

# Preferred Interaction, Don't Leave Home without It!

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## *Abstract*

*In this paper we restructure the idea of ubiquity, seamless and seamful design into a single collaborative framework. We briefly explore the notions of seamlessness, seamfulness and invisibility in connection to the design of ubiquitous system. Additionally, we also briefly explore the connection of the activity theory to the above notions when we deal with user interaction. This leads to the taxonomy for evaluation of the ubiquitous computing system. One of the purposes of the taxonomy is to clarify the map of notions invisibility, seamless, and seamful. Additionally, the taxonomy shows that one alternative support to the seamfulness is to have the ubiquity in the interaction modal so the user have a degree of independent to have their preferred interaction. This idea is the motivation of the development of the ubiquitous tabletop augmented reality interaction kit in institute FAW. The experimentation on the idea implementation is illustrated.*

## **1. Introduction**

Ubiquitous computing is concerned with shifting the ratio of users to computers from many-to-one, through one-to-one, to one-to-many [1]. Ubiquity involves multiple, heterogeneous devices providing highly dispersed input, output and computational capability. One of the most influenced viewpoints for ubiquitous computing is the notion of *invisibility* from Mark Weiser[2]. Mark Weiser stated that a good tool is an invisible tool. By invisible, it means that the tool does not intrude on our consciousness; the user focus on the task, not the tool.

Furthermore, Mark Weiser gives an example for the invisible device in the form of electric motors. It is described that the early adaptations of electric motors are bulky and apparent. However, along with time the adaptations of electric motors technology are becoming more invisible. We, the user of the device that uses motors, are no longer aware of the existence of motors even though it is abundantly used e.g. from dozens of electric motors as parts of the car into a vibrator motor in our cell-phone. In interaction sense, we do not even need to realize that they are exists.

Later as described, for example, by Matthew Chalmers et al. in [3], the notion of invisibility has been translated into requirements for seamless integration of computer system components, human computer interaction or the physical and digital domains in which interaction occur. For example, invisibility is translated by IEEE Pervasive Computing as a seamless combination in the environment that is saturated with the computing devices and yet gracefully integrated with human users. IBM Pervasive Computing translates invisibility as the degree of seamlessness and integration that collaboration between computing devices should be.

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Despite that seamlessness is an attractive quality of the design, it is considered by Weiser in [1, 4] as misleading or misguided concept. He emphasizes that the importance of seamfulness: “making everything the same is easy; letting everything be itself with other thing is hard”. Weiser sees seamlessness can only be achieved, at least in practice, by reducing functionally the devices into their *lowest common denominator*. It is sacrificing the richness of each tool in order to solve compatibility issues. Moreover, the problem is not just come from integration of various devices but also on how we see the hierarchy of the device. When one tool is decided as the primary device, the other are reduced and simplified so that it conform it. [3]

Weiser suggest the device should sense, models and let the user take advantage of the context of other things, such as nearby objects or people in their environment. Furthermore, Chalmer et al. in [3] further suggest that letting an ubicomp system be itself means accepting its entire physical and computational characteristic – that maybe either weaknesses or strengths. A user’s activity is influenced by what they perceive and understand of sensors, transducers and other I/O devices, as well as system’s internal models and infrastructure.

In the same spirit of reconciliation between seamlessness and seamfulness in respect to invisibility, in this paper we propose taxonomy to evaluate ubiquitous computing system. We mention concept of activity theory to show that the Weiser’s concern for invisibility and later the emphasis on *seam* quality is in fact already the concern of human interaction design for the first place. In the next section the taxonomy is described. Moreover, the idea of ubiquity for interaction modal is also indicated. The following section describes the preliminary development of the device that supports the concept of ubiquity of interaction model. The last section of the paper concludes the contribution and discusses the future works.

## **2. Seamlessness and Seamfulness in Ubiquitous Computing System**

### **2.1 Activity Theory**

For the purpose of this work, activity theory can be seen as a framework for analyzing human activity for the purpose of designing an artifact. In the past years, it has been used in human computer interaction design to overcome the problems with the use of theories that based on cognitive science [5].

Activity theory is a powerful descriptive tool that provides concepts and a vocabulary for describing human activity. An activity is the basic unit of human behaviour that can be analysed with a meaningful context. It is the fundamental building block of human behaviour. The purpose of carrying out an activity is to turn an objective into an outcome. Within each activity that is carried out, there are six components i.e. subject, the tools, the objective, the community, the rules, and the division of labour (cf. Figure 1). All of these components are entangled to each other to create the whole context of human activity. Quek et al. in [6] describes the activity theory as in the following paragraphs.

The subject carries out an activity using tools to achieve an objective, thereby turning the objective into an outcome (see fig. 1(a)). Therefore, the relationship between the subject and the objective of an activity is said to be mediated by the tools. The subject can be either an individual or a group of people. Tools can be physical, such as a hammer, pen, or saw. They can also be psychological, such as language or mathematics. The objective can be a material thing, such as a physical product, or it could be intangible, such as an idea.

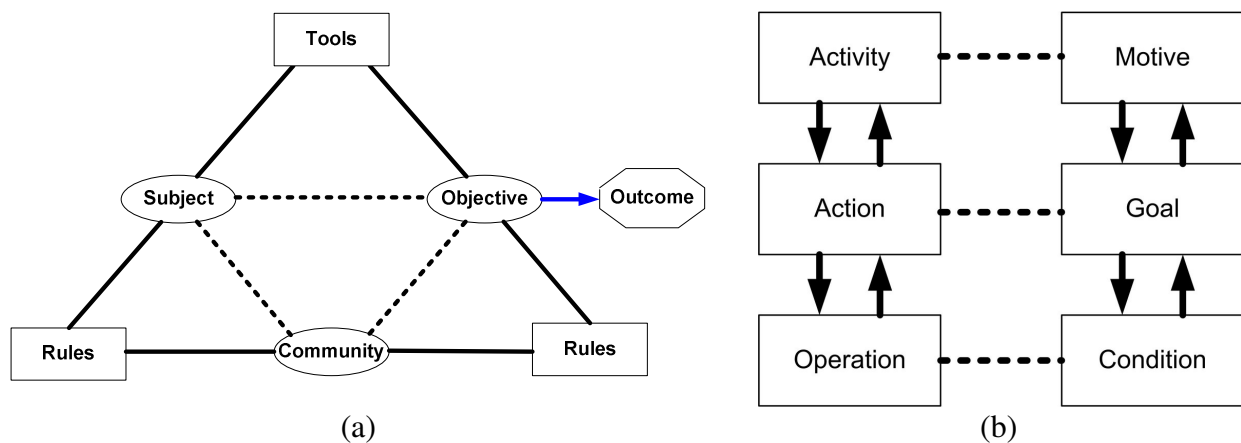


Figure 1 Activity theory diagram; (a) an activity; (b) an activity hierarchy.

The community encompasses all the subjects who share the same objective. The relationship between the subject and the objective is mediated also by the community. Rules govern the subject's actions and behaviour within the community. The relationship between the subject and the community is mediated by the rules. Finally, we have the division of labour, which the community uses to achieve the objective. The division of labour refers to the way work is divided between the members of the community, both vertically (between management and workers) and horizontally (between colleagues of the same rank) in an organization. The relationship between the community and the objective is mediated by the division of labour.

In connection to invisibility, there is important aspect of activity theory that is interesting to discuss here. According to Kaptelinin in [7], activity theory consists of five basic principles that form a conceptual system. The five principles are objective-orientedness, internalization/externalization, tool mediation, hierarchical structure of activity, and development.

Every activity is different and activities can be distinguished from each other according to their different objectives. The objective of the activity is what gives it direction. This is what is meant by an activity being 'objective-oriented'. No activity can exist without a motive. To describe activity in more fine resolution, the theory represents activity in hierarchical manner. There are three hierarchical levels of an activity (see fig. 1(b)). An activity is composed of actions, and an action is composed of operations. Each level of hierarchy has a corresponding *raison d'être*. An activity has a specific motive, an action has a specific goal to reach and operation has a specific condition to fulfill. The different between those three is in the level of consciousness the activity is conducted. Quek et al. in [6] gives an example the activity to search for a particular piece of information on a website. One of the actions could be the need to 'search for the website', and 'go to the topic of interest'. Further the action 'to search for the website' can be implemented into operations with a specific condition to fulfill such as such as operations to 'type our search term into a search engine', and 'click 'search''.

Activity theory differentiates between external and internal activities. An internal activity is that which is performed in the mind. This is normally done to try potential interactions with reality without manipulating real things. Examples are such as mental calculation, mental simulations, thinking through alternative plans etc. External activities are those that are performed outside the mind, such as sketching diagrams, and those that involve physical objects. We cannot analyze

internal activities separately from external ones, because they transform into each other. Internalization is the process of transforming external activities into internal ones. We are only able to internalise knowledge through performing an activity externally, i.e. we learn by doing. We then can use this knowledge to help us to make decisions mentally without having to manipulate real objects. Internalization allows us to mentally consider the outcomes of different actions before we decide which to choose. Externalization is the process of internal activities transforming into external ones. This happens when we have a prediction of the result that we should achieve, and we go on to interact externally with the real thing according to what we have planned internally

One of the central ideas behind activity theory is that every activity uses tools to achieve its objective. Tools can be physical or psychological. Physical tools can be anything from a pen and paper to a hammer and nail. Psychological tools are created by society, and are directed towards the control of behaviour. These are such as language and mathematics. Psychological tools alter the flow and structure of mental functions, just as physical tools alter the way our work processes evolve. Mediation is not a process of one direction i.e. subject use tools to achieve its objectives through externalization. But it also means that the tools will eventually affect the subject by having internalization. Our behaviour is restricted to what the tool will allow us to do with it. Hence, we see the world as the tools permit us to see.

It is obvious that all tools carry with them a historical background. The collected experience and skill that was involved to develop them that forms a history of development are integral parts of a tool. Tools are integral and inseparable parts of human activity, and we need to understand how they have developed in order to fully grasp how a subject uses them to achieve their objective.

## **2.2 The Invisibility Redefinition**

Weiser in [8] describes invisibility as the state when the conscious act of using the tools or technologies are not required to perform a specific activity: “Such disappearance is a fundamental consequence not of technology, but of human psychology. Whenever people learn something sufficiently well, they cease to be aware of it. When you look at the street sign, for example, you absorb its information without consciously performing act of reading.”

According to activity theory, the disappearance could come from several ways. It could come from the same process that Weiser has mentioned above i.e. the shift of a specific activity level in activity hierarchy, e.g. from activity to action to operation, which is a part of maturity level on internalization/externalization process of the user. This leads to notions of the degree of user experience in such activity i.e. a novice, an intermediary or an expert. The same system can be seen by different people as a system with different invisibility achievement. Having the same street sign for people from different countries can lead to a different conclusion, action or even action-less.

Another possibility of the disappearance is an evolutionary nature of the tool's development process. A tool development with smooth stages over time will create a disappearance illusion. Nobody even realize how smooth the transition between punch card input device to a keyboard, since keyboard has already being used for a long time. A desktop computer is smoothly adapted as a new breed of electronic typewriter decades after the electronic typewriter was introduced to replace a mechanical typewriter. When we use a desktop computer today as a word processor, it is basically can be used exactly the same as the typewriter.

Another example is the car multimedia system. A transition from analog, audio only, mono system to fully digital, multimedia system is so smooth in such a way that when we compare the interface for car multimedia systems in the last decades to the newest one, the paradigm is still the same.

It is understandable that Weiser describes seamless as a misleading concept. Unfortunately, despite it triggers new breed of application that is based on the ubiquity of computing power, the introduction of seamful as a term that more closely describe invisibility is also in fact lead to another “misleading” endeavor. Some of the work rigidly consider seamless as a bad thing and looking just for the seamful quality so it ends up to the tools that look like a computer, act like a computer and do what computer do, which is a computer; the notion that Weiser want to avoid by introducing invisibility.

We should separate the notion of seamless and seamful from the ultimate goal of ubicomp system invisibility to get a better understanding on the structure of the problem when dealing with ubicomp system design. The understanding of the source of invisibility is crucial since it can not be separated from the context of time and human activity. The invisibility that Weiser has indicated is not directly related to the notion of seamless or seamful in itself, but in the relation to the evaluation of the role of the device in the context of human activity that the device support. And that means with the history of the device as well.

### **2.3 Ubiquitous Computing System Evaluation**

Having a computer to be developed as a ubicomp system, when designing the system we can divide the system into three layers subsystem i.e. networked data communication subsystem, presentation subsystem, application subsystem (cf. Figure 2). The network data communication subsystem deals with the problem networking as in seven layers of OSI model of networking with additional specific ubiquity problems such as the support for mobility, adaptability to various computing environment, capability and devices. The ideal nature of this layer is the ability for any computing devices to be able to introduced to or leave the environment, coexist with other device and collaborate with one another in as seamless as possible. The seamless nature can be seen from various points of view such as seamless against the variation of physical transport medium, transport protocol etc.

The presentation subsystem deals with the problem of the paradigm of presenting the data to the user. Intangible presentation paradigm is the presentation concept on how logically the data is presented to the user in the form of user metaphor, layout etc. The tangible presentation paradigm is the presentation concept on how the logical presentation manifest in the real world. Much works has been done to shows that the computing device can morph into any shape in the real physical world.

Logically, it is desirable to have a consistent representation of data between both paradigms. The intangible presentation requirements tend to promote seamless properties. It is required for seamless working over various computing devices between possible presentation paradigms. The use of xml schema, 2D GUI concept can be seen as examples of the resulted technologies. However, the tangible part of presentation is obviously having a different agenda. The manifestation of the data is specific to the device capability. This trait can be exploited to represent the device as a device itself, a seamfulness property.

The application layer deals with the problem of the way the application treat the data gathered from the network, the other two subsystems and other special devices (e.g. GPS, sensors etc.). Obviously,

the way the application treat the data is also application specific. Moreover, it is also depends on the capability of the computing device and user preference. The application can choose (or is forced) to manipulate, filter or even ignore the data as the application intended, even when the available data is abundant. The computing device that only has a LED as output device can only indicate a binary data. For example, the USB storage embedded in a mug similar to the MediaCup ([9]) can use a LED that indicates whether there is a new data saved for the last 10 minutes. In respect to the available data, the application can be seen as seamful when it can give a choice to the user to get the data that the user want to be showed. If the application forces the user to only get a specific data, then it is considered to be seamless.

Hence, we propose that the meaning of seamless and seamful are depends on the context. The context will also decide which one is the requirement and which one is liability.

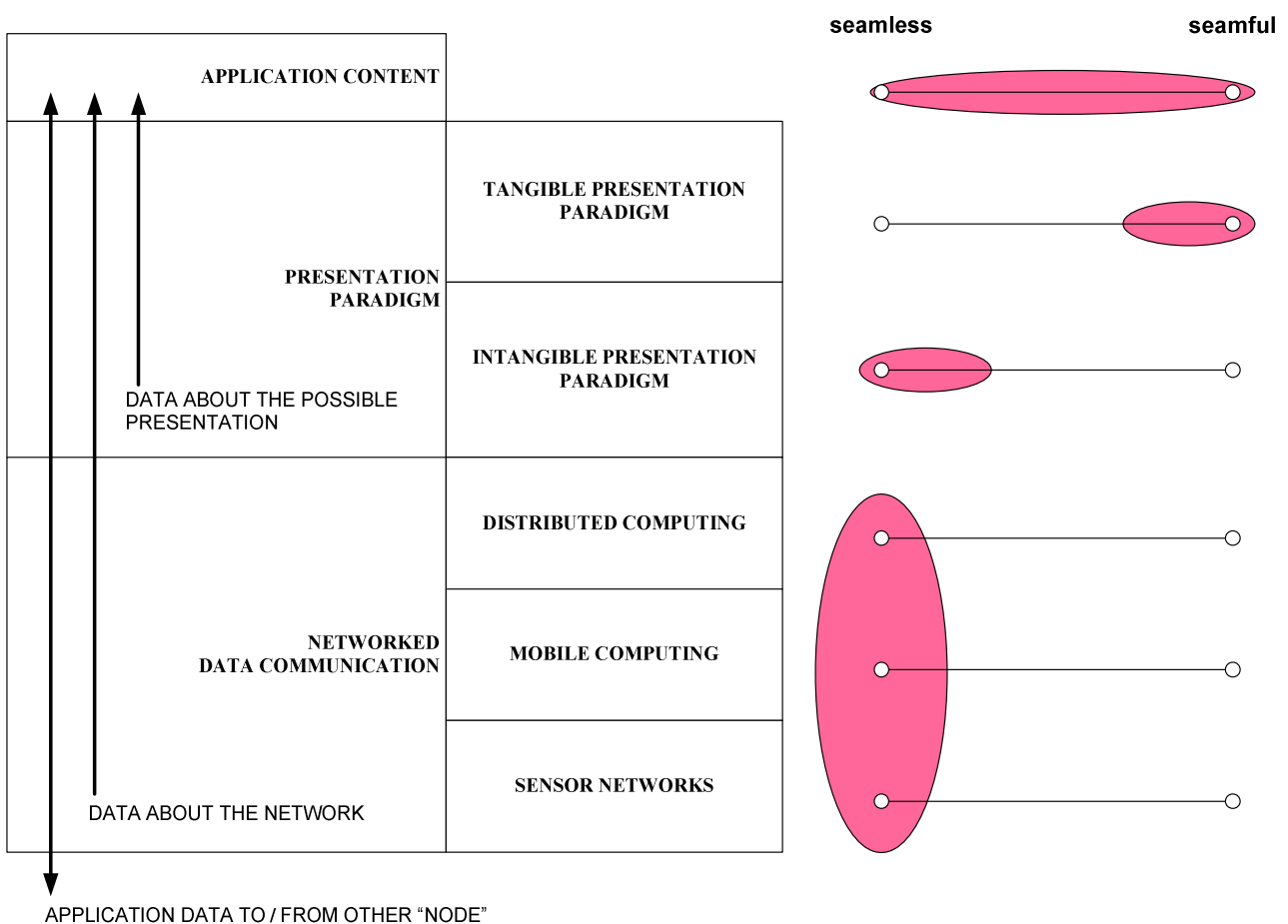


Figure 2 Evaluation criteria of Ubicomp System. Shades region shows the typical desirable result.

### 3. Design Study: Ubiquitous Tabletop Augmented Reality Interaction Kit

In the previous section, we have defined the invisibility to be a separate notion to the seamlessness and seamfulness. One of the possible ways to support invisibility on the application layer is by having a seamful tangible presentation. Having seamful tangible presentation means that the user can choose the way and what data is presented without any time and spatial constraints.

The idea is quite simple; having numerous computing devices around, we can access all the information of all devices from the preference device and the preference interaction modal, an interaction computer. The use of interaction computer does not mean that the computer is used only to support the interaction rather than it has the capability to support tabletop AR interaction concept. This is the basic idea of the Ubiquitous Tabletop Augmented Reality Interaction Kit.

The goal of the device is by utilizing the advance of ubiquitous computing, projector technology and computer vision, the tabletop augmented reality interaction that usually need to be setup in special environment can be made ubiquitous so that the user can use the preferred interaction almost anywhere and anytime.

Schmidt et al. in [10] describes the idea to use our everyday environments as interface to computer-based services to be an intriguing vision toward more accessible and inclusive user interfaces. The principal idea is to augment common structures and everyday artifacts as interaction devices that inherit design affordances from the physical world for interaction with the digital realm. The key motivation is to yield interfaces that are experienced as familiar, natural and fitting in our environments, to the extent that they become peripheral to everyday activity.

Tables provide a convenient environment for the people to meet, discuss, look over prepared documents, and to present ideas that require face-to-face collaboration. It is a traditional place to work which can be seamlessly changed from individual workspace context to collaborative workspace context. It is a natural and intuitive device for collaborative as well as individual work. However, when we work with digital data, by mean of computer, it is designed and commonly used in single user desktop environments and handheld devices.

Tabletop augmented reality (AR) applications with multiple cameras and projector systems are becoming more and more popular. The current generation of projectors allows a fast combination of multiple projectors that can be used simultaneously. Molyneaux and Kortuem demonstrate in [11], how the future environment can be more accommodative to the ubiquitous display paradigm rather than conventional collection of displays.

### 3.1 Challenge

Schmidt et al. in [10] describe four points that are particularly critical for a successful implementation of a ubiquitous pointing device i.e.:

*Preserving the Original Functionality of the Surface.* When adding functionality to objects of everyday life it is important that the original functionality of the artefact is not sacrificed. In the case of a table – augmenting the coffee table with a pointing functionality should not enforce a different way of using the table while it is used in its usual way. Even when it is used for pointing it should still be usable for its original purpose. In other words pointing should be still feasible when the table is occupied with objects. We add mobility requirement that the system should have a capability to utilize any reasonable flat surface for interaction.

*Many Surfaces – one Pointing Device.* It is obvious that an interface that is ubiquitous can not be bound to a specific place or artefact. In an ideal case, interaction is possible from everywhere without switching interfaces. In the case of surfaces the challenge is to realize a seamless transition from surface to surface when interacting. The anticipated implementation would allow the user to use any surface – that is convenient at this moment in time – to be used as a pointing device.

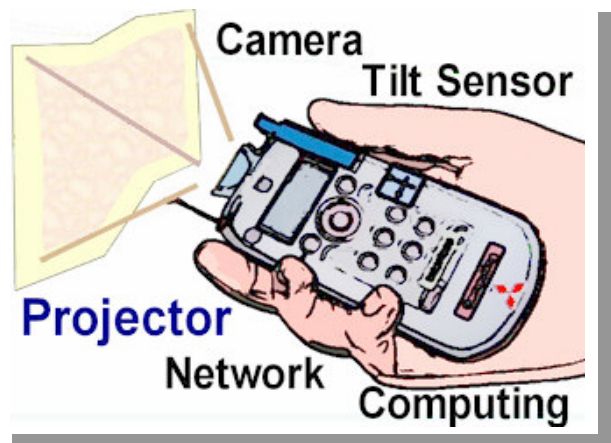
*Unobtrusive Realization.* Building an ubiquitous interface should not make the table look like a computer. The appearance of artefacts is often one of their main properties. Especially in personal environments furniture and artefacts are an essential part of the interior of a home. Introducing the technology should no require a change in the appearance of a table or shelf. The interface should be a part of an invisible computer – because the interface is often what people perceive as their computer.

*Robust and Reliable Implementation.* When including sensing capabilities into surfaces it has to be done in a robust and reliable way. The different ways in which surfaces are being used have to be taken into account, e.g. it has to be anticipated that people may sit on a table. Especially when considering home environments reliability and zero maintenance becomes a crucial issue. When designing a solution one should be aware that calibration and maintenance are hindering the deployment of such technologies.

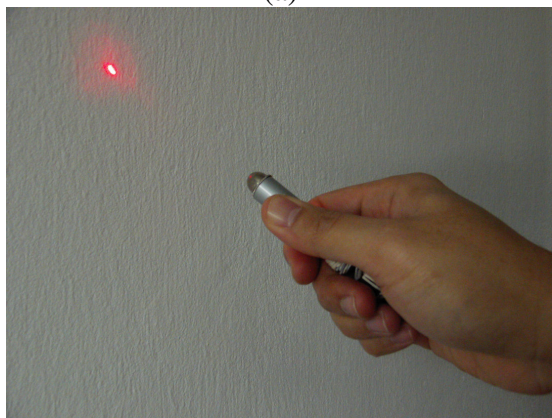
In order to implement the idea, we need to take the advantages of the advance of various technologies in recent years (cf. Figure 3). It is obvious the ubiquity of computing power is the enabling key for the advance of all technologies nowadays. The ubiquitous display technology that brings the possibility to use any surface as a display with the mobility feature boosts up the feasibility of the idea. Another important consideration is the user interaction technology that also has to support the mobility feature without giving up the possible attained quality.



(a)



(b)



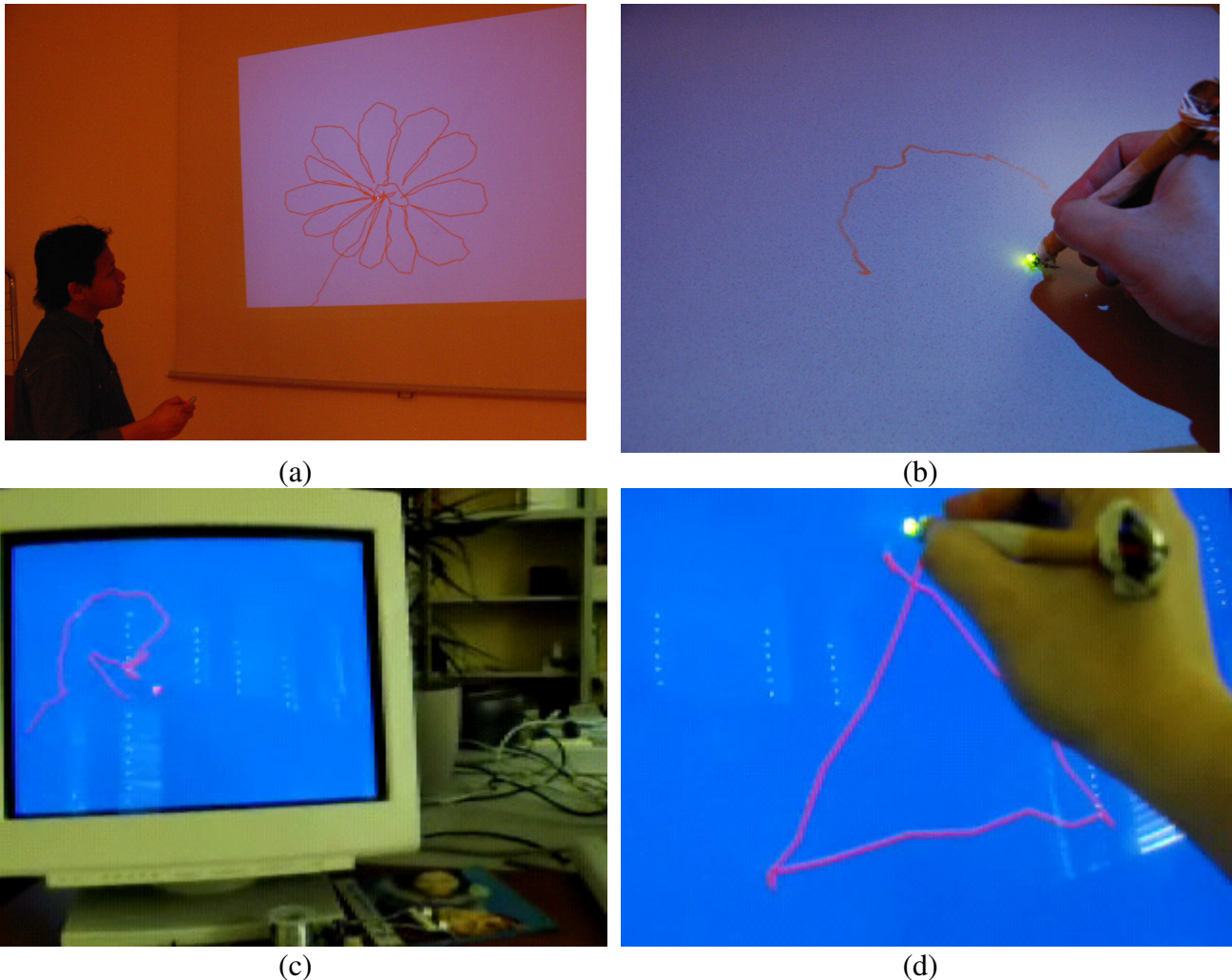
(c)



(d)

**Figure 3 Basic technologies for the ubiquitous interaction concept; (a)-(b) handheld projector technology [12]; (c)-(d) visual based interaction device technology e.g. laser pointer, LightPen.**

The tabletop augmented reality (AR) application setup is typically bulky and needs constant maintenance. Although, the standard projectors are much better than the projectors years ago, but still it can be considered bulky and cumbersome for mobility requirement. Raskar in [12] shows the use of handheld projector based on the new LED technology for many applications (cf. Figure 3(a)-(b)).



**Figure 4 Experiment using the prototype of ubiquitous tabletop interaction; (a) on the wall using laser pointer; (b) on top of the table using LightPen; (c) on the surface of the monitor using laser pointer; (d) on the surface of the monitor using LightPen**

Despite its prospective, computer vision technology only recently attracts researcher to be a technology that can be a part of AR system. Nobody has any doubt on the potential of the technology. Unfortunately, it is usually rendered unexplored due to several critical points i.e. the availability of a robust algorithm to interpret information from images and the scalability problem. The traditional pin-hole mathematical model for camera representation, as a baseline for camera calibration, uses many assumptions that limit its applicability. Moreover, the implication of using such a model leads to techniques which suffer from the assumption and the implied problem structure induced by the model. The reason behind the inadequacy of the traditional mathematical model for camera representation is not only in performance side such as resolution, speed and accuracy but also more systemic in nature e.g. the trend to use a highly distorted fish-eye lens camera to get wider view angle and the use of non-standard planar surface for interaction to create

different user experience. We have developed algorithms to overcome those problems so we can use the vision technology in tabletop AR application in more ubiquitous manner. Hence, when we integrate it with the hand held projectors from Raskar et al., we will have a really ubiquitous interaction in our hand. The user of the device can utilize the preferred interaction modal almost anytime and anywhere.

Since we do not have any access to the handheld projectors, we have built our prototype using standard projectors. At this stage the prototype is working well in planar or non-planar surfaces such as the wall, table surfaces, in the widely available monitor screens or even any surface that is considered highly non-planar. The setup time is typically around 5 minutes, so the user really can use it in mobile. Moreover, we also have developed a collaborative framework for the device so it can be used in collaborative manner. Figure 4 illustrates the experimentation results.

## 5. Conclusion & Future Works

We have discussed the taxonomy that shows the relationship between seamless, seamful and invisibility of ubiquitous computing system. The analysis of the taxonomy gives an idea of the ubiquitous interaction device that makes the user can always use its preferred interaction modal without any spatial constraints. The preliminary implementation of the device has been illustrated.

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