updating the image every processing time, agent can be augmented to the real world. The agent detects the image which loads into the program and decides which direction to walk according to the intensity of bitmap.

The camera will capture the image from a freehand drawing to be a bitmap and input it into the software agent. Agents will detect bitmap to choose behaviours to interact with the object which is drawn.

### 4.2.2 Interface of software

Some parameters have to be set up for instance the size of agent, boundary control and some agent behaviours. Some parameters have to be adjusted via visual c++, although many of them can change parameters via interface. The following numbers are some significant interface menus in order to adjust these parameters to make it suitable for each experiment.

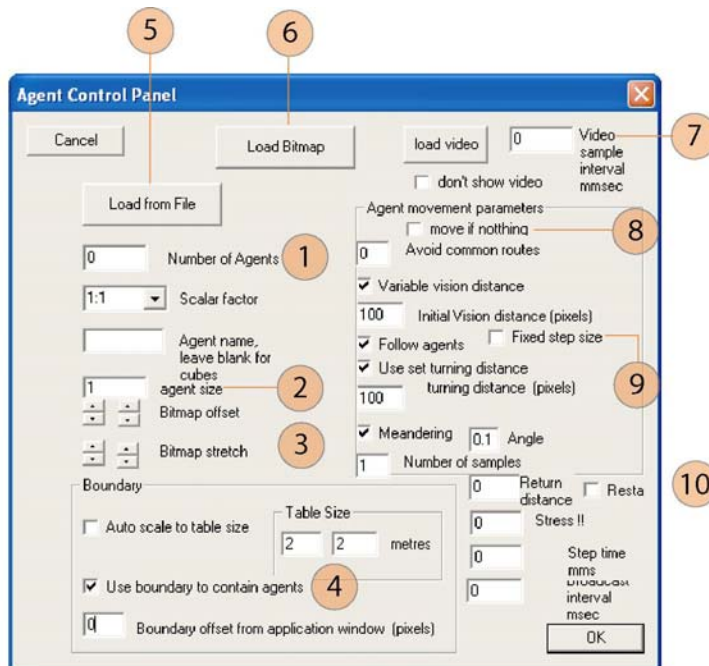


Figure 9. Interface of Eva software

1. This interface is for changing the number of agents. The number of agents can be as many as required (more than billion) based on the computer capabilities.
2. Sometimes the scale of the site or layout does not match the standard agent size. This menu is useful to adjust the size of agent.
3. Bitmap offset is very useful to adapt the position of the image from load bitmap or load video to match the camera. This will be described later in the technical overview section.
4. The back line frame in this picture is the boundary which is set to control agents in the window size. Otherwise, they may go outside the window frame.

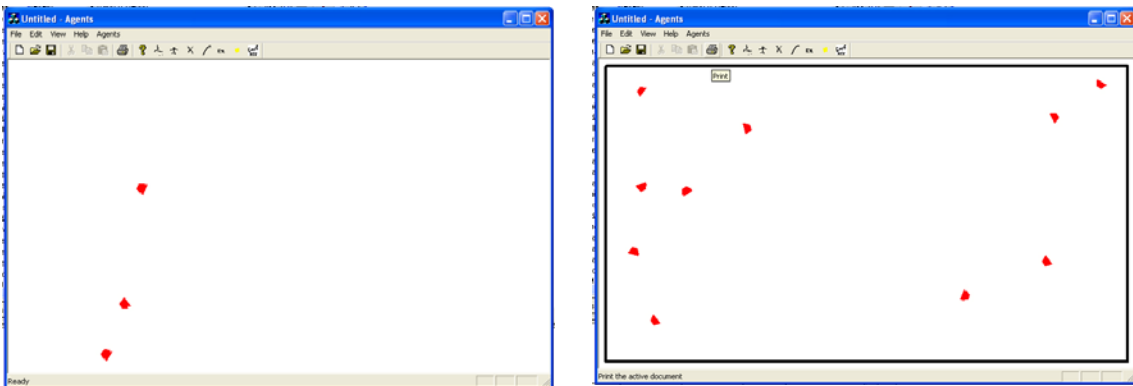


Figure 10. Show boundary to contain agents

5. This program can be saved for further work next time. For example last time I saved file as myagent.agt. I can open to work by using load from file menu.
6. The picture or lay out can be imported to this program by using “Load Bitmap”. The picture file should be bitmap file(.bmp).

7. If the web cam is connected, the video image can be loaded by using “load video” menu. The web cam captures the moving image from the physical world as an input to the program. Agents can walk while the video image is continuing to be loaded as background picture. It seems that agents walk in the real world.
8. If there is nothing in the scene, agents will wonder around and sometimes they will not move. “Move if nothing menu” is for making agents move as normal though there is no configuration in the scene.
9. When agents walk near the configuration, they will move slowly to decide which direction to go next. If “Fixed step size” menu is ticked, agents will move constantly even though they are near configuration.

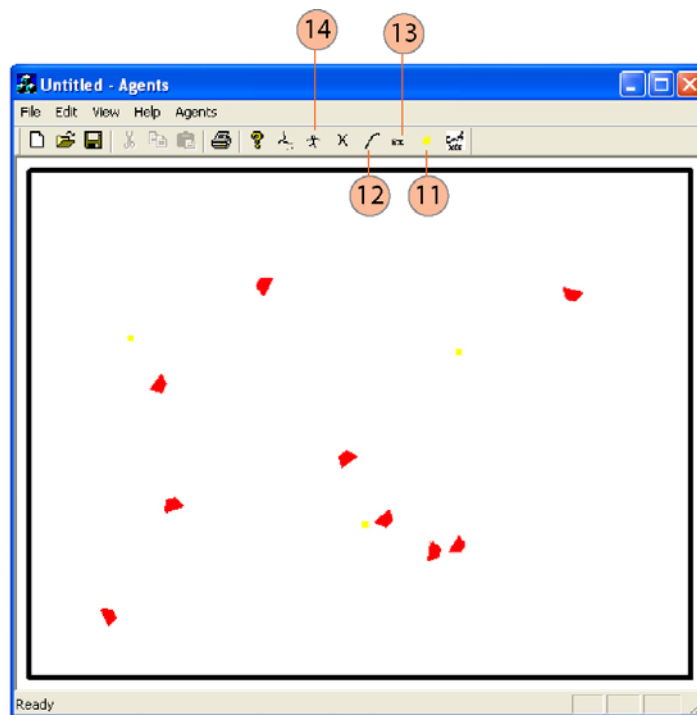


Figure 11. Interface of software

10. “Restart” and “Return distances” menu is used when the start position is specified. The start position can be defined by using “Make agents start point”. Agents will come out from the start point. Then return to the start point after walking steps equal to parameter which is specified in “Return distances”.
11. The yellow point in the menu bar is “Make agents start point” which is for defining the start position of agents.
12. “draw trails” is for 2D display path analysis of agents movement. It will draw the line following the agents’ movement.
13. Agents can be paused by clicking at “Start/Stop agents movement” menu.
14. “Agents or draw line” is for drawing a configuration line or adding agents.

## **5. Technical Overview**

### **5.1 Matching Camera**

The main task for the set up was to match the web cam to capture the same size and position of the display on the surface. If the video image and the display surface do not match each other, agents will perceive incorrect positions because agents will detect lines only from the web cam. While video image input and the position of display on the table are adjusted to be the same position, to move projector, mirror or web cam is not convenient as using “Bitmap offset” menu. Therefore this menu is very useful to match the video input image and display image which is projected on the table.

### **5.2 Camera Distortion**

The video image input from the camera cannot exactly match the projector display on the table. The video image input on the edges of the projector display surface will slightly be out of alignment with the real position of the object. This is the same as a photograph. Photographs often curve a tiny bit in or out when they are near the sides of an image because in reality the lens of camera is not flat. The problem is assumed to be camera distortion. This is a phenomenon that occurs when using small lenses with a wide field of view. If the projector display on the table is larger than the current size, it will cause more distortion because of the greater distance away from the centre of image. There are many methods to solve this problem. One of them is using Gandalf library [2003] which is a computer vision and numerical algorithm library, used in C programming language, which allows you to develop a new application. It supplies the function for adding and removing image plane distortion.

### **5.3 The limitation of display size**

The size of the projector display on the surface in this project is not large because the maximum resolution of a web cam to capture video image is only 640\*480 pixels. Although there is a web cam which has better resolution than this, it is still very

expensive. Moreover, in this project the large size of mirror was not used. If larger size mirror and better web cam are used, the projector can be pushed back to increase the distance and the size of display will be increased.

#### **5.4 Lighting Condition**

Lighting condition of the environment affects to agents because agents detect configuration from colour intensity of bitmap. In order to make agents follow correctly with the sketch line, the camera setting and colour intensity parameters which the agent uses to detect the line. In addition, the material also affected the agents. Sometimes agents walked through the line because transparent plastic reflect the lighting above the table. The reflection made the image input too white so agents cannot detect the line.

#### **5.5 Video feedback**

After the web cam was matched with the display image. There were still some problems to be solved. First is the mirror effect which happens when two mirrors are opposite to each other. There will be an infinite image reflect in these two mirrors. The web cam which captures images from the display and input them to the computer to display is also the same as two mirrors. For example, from the figure [12] agents seem to have several ghost shadows. Second is the delay of web cam. It keep feeding the video image into the software, especially moving images such as when you move your hand over the table, web cam still keep the image of your hand to display and the image will blink for a while. The last problem is a display image of users' hand will appear while sketching. Some user feels that it interferes and make them dizzy. All of these problems can be solved by removing the video image. After the system receives the video image, agents detect the image. Then the background image in the program will be refreshed to be white every time. Therefore agents perceive sketch lines though the white background.

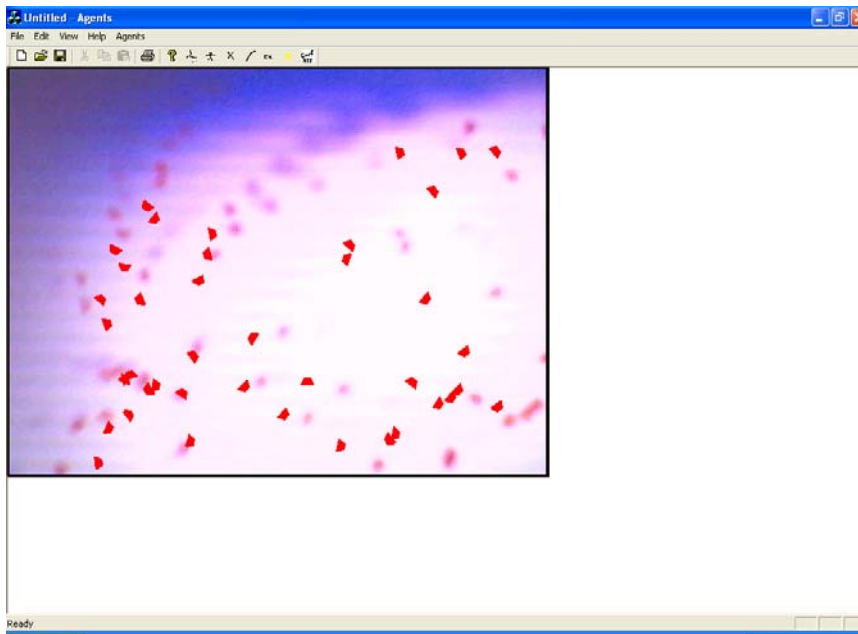


Figure 12. Video feedback

### 5.6 Agent move slowly

Loading video images costs a lot of computer memory which make agents move slowly. Therefore the component to adjust frame rate and video sampling interval are added in this software to solve this problem. The frame rate of video image can be reduced to be a minimum of five frames per seconds which can make agents move quicker. However when reducing the frame rate, video image might not update fast enough to make agents detect the sketch line. The video sampling interval therefore has to be adjusted to help (Figure 12). When the analogue signal from the web cam is converted to digital, the analogue must be sampled, which is to read or to measure, at discrete interval of time. "Video sampling interval" menu is added to specify the length of interval which is the inverse number of the sampling frequency. The smaller number of interval is the higher number of frequency to update the video image. By using this method, Agents can detect the sketch line in real time though web cam frame rate is reduced. The number of video sampling intervals which were found to be suitable in this project was about 200-500 milliseconds.

### 5.7 Combining Load video and Load Bitmap

Loading picture file of the site or layout into this software is convenient. Nevertheless to load bitmap and load video at the same time needs some function to be adapted. The bitmap file and video image that are loaded in the program at the same time can be seen as layers in “Adobe Photoshop”. The source file overlaps destination or background image. Therefore the top layer, load bitmap, needs to be transparent in order to see the background layer which is a video image. Although a simple interface for transparent bitmaps is not provided by Microsoft® Windows™ graphical environment, it can be simulated by using a mask bitmap in BitBlt function [for detail, MSDN Library Visual Studio 6.0]. The colour white and black are assumed to have value which are 1 and 0 (for the value of other colour will be between 0 and 1). They are assigned to be transparent pixels and Opaque pixels. Transparent pixel will not affect the destination which is background video image. In contrast, opaque pixels will affect destination which will replace anything that was there. By using these values, BitBlt function specifies a raster operation (ROP) which is used to combine the bits of the source and destination. At first, SRCCOPY was used in this software but it did not work when loading bitmap and video at the same time. The program will display only load bitmap because this method copies directly to the background. Then SRCINVERT was used. This operation can combine load bitmap and load video by inverting the bitmap onto background then restoring background to the bitmap again [Figure13]. However it still does not work to my requirement so the other methods were tried. The most suitable operation was found to be SCRAND [Figure15]. This method converts the white colour to be transparent and leaves the black colour to be opaque. The video image is behind the picture image and there is no tracing between video image and bitmap image like in SRCINVERT. Therefore SCRAND was decided to use in this project.





Figure13. SRCINVERT

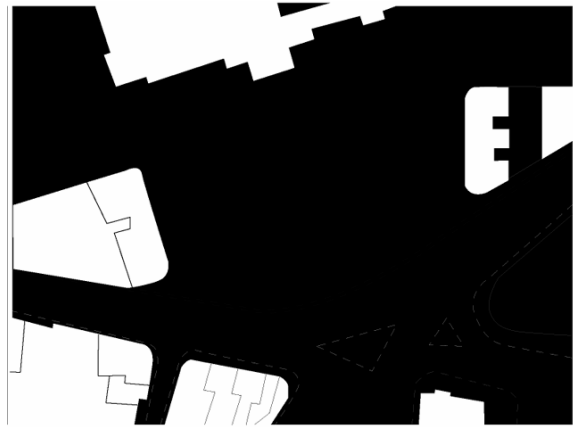


Figure14. Source file (.bmp)



Figure15. SRCAND

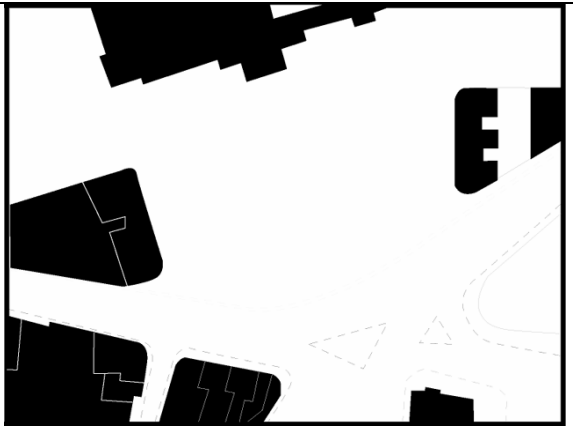


Figure16. Source file (.bmp)

## 6. Methodology

The plaza always related to the movement of pedestrian. As it is a node that pedestrian uses to rest or pass through. Therefore in this experiment, the plaza is chosen to be a site for the design task. The main goals of this experiment are to test the hypothesis that the movement of the agent will not disturb designers' thinking while they are sketching and to see how designers think while interacting with feedback information. The task that will be given to designers is to design three new buildings in the plaza. There are seven existing buildings around the plaza and three access points representing tube stations (see Appendix B). Designers will be divided into two groups. The first group will be tested by using the system before sketching in the physical. The second group will design by normal sketching before using the system. The assessment in this experiment will be a qualitative assessment. During the test, video recording will be used to collect data which will be analysed and combined with the interviews and questionnaires after the test.

Building 1	Sculptures, Bookshop and Photo exhibition
Building 2	Modern art exhibition and Souvenir shop
Building 3	Café

Table 1. Three new buildings in the experiment task

### 6.1 First sketch in system GroupI

Subject 1, 2, 3, 4 started designing with agents. Subject 1 is a Ph.D. student in urban planning but her background is also architecture. She has never used CAD software. Subject 2 has experience in architectural professional for nineteen years.

Subject 3 is student in M.arch. She has an experience as an architect assistant for one year. Subject 4 is an interior designer and has worked as an architect for 2 years.

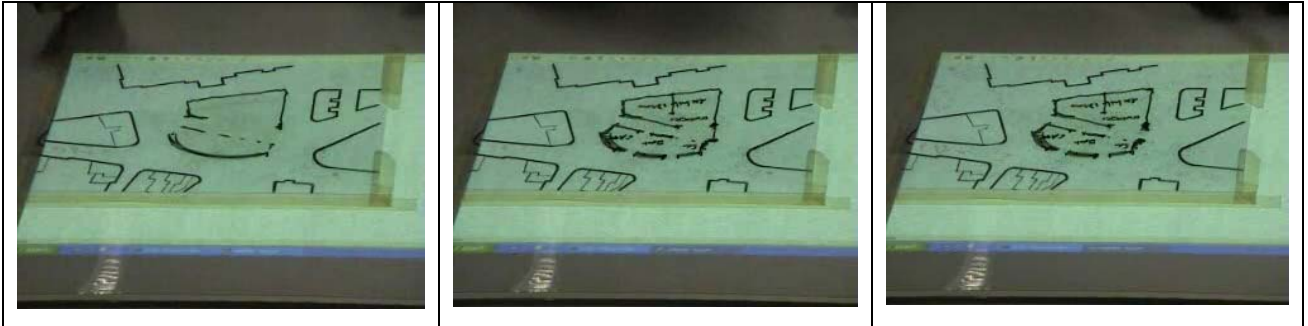


Figure 17. Subject8 Sketch in Eva agent table

From the sketch with agent, Subject 1 defined shape of the buildings not only from the site but also influenced by the movement of agent[Figure 17]. The reflection-in-action is triggered by the interaction with the real time agent because she explained that the curve of building was designed according to the flow of agent movement. This is the same as the entrance of buildings that she defined from looking at the agent movement. At first her theory in action to approach her building did not succeed. The reflection-on-action happened as she stopped to evaluate and said that “nobody came in”. In order to solve this problem she has to set her hypothesis testing why the agent did not walk through her buildings and explore her hypothesis. She changed circulation to cut the building into two main parts. Then she stopped to evaluate the result. Her hypothesis was correct because her buildings could now attract agents. As she appreciated the result, she decided to finish and said that the central circulation will be larger than this and the mass of the buildings will be smaller.

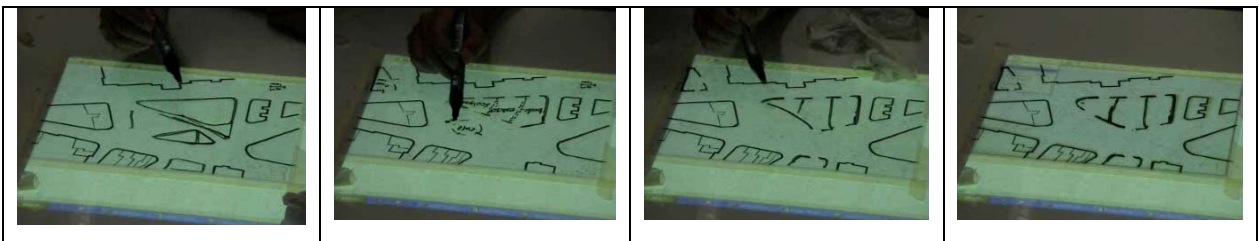


Figure 18. Subject2 sketch in Eva agent table

Subject 2 drew the main buildings in the centre plaza. He reflection-on-action to think and observe agents movement. He interacted with the agent and reflection-in-action by defining the shape from site and agent movement [Figure 18]. His main idea was to make the pedestrian flow between three stations. He explored the shape and position of buildings. He changed them many times after he stopped for evaluation. He reflection-on-action by combining the agent and the sketch which talked back to him. For example he changed the position of the café to the edge because he found that the previous position obstruct the agent [Figure 18]. He was satisfied with the result of this new position because it emphasize the axis to link two stations and make for a better flow of agents between three stations. Finally, he explored the curve of main building. However he did not appreciate it so he changed it back as it was before.

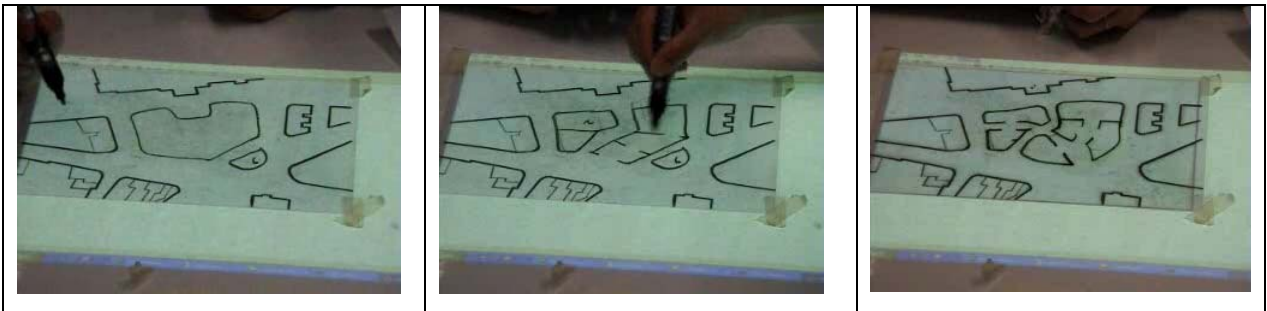


Figure 19. Subject3 Sketch in Eva agent table

Subject 3 felt frustrated and found it difficult to design while sketching with agent. This problem is assumed to be that her theory in action does not match the agent movement. Before she started the test, she drew the line to lead agents walking to the court but agents did not go and just walked around. She said that her approach should lead agents to walk to the court but asked why it did not. While she was interacting with the agent, she defined the shape of building into two masses first. After that she observed agent and reflection-on-action to specify the main entrance by starting to define circulation between buildings. She explored the circulation and entrance many times. She transformed the layout and circulation where as she was dividing space for each function [Figure 19]. She reflection-in-action with agent. She explained that while she was exploring the mass of building from the context of site, she got the circulation from

agent. Then this circulation shifted the overall concept. The new form and circulation emerged which totally changed from the starting design.

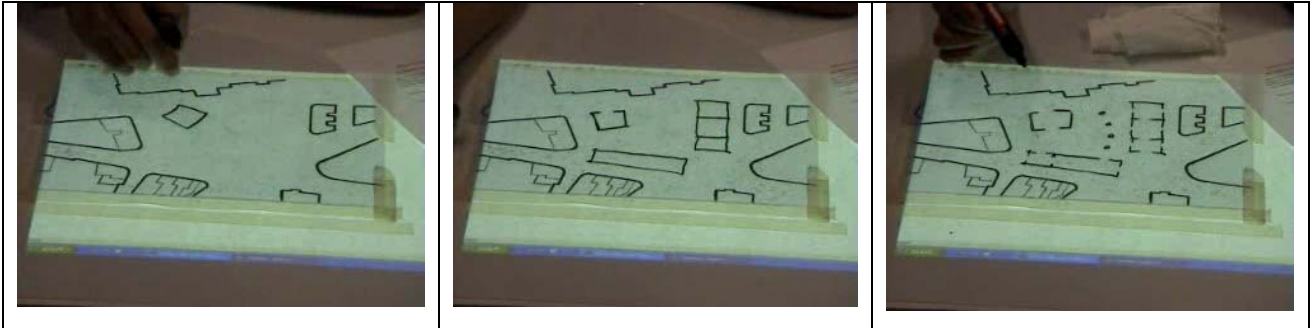


Figure 20. Subject4 Sketch in Eva agent table

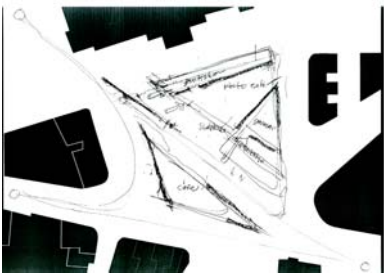

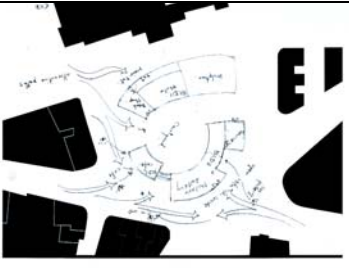

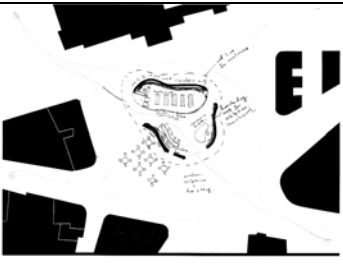

Subject 4 reflection-in-action when she saw the movement of agent. She first explored the shape of the building from the movement of agent. She drew the first shape which did not relate to site. After that she changed the shape of building to relate to the site. She positioned all building and divided the function inside the building. Then she stopped to see the movement of the agent and reflection-on-action to decide the entrance of buildings. During this time, she frequently stopped and changed the entrance of buildings. After that she rescaled the cafe and drew the curved partition. Finally she changed it into a dot. She explained that this partition will lead the agent to come into her building.


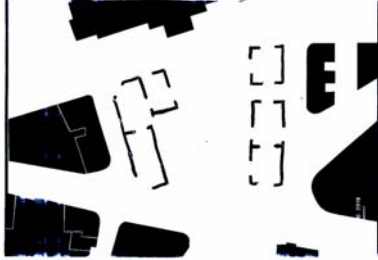
<p>Figure 21. Subject1 Sketch in physical</p>	<p>Figure 22. Subject2 Sketch in physical</p>	<p>Figure 23. Subject3 Sketch in physical</p>	<p>Figure 24. Subject4 Sketch in physical</p>

In the physical sketch, though there is a little change of design from the system. All subjects use the same concept. They spent a little time to finish their task and no change while they were sketching.

## 6.2 First normal sketch, Group II

Subject 5, 6, 7, 8 did the task in physical sketch before using system. Subject 5 is a Ph.D. student in history and theory of architecture. She is a lecturer and also has experience in professional practice for one year. Subject 6 is a student in MSc Lighting Design. Subject 7 is a student in urban design but has experienced in architecture for three years. Subject 8 is student in MSc Virtual Environments.

	
<p>Figure 25. Subject 5 sketch in physical</p>	<p>Figure 26. Subject 5 sketch in Eva agent table</p>
	
<p>Figure 27. Subject 6 sketch in physical</p>	<p>Figure 28. Subject 6 sketch in Eva agent table</p>
	
<p>Figure 29. Subject 7 sketch in physical</p>	<p>Figure 30. Subject 7 sketch in Eva agent table</p>

	
Figure 31. Subject 8 sketch in physical	Figure 32. Subject 8 sketch in Eva agent table

From the physical sketch, subject 5 connected three points by drawing the line to link three points. This link became the circulation and the shape of building. In the system, she stopped to see the movement of the agent first. Then she figured out three spaces and divided the space for each function later.

Subject 6 also drew the arrow to predict the possible ways that pedestrians might use. Then she took that prediction to define the approach, sequence and orientation of each building.

Similar to subject 5, subject 7 drew the line to link the points and predicted the path of pedestrians between three stations. Then she drew the shape of building. Although she intended to group buildings under one roof, she separated each building by circulation to divide the space into three areas and added details by drawing furniture layout in each space. In EVA agent interaction table, she drew the same design as the physical sketch.

Subject 8 defined shape from the site and emphasized the axis at the main entrance of the existing building. He grouped the buildings to have outdoor courtyard space. He claimed that his opening and access to building related to the three stations.

From the sketch with agent, even though the design of subject 5 was changed from the physical, the main reason was not the movement of agents. Subject5 explained that she changed from the physical sketch because she wanted a variety of design. She also looked the direction of agents but it had little effect on her design. As she does not believe that agent will create an overall pattern like the real world, she did not pay much attention to the agents. Agents in her opinion were not useful at all and it quite disturbed her thinking.

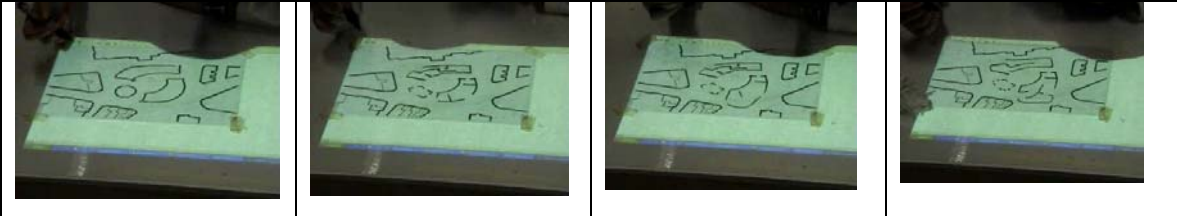


Figure 33 subject 6 sketch in Eva agent table

Subject6 drew the shape which was similar but not exactly the same as her design in physical sketch. She completed the configuration of three buildings then she observed the movement of agents to decide the access for the entrance of each building. Due to the reflection-on-action by the agent, she spent a lot of time in design. She frequently stopped to evaluate the agents' movement then explored the shape of buildings and articulated space for each function at the same time. It can be seen that she enjoyed her exploration testing the shape and entrance to see how it affected the movement of agents. When she was satisfied with the result, she stopped testing. She described that the design seems to have a relationship between space and flow more than the design in the normal sketch. Space is not articulated only in room but interlocked to each other. Furthermore interaction with agents gave her an unexpected result.

Though subject 7 said that the agents seemed to be wandering around and not responding to the design, she still thinks that agents are useful to visualize pedestrian flow. However she did not pay much attention to the movement of agents during design. As she did not reflect on agent simulation, she spent little time to finish the design which was exactly the same as the physical sketch. The problem might come from her attitude because she claimed that although this system seems to be interesting, it still cannot design in 3D. A 3D appearance of space will affect the design more than just 2D.

Subject8 started the same design as a physical sketch. Then he changed the composition and the entrance of buildings to attract agents. Agent triggered his reflection-on-action two times. First he changed the layout of building by moving the building2 and aligning it into straight line with building3 [Figure 19]. Then he extended the building on the left as a cantilever to attract the agents. He satisfied the result and concept that make agents pass through his building into the courtyard.



	Group I (System sketch First)				Group II (Physical sketch First)			
	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8
<b>Background / experience</b>	Architect (Urban planning)/ 1 year	Architect/ 19 years	Architect (March student)/ 1 year	Interior/ 2 years in architect firm	Architect & History theory/ 1 year	Architect (MSc Lighting design)/ 0 year	Architect (Urban design student)/ 3 years	Architect (VE)/ Lecturer
<b>Entertainment</b>	Enjoyable	Very enjoyable	Enjoyable	Very enjoyable	Normal	Enjoyable / Challenging	A little enjoyable	Enjoyable
<b>Interfering while thinking</b>	No	No, influence	No/ But feel frustrated because agents seem to be random	No	Yes, Not useful	No, enjoyable to explore the result	No (but did not pay attention much in agents)	No
<b>Difficult to use of system</b>	Normal	Easy	Difficult “Is it behave like real”	Normal	Difficult “Not understand agents”	Very easy	Normal	Very easy
<b>Agents affect to the design</b>	Yes (Double check my design)	A little , The site is more influence	Yes, if it is real map of people, Guideline Circulation	Yes	No, agents seem to be random	Yes	A little (agent appearance should be 3D)	Yes

Table2. Show overall result

	Group I (System sketch First)				Group II (Physical sketch First)			
	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8
<b>Concept and strategy changing between physical and agents</b>	Yes	No / Change design a little	Yes/ Location of function and main entrance	Yes	No	No	No	Yes
<b>Preferable Result of Design</b>	Both	System	System	System	Both	System	System	System
<b>Design by intention or interaction with agents</b>	Both	Both	Both	Both	Intention	Both	Intention	Both
<b>Factors in system that affect design</b> (from less to the most affect 1-5)	- Sketch interface (5) - 2D path analysis (5)	- 2D path analysis (5) - Image of agent (4)	-Real time interaction agent(5) - 2D path analysis (4)	- Real time interaction agent(4) - 2D path analysis (3)	- 2D path analysis (3)	- Real time interaction agent (5) - 2D path analysis (3)	-2D path analysis (4) - 3D image of agents and space(4)	- Real time interaction agent(4) - 2D path analysis (5)

Table2. Show overall result

### 6.3 Overall result

While testing, 2D path analysis was introduced to all subjects. All of them think that it is very useful because they can see overall picture. However they preferred to interact with the agent more than the 2D path because they think that it is more enjoyable.

	Group I (System sketch First)				Group II (Physical sketch First)			
	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8
<b>Time to sketch in System</b>	6 min	12 min	12 min	8 min	2:30 min	20 min	4 min	7 min
<b>Time to sketch in Physical</b>	2:40 min	1 min	2 min	4 min	6:20 min	9 min	6 min	10:40 min
<b>Number of design change in System</b>	1	6	4	4	0	12	0	2
<b>Number of design change in Physical sketch</b>	0	0	0	0	0	3	0	0

Table3. Compare change in design and time spent between system and physical

Most subjects enjoy while they are interacting with real time agent. They described that they enjoy exploring the result. Therefore their enjoyable is not only come from interaction with agent but it also come from their curious to know the result of their design. In addition, most subjects prefer the result of design from this system. Some of them feel that interaction with agent leads to preferable and unexpected result. This might support creativity in design.

From the experiment, most subjects agreed that agent affect on their design. As agent also talks back to subjects the same as sketch while subjects were sketching in this system. They combined their intention with agent movement into their solution of design.

From table 2, the quantitative data of time spending in the system and number of change in design can be used to confirm the effect of agent. First, agent may give subjects an unexpected or unwanted result so they reflection-in-action and reflection-on-action to evaluate and change their design. Therefore there are six subjects that the numbers of design change in system more than in physical. Second, as the agent motivates the reflection process; this process makes most subjects evaluate and reevaluate their design. They set their exploration, move testing and hypothesis testing in design until they satisfy the result. Therefore most subjects in group II increase to spend time in system though they already think in physical at the first time. In addition, all subjects in groupI spent time in system more than physical.

In brief, there is only one subject felt that agent interfere with her thinking. The problem might be her attitude that agent pedestrian simulation is not useful. It cannot be similar to the real pattern of pedestrian movement. In contrast, other users both in the first group and second group had no problem while designing with agents. They enjoy sketching in this system. Thus it can be concluded that real time interaction agent does not interfere with designers thinking while they are sketching.

## 7. Conclusion

In EVA agent table, the communication medium for designers not only involves the sketch but also agent simulation. Agent movement which communicates with designers can be seen as a catalyst in the reflection process because from the experiment it can cooperate well with intuitive process in reflection. This is significant for their experiment testing. At first, they start from exploration testing to see how their approach affects agent movement. After several experiments conducted, they can then reevaluate their design. Moreover, they test hypothesis to find out why the agent does not move in the way that they want. Hence, they start move testing experiment and adjust their design until they obtain satisfactory result both from the spatial configuration and the movement of the agent. During this process, the agent may enhance creative thinking while designers move their frame to find a preferable and unpredictable or surprising solution. Furthermore, participants enjoy the exploration. As they claimed that 2D path is very useful, but most of them still prefer to interact with the agent movement. The reason is because it enables them to explore and test their idea so they feel enjoy like playing a game: To win and succeed in their experiment or to lose and try again. Enjoyment is not only derived from interaction with agents but also from their curiosity to know the result of their setting frame. Therefore, it can be concluded that agents do not interfere with designers' thinking. In contrast, it enables the reflection process which is necessary to serve the designer in experimentation in order to find the solution for the design. In addition, the agent as feedback information does not interfere with thinking, thus, it can be added in sketch to enrich the design process.

## **8. Future Development**

The EVA agent table is motivated by integrating feedback information on agents pedestrian simulation in the sketch thinking process. It opens up a new possibility to add feedback information to interact with designers in the early stage of the design process which is sketch. Although this system works quite well, it is still in the infancy stage of development. From the users test in the experiment, this system should be technically improved and adjusted to the nature of a designers' sketch method. The following are the issues which can be considered for improvement.

### **8.1 Interface**

This project tried to use a simple and inexpensive interface; web cam, pen and paper or transparent plastic sheet. Users can interact with agents by using the physical interface but they still have to choose a menu in the program by using mouse. In the future, if shape recognition is added to the system, users can choose a menu from the program by physical interface. For example, using a black object to the position of the menu will act the same as a click mouse on that menu.

### **8.2 2D path analysis**

From the tests, users enjoyed interacting with agents but most users find that 2D path analysis is more helpful. They analysed overall contexts better by seeing 2D path analysis. However agents move slowly when showed with 2D path analysis. In addition web cam will capture the 2D path and the agent will detect 2D path as a configuration. Therefore the solution is to add an alternative for interaction with 2D path analysis, for instance while users are sketching, 2D path is generated and changed according to the users' sketch.

### 8.3 Agents

Some users feel that the agents pedestrian model brings the site to life. Nevertheless there is only pedestrian simulation in this system. To combine with other type of agents could make the site more life like. Many types of information in the real world are able to be simulated by using agents. Agents can represent the wind and traffic simulation. These types of agents will be added in this system for future research.

### 8.4 Convert Raster to Vector

Even though this system is able to save file, it is unable to save in vector file. Vector file, such as .dxf, will be useful for designers to develop design further in CAD. At present many software programs are designed to convert raster image to vector for instance Algotlab R2V, Vextractor and R2V but it will be more convenient to combine the method of changing picture file to vector file in this system. I suggest to use the Hough transform algorithm which is a technique to isolate features of particular shape within an image. However, this method is still not enough to convert a sketch plan in a meaningful way as in reality, there are always noises in image file. Therefore, it also needs graphic recognition to refine shape to be as designers' want. (more detail on Architectural floor plan analysis in Lladós *et al.*, [2000] )

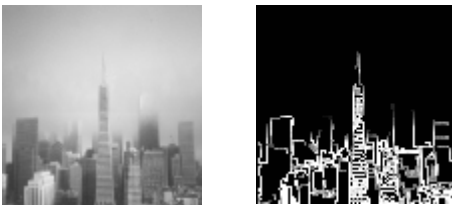


Figure 30. Image Noise Problem

### 8.5 Layer

Designers usually uses text labels to make notes in their sketch. This cannot be used in this system because agents will detect text as a configuration and this will affect agents' movement. There are still many symbols which designers want to use in this system such as steps, water and tree. Although they can use a colour pen with a low intensity for agents not to detect, it will break down the flow of thinking very much and it

is not comfortable. If the system has another layer where agents will not detect these element, designers will find it convenient to use these symbol.

### **8.6 3D visualization**

Some users prefer to look at the context and sketch in three dimensions. From this program, there is possibility to generate three dimension objects both in configuration and agents which can be done in openGL performer.



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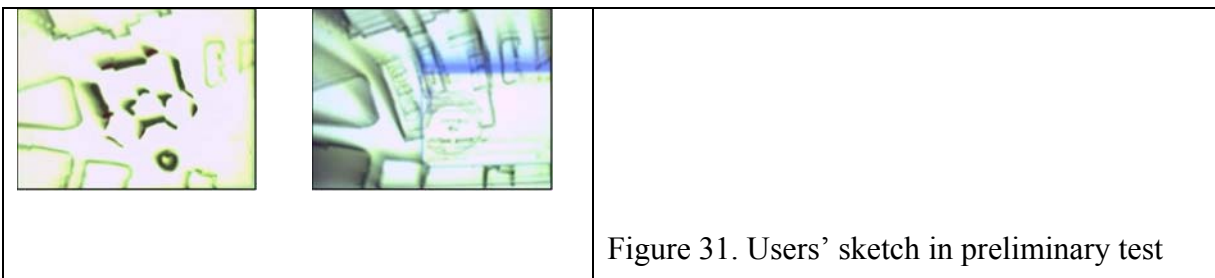
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## Appendix A

### Preliminary test

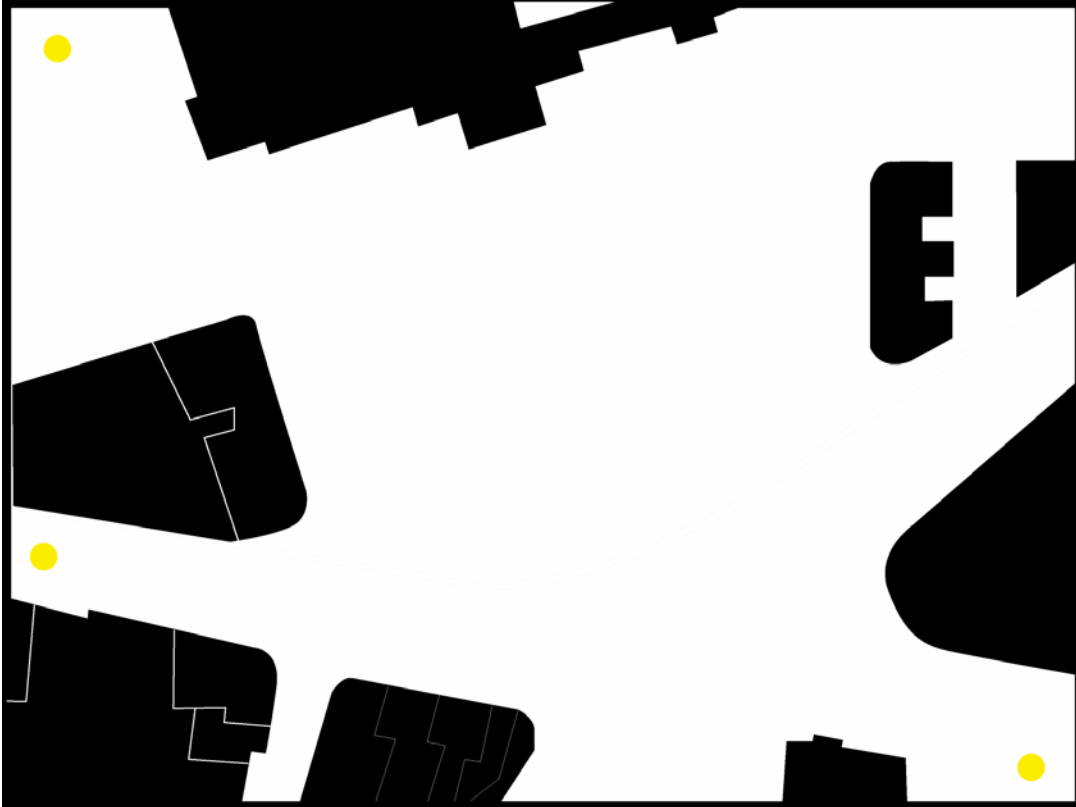
Two subjects were tested in this process to check that the system could work well. These two users come from different backgrounds. One is an architect and another is an interior designer. Both of them have experience in professional work for three years. The experiment task was provided to the users. The task requirement was to design an outdoor plaza which has exhibition space, sculpture and an outdoor rest area. They started to design by the physical sketch then they designed while interacting with real time agents. Both used the same strategy when they designed with real time agents. They started with the sketch that they drew in physical and then changed and adopt the configuration for entrance. The problem that they mentioned in this task was on other symbols which are not configuration such as trees, waterscape and steps. In addition, there was a technical problem which needs to be solved. Agents did not detect lines in some area. They walked through the configuration. This problem was assumed to come from the reflection of material and colour intensity parameters which agents used to detect bitmap.

Form the results, they enjoyed using this system and were satisfied with the result of the design using real time interaction agents. Agents helped them to facilitate adapting their design. They claimed that agents did not interfere while they were sketching. However both of them already thought and sketched in the physical. The next experiment would be tested by switching some of users to first sketch in real time interaction agent.



## Appendix B

### Experiment tasks



#### Task:

The group of buildings around this plaza is an art museum. There are three points, spotted in yellow, where people come in and out like the flow in a tube station.

The requirements are to specify the new buildings in this area and also arrange the rest of the space to be an outdoor plaza.

There will be three new buildings to be oriented in this area. The first building must have three main spaces to set up sculptures, open a bookshop and a space for photo exhibition.

The second building has a space divided into 2 parts, one part provides to set up a modern art exhibition and another part to open a souvenir shop. The last building will be a café.

1. Physical sketch; design a suitable configuration for these new buildings and outdoor plaza.
2. Designs a suitable configuration by interact with agent pedestrian model.