Design of Attractive Virtual Spaces for E-Learning

Yuki Sogabe, Marion R Finley, Jr., Member, IEEE,

Abstract-- The work in progress described in this paper extends previous work on the construction and testing of virtual communications spaces for use in creating attractive Internet/Web-based environments for e-learning. The spaces created, or, more precisely, the underlying Internet/Web-based systems that support these spaces, are related to human factors via utility. Once again, the M\textsuperscript{COTS} ("mass-market components off-the-shelf") approach is favoured, that is, standard, easily available, off-the-shelf equipment is used for the experimental tests. The fundamental objective of the previous work: remains, namely: to build e-learning environments that are “attractive” to students and that will assist in the recruiting and maintaining of new student clientele. Initial formal definitions of the concepts of virtual (communications) spaces and “attractiveness” are given.

Index Terms-- e-learning, M\textsuperscript{COTS}, human factors, utility, virtual communications spaces.

I. INTRODUCTION

A. Virtual Spaces and Human Factors

In spite of the title of this paper, the subject matter treated is one of fundamental importance in telecommunications, touching on basic networking infrastructure as well as advanced, user friendly, multimedia communications systems. In this paper, the authors pursue work that was reported last year on the construction and testing of virtual communications spaces for use in creating attractive Internet/Web-based environments for e-learning [12]. In the work in progress described here, they wish to relate the spaces created, or, more precisely, the underlying Internet/Web-based systems that support these spaces, to human factors, eventually through utility functions relating system parameters to such things as willingness-to-pay, (user) satisfaction, and so on, much as was reported in the work of Akimaru et al [1] and in Yamori [18]. Once again, the M\textsuperscript{COTS} (“mass-market components off-the-shelf”) approach [4] is favoured: as much as possible, the authors wish to use standard, easily available, off-the-shelf equipment for their experimental tests. The work reported here builds on the initial encouraging results obtained last year and represents work in progress.

B. Predicting Acceptance of New Telecommunications Products

The underlying intention of the authors’ work is to attack a fundamental vexatious issue plaguing the computer and telecommunications field, namely, how to predict the intended customers’ acceptance of a new telecommunications service or a new computer or telecommunications product. The path towards acceptance of new products or services is strewn with the wreckage of often highly vaunted products that failed miserably and spectacularly on the market. These failures generally were not the unique fault of bad engineering design and implementation, but usually of a deep lack of appreciation of what factors will really attract the intended customers to the product and maintain the customer’s interest. Certainly the reader can call to mind examples of this phenomenon, for example, teletex, various computer products, and others.

By the same token, while attempts to predict the acceptance of carefully planned and executed new services or products have usually failed, some services that appeared at first of little general interest have exploded on the telecommunications scene, much to the great surprise, and often outright disbelief, and many prominent corporations and individuals. The most flagrant example of this phenomenon certainly would be the explosive development of the World Wide Web, and perhaps of the Internet in general, in the early part of the last decade of the twentieth century. One need not remind the reader that one major software corporation and its leader at first failed to appreciate this phenomenon and entered into serious exploitation of this new medium only after seeing a real threat to its very own products.

Clearly the art and science of prediction of the impact of new products and services is a vast one in which the technical and engineering properties of the products or services are subtly and deeply related to human needs, aspirations, perceptions, and limitations, be these financial, psychological or sociological in nature. We have, therefore, the situation in which our sciences and technologies must interact deeply with those sciences and disciplines that deal with the full spectrum of human behaviour. In the authors’ work, attention is limited to the creation of attractive virtual communications spaces (which will be called in this article, simply “attractive virtual spaces”). The keywords, “attractive” and “virtual space” have rather precise and limited meanings that will be given later in this paper. Intuitively, however, they refer to a kind of environment, a specialized cyberspace one might say, created by computers, peripherals, and networks, that appeals to the intended users to the extent that the latter will be attracted to it and be willing to pay for access to it.

C. Fundamental Objective of Current Work

The fundamental objective remains that of the previous work cited above, namely, to build e-learning environments that will prove attractive to students and effectively assist in the recruiting of new student clientele. This would then counteract the current trend in Japan to
decreasing university enrolments [5]. Moreover, in all this, the authors wish to take maximum advantage of the current and emerging telecommunications technologies, in particular, the emerging multimedia wireless and other wireless technologies such as Bluetooth [8].

In this following, the objective cited above is broken down into some basic steps, namely, first of all, that of attempting to develop a formal definition of the concepts of virtual space and of "attractive." Then, these two will be juxtaposed to give an initial definition of "attractive virtual space." Next, the authors develop some initial design procedures for attractive virtual spaces and build some examples. These latter will be subjected to various experimental tests with human subjects. Once again, they will select some university courses and a sample of the student population for these tests. Student reactions will be polled and the results then analyzed. Another step in meeting the above-stated objective, then, is the very art of creating effective questionnaires for these polls. The results of these polls will assist in the derivation of meaningful utility functions that will be used to characterize the level of attractiveness of virtual spaces as functions of key system parameters.

II. “ATTRACTIVE” VIRTUAL SPACES

A. Cyberspace, Virtual Reality, and Virtual Spaces

These terms all refer to related, if not perhaps completely identical concepts. Basically they refer to an artificial environment that is created electronically through the agency of computers, computer networks, specially the Internet and the World-Wide-Web, and various kinds of input, output, and display devices [2][17]. Such artificial environments are "space-like" in that, in some sense, a human being may interact with objects in these environments and move around in them: "places" may be identified in these environments to which the human may move. Hence, in some such environments, the human may move from place to place, that is, "navigate" or "browse" through the environment. There are two extremes for these kinds of environments, namely immersive and non-immersive [2]. In immersive environments, the human user is literally surrounded by the physical objects that form part of the physical infrastructure of the environment. In the non-immersive case, the human user usually observes the environment on a display device such as a conventional computer visual display. In practice, most environments fall between these two extremes. For example, the user may use a visual display plus earphones, camera, and microphone.

The term virtual space has seen many uses and the authors have been influenced by such as Fernandez et al [4] and Jensen [7]. For the moment, a virtual space, \( V \), will be informally characterized as a quadruple consisting of a collection of objects, \( O \), a collection of points, \( P \), a topological space, \( T \), over these points, and a metric, \( m \), over \( T \). \( R \) is a set of protocols relating the objects among themselves. That is,

\[ V = \{ O, P, T, R, m \}. \]

The objects are primitives that will be associated with the points, or collections of points, of the topological space. As examples of points, one might consider such things as URL’s, IP addresses, MAC addresses, etc. Objects may be pieces of equipment, human users, or software constructs. Generally, objects will be defined using a language such as the UML (Unified Modelling Language) [10]. Compound objects will be sets of objects with specified relations between the objects. A topology is essentially a connection diagram relating points and objects to each other. A metric will be some measure over the elements of this connection diagram, for example, the total packet delay between two points. That is, in a virtual space, the concept of distance is related to the passage of time, and not necessarily of geometrical distance. Of course, \( m \) may be a function whose independent variables include time and geometric distance measures.

The dimensionality of a virtual space implies at least the four dimensions of space-time and perhaps other dimensions as well, for examples, dimensions that include human behaviour. This is a complex issue and will not be considered further in this paper.

The specification of a virtual space, \( V \), may be made a various levels of granularity, depending upon the aspects of the space upon which one wishes to concentrate. For present purposes, the emphasis is at a coarse level.

It should be noticed that this characterization of virtual space does not specifically isolate real-world external objects, for example, the human users or physical devices, from objects that are software constructs, for example, avatars or other objects displayed on the user’s screen. Moreover, some objects may span the external real world and the world of software constructs, for example, the blending of some physically displayed object with objects in the physical environment. Rather, what counts is, that, in an object-oriented fashion, every object of the space will be characterized by a set of attributes and behaviours. Therefore, the frontier between what exists in the external real world and what exists solely in the system becomes blurred and now “reality” entails objects and relationships that exist in a man-made system … and in the mind of the user. A virtual space, however, is supported by a multimedia communications system infrastructure as well as by physical objects such as rooms, chairs, etc. While the specification of a virtual space may not explicitly define these objects, yet they can be included at a higher level of granularity. In this work, we shall be interested in the relationships between certain key internal system parameters and some aspects of human behaviour and shall content ourselves with just enough granularity to cover these.
The characterizations given above represent an attempt to give a formal, theoretical framework for the study of virtual spaces. This framework would then permit an exact characterization of the main properties of any specific virtual space, permit a systematic approach to building virtual spaces and perhaps eventually lead to a means for predicting some of the properties of implemented virtual spaces. At this point, the definition is clearly still incomplete, but essentially a virtual space, or more accurately, a virtual communications space, is a kind of topological space whose points are the addresses of users or internal network nodes, and in which subspaces or manifolds will correspond to user communities, that is, aggregates of users, for example, as the members of an Internet-based discussion group. Neighbourhoods, a fundamental topological concept, will correspond to the set of local objects surrounding the user, perhaps those linked by the Bluetooth technology or by a micro-LAN. These spaces may have some continuous aspects, for example, the time axis or other dimensions corresponding to analogue phenomena in the real world and are inherently multidimensional.

B. Human Factors

In industry, the term human factors refers to aspects of human behaviour, both physical and psychological, that relate to particular environments, products, or services. The word ergonomics is used in the same sense. There is the specific implication that human factors may be reduced to measurable quantities. Human factors are used to study the possible acceptance of a new product or service by the targeted users or consumers. The term usability has a similar connotation, even though human factors refer to a larger area of study, including such things as responses that are unrelated to usability, for example, reactions and preferences in relation to visual and other sensory stimuli [15].

In the study of human factors in relation to a new product or service, test groups of volunteers or paid subjects are presented with a set of key questions about the product or service. The questions may be posed verbally or via a polling technique with carefully designed questionnaires. The study of the test group’s responses may lead to a redesign of the product or service. Human factors studies play a crucial role in the development of new products or services and help determine how human beings react to the technical aspects of these products as well as to new types of products and services.

C. Objective Functions, Fitness Functions

For a given system, performance criteria may be specified and a function constructed that relates key system parameters to these criteria. For example, the efficiency of a combustion engine as a function of engine oil pressure and operating temperature, may be related by such a function. This kind of function is called an objective function. It may be known a priori or it may be constructed empirically by experimental tests with the engine. A variant of objective functions are the so-called fitness functions used in the application of genetic algorithms to the system design [6]. In general, the objective functions are used to optimise system performance by choosing the values of the key design parameters so that the objective function is optimised.

D. Utility and Utility Functions

In the present study, the purpose is to identify those human factors that determine the level of attractiveness of a given virtual space and then to relate these factors to key parameters of the virtual space. This may be done by using so called utility functions [3]. In economics, these are functions that specify the utility (well being) of a consumer for all combinations of goods consumed (and sometimes other considerations). Such functions capture critical aspects of the consumer’s attitudes towards the goods being proposed to him. In this work, they will capture attitudes towards new proposed telecommunications products or services. Examples of utility include willingness-to-pay, user satisfaction, and so on [18]. Such utilities may then be related to key parameters of the virtual spaces being considered, for example, screen definition, transmission delays, and so on.

E. Attractive Virtual Spaces

As for the concept of "attractive," this, of course, intuitively simply means "capable of attracting, intriguing, and holding the interest of members of a target population," in the case of the authors' work, the potential candidates for using the e-learning services they are developing. Attractive virtual spaces in the context of e-learning would then tend to attract and maintain interest in the target student population. Utility functions may be used to measure the attractiveness of a given virtual space. Using skillfully designed questionnaires to poll users attitudes as function of key system parameters, as indicated above, one may identify the factors that make a virtual space attractive to the intended users and build empirically the corresponding utility functions. More precisely, results of the polling will give values of the utility as function of the system parameters of interest. Then, by using standard curve-fitting techniques, one may derive functions for the utility.

As an example, consider the virtual spaces that are effectively defined by cellular telephones among a population of teenagers (some of the most avid of cellular telephone users in countries such as Japan), we see a number of properties that make those spaces attractive: immediacy of access, relative privacy, access anytime and anywhere, compactness of the physical devices themselves, the low cost of e-mail (as opposed to voice conversations), and so on as salient attractive features. The objects of these virtual spaces, as perceived by a user, would be the users themselves, the objects displayed in the display window, objects handled by the system, for example, e-mail, etc. The points of the space would be the network addresses associated with the objects of the system. The topology would be that of the cellular
system and the measure might be end-to-end delay of messages transmitted over the topology. A poll could be conducted using a volunteer group of users to determine the utility willingness-to-pay, for example, as function of the two (global) system parameters, voice quality and screen size. Voice quality is, of course, related to a number of internal parameters (encoding scheme, transmission rate, etc) and screen dimensions relate to the external form of the device. Yet these two factors might be critical in assuring the attractiveness of the virtual space created by the cellular telephone system.

To discover what is attractive and what is not is an experimental process for which there is no hard and fast rule: one must simply rely upon intuition to try to identify those factors that appear to be critical for rendering the system product or service attractive. Once such factors are identified, however, then one should attempt to build meaningful utility functions to guide the system designer. Throughout the design process, tests should be conducted with human subjects to assure oneself that the product remains attractive as it approaches use in real-world applications.

F. Definition of Attractive Virtual Space

If \( u = u(p_1, ..., p_n) \) is a utility function of parameters \( p_1, ..., p_n \) where the \( p_i \) are the critical parameters of interest for a given virtual space \( V \), then we say that \( V \) is attractive with respect to the \( p_i \) of a given utility \( u \) if, for values \( v_0, ..., v_n \), \( u(v_0, ..., v_n) \) is a maximal value of \( u \). The word maximal is used here rather loosely to mean a relative maximum that will satisfy the needs of the modeler at the moment. Since \( u \) may be an ill-behaved function for maximization purposes, in practice a relative maximum may be sufficient and such a relative maximum will be called a maximal value. The concept of attractive virtual space then is defined relative to some form of utility and some system parameters. This corresponds to our intuitive idea of the concept “attractive” as being a subjective evaluation according to various criteria. In the case of human beings, these criteria often are difficult to render explicit, hence the need for human factors studies as mentioned above.

III. DESIGN AND TESTING OF ATTRACTIVE VIRTUAL SPACES

With the aid of the concepts and mechanisms presented on the previous sections, the strategy of the authors then is to attempt to build experimental virtual spaces, subject these to testing with human participants, study their reactions using various polling and interviewing techniques, then attempt to derive meaningful utility measures. The latter then will be used as a basis for further development and experimentation. Thus, there will be an alternation between experimental work on the one hand and theoretical developments on the other.

In the conceptualization of that which constitutes attractive, the seminal work of Norman [9], Raskin [11], and Shneiderman [12] are being found in the search for the qualities that might render an object, here a virtual space, attractive. At this time, these and related work and ideas are being explored in the quest to derive meaningful criteria for attractiveness as well as to find viable utility functions. Up to this point, attractiveness criteria have been sought by strict intuitive reasoning, which, all the same, has proven to be effective in the design of several experimental virtual spaces in the context of e-learning. These spaces were used in several trials in real classroom situations. In these initial trials, the formalism developed above was not yet available and no formal utility functions were used. These trials are summarized below to give the reader an idea of the approach being used in this work.

In a first e-learning trial [13], the underlying physical configuration for the corresponding experimental virtual space was as follows: (1) in the professor’s laboratory, there were three PC’s, one used for streaming content, another for the professor’s slide presentation using standard software for such and well as standard videoconferencing software, camera, microphone, speakers, and the last PC used for communication between the professor’s assistants, one in the laboratory, the other in the classroom, (2) in the classroom, PC’s connected to the PC’s in the laboratory, again one with standard videoconferencing software, for professor-student exchanges, the other for exchanges between the assistants. The PC receiving the professor’s presentation and the streaming content was connect to monitors distributed throughout the classroom. Both sides could then see each other and the professor could deliver his slides, lecture directly, or use the streaming server for synchronous presentations of recorded materials. The two rooms and their own internal networks were interconnected by the University’s fiber-optic FDDI LAN. Locally 100 base 10 ethernets are used. This configuration is displayed in Figure 1. In this experiment, the professor delivered a real-time presentation using the presentation and videoconferencing software to the students in the remote classroom, who could see his image and the slides. He could also use the streaming server to send pre-recorded content. It is perhaps of interest to note that he gave his presentation in English with the aid of a translator who was in the room with the students. This experiment was dubbed the “Matrix” experiment, since the virtual reality theme of the then popular movie, *The Matrix* [16] was adopted as the theme of the experiment. The trial presentation was an overview of multimedia communications systems for an undergraduate seminar. The duration was 90 minutes. The experiment was followed by a survey in the design of which, unfortunately, the authors had no part. But, all the same, using the answers provided, it was clear that the students found the virtual space created by the configuration of Figure 1 attractive, at least to the extent the experience was interesting and fun. A number of useful technical points were made that helped guide the authors in future experiments. One serious problem was the relative poor quality of the streamed images. A similar trial was conducted recently in which a wireless
LAN replaced the local network in the classroom. This time again the poll was conducted outside of the author’s control, but yielded similar results. Several other trials have been conducted, using wireless LAN’s in conjunction with the University’s FDDI network. The results of these tests will be presented at a later date. Finally a recent trial done in connection with a graduate seminar on multimedia systems was conducted using a slightly modified version of the configuration of Figure 1 in which again a wireless LAN was used locally.

IV. CONCLUSIONS

A. Results of Work To-Date

So far, feedback about these trials suggests some essential elements of attractive virtual spaces, as applied in the context of e-learning. These trials, as mentioned, did not use the formalism presented in this paper, in particular, no formal utility functions were used. All the same, as will be reported elsewhere, a number of candidates for utility functions have emerged from these trials. The M²COTS approach was shown to be viable, specially to the extent that the costs of wireless connections and broadband Internet access fall to a range that is affordable by the average consumer.

B. Future Work

Using the above-mentioned candidate for utility functions, the next steps will consist of expressing them according to the formalism presented in this paper. The UML will be used and optimization procedures, such as genetic algorithms, will be applied where feasible. At this time, it may be said that a realistic idea of what constitutes an attractive service is slowly emerging. The techniques being developed are expected to prove useful in predicting the probability of success of new products or services.

ACKNOWLEDGMENT

The authors wish to acknowledge the support of the National Science Foundation of the Ministry of Education and Sciences, Government of Japan.

REFERENCES


Figure 1

---

CS = Communication Software  
SS = Streaming Server  
RC = Remote Control  
PC1 RC Host  
PC4 Communicate  
PC5 Communicate  
HUB  
University Intranet  
FDDI  
10 BASE  
100 BASE