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A NEW TASK DISTRIBUTION MODEL TO INCREASE USER PERFORMANCE IN COLLABORATIVE VIRTUAL ENVIRONMENT

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Abstract

Collaboration and teamwork is important in many areas of our lives. People come together to share and discuss ideas, split and distribute work or help and support each other. The sharing of information and artefacts is a central part of collaboration. In this paper, a new task distribution model is proposed to increase user performance in CVEs. The model defines the task distribution strategy among multiple users in CVEs which is based on task selection and distribution mechanism among users via awareness mechanism for increasing user performance in CVEs. The effect of tight and loose coupling is also discussed in the model for user performance. The main objective of proposed model is to manage and control the concurrent user actions for better user's performance.

Keywords: Virtual reality, collaborative virtual environment, 3D interaction, awareness, user performance

1.0 INTRODUCTION

"Collaborative virtual environments are virtual reality systems that offer graphically realized, potentially infinite, digital landscapes. Within these landscapes, individuals can share information through interaction with each other and through individual and collaborative interaction with data representation" [1]. Some of the applications of CVEs are assembly task, tele-presence, education, entertainment and collaborative design in engineering and military training [2]. More advanced CVEs, which support complex, real time and haptic collaboration have been suggested for numerous applications, mainly in the area of training [3, 4, 5]. Avatars (Humanoid avatars, Ball, Sphere, and Circles etc.), audio, video support and textual data are the main requirements for CVEs. Audio and video support is basically used in teleconferencing and video conferencing. Multimodal (audio, visual and haptic) virtual guides are used for user assistance in CVE for awareness to achieve better performance [7, 8].

In virtual environments navigation, selection and manipulation of various objects will be carried out. Interaction among various objects and environments may take synchronous and asynchronous forms [6]. In *Synchronous* type of CVE the simultaneous manipulation of separate or the same attributes of an object are carried out. For example one person hold the object and the other paints it or suppose two or many peoples displace or lift a heavy weighted object together. While in *asynchronous* type of CVE the sequential manipulation will be carried out with the distinct or with same attributes of the objects. For example one person changes the object position and another person changes it further. To perform collaborative task in CVEs either synchronously or asynchronously awareness is important to achieve better performance.

The awareness concept in a CVE as it is defined in [1] mainly concerns the activities of other users and their presence. Awareness is actually the feelings of a user about the presence of other users in shared space. We can say that it is the knowledge of a user about the actions, intensions and status of other users in collaborative virtual environment. The awareness measures the degree, nature or quality of interaction between two objects or users [9]. In order to perform a cooperative and/or collaborative task efficiently, the users need to be aware of each other activities. Communication among the users is an essential factor for better performance in collaborative tasks. The communication may be verbal such as audio or nonverbal such as visual, gestures based, pointing to or even facial expressions.

In CVEs as multiple users are involved for task execution. So either all the users will work on a single task or the task is divided into subtasks and users work on it in groups. All users will complete their assigned task to achieve better performance by using various awareness modalities. Benford & Fahlen [11], Sandor *et al.* [12], Ullah *et al.* [19], Otmane *et al.* [18] and Rodden *et al.* [14] presented models to increase user performance in a cooperative and/or collaborative virtual environment.

Awareness modalities is used as a tool to increase the user performance in CVEs, for which present the task distribution model that is used for collaborative work in CVEs is presented. In addition, the importance of collaboration and/or coordination and awareness between users during the execution of collaborative and/or cooperative tasks based on coupling among the users performing the task will be studied. This new investigation will help in the development of assembly task, learning virtual environments and tele-operation systems for collaborative and/or cooperative task.

This section is followed by the related work. In Section 3 the proposed task distribution model is described. In Section 4 conclusion and future work are given.

2.0 RELATED WORK

The best-known work performed for the management of interactions in the CVEs is the spatial model of interactions proposed by Benford & Fahlen in 1993 [11]. Basically it is used to control data transmission in CVEs. The main theme of this model is to use the space properties as a base to start and allow interactions and communication among the objects of CVEs. In this model the virtual space is breakdown to metric spaces, to measure different objects directions and positions. The objects have to change their positions and perform orientation in CVEs. For orientations and positions settings, objects of the CVEs have the capability to change their interaction and communication. Interaction between the objects occurs via combination of media transmission like text or visual, audio and video through specific interfaces.

In Benford model a set of interesting concepts such as the aura, focus, nimbus and the awareness are defined. According to Benford model interaction between two objects becomes possible whenever their auras collide or overlap. In this model only modalities are described to increase the user awareness for better performance. The auras of all users are not necessary to collide with each other for interaction between objects to increases the awareness level in CVEs [19] and auras of all the modalities are not same. In spatial model of interaction, it is apparent that focus, awareness and nimbus required to be made more directly visible and controllable within the interface. Further work is required to refine and "fine tune" the expression and calculation of nimbus, focus, and awareness.

Another limitation in the spatial model is the limited support for contextual factors in interaction (being in a room compared to being in an open park) [9].

Benford model was extended during the years. Sandor *et al.* [12] uses nimbus, focus and awareness concepts on semantic networks objects and relations. In this approach structure of the deleted or updated objects history and relations are build [12]. To maintain the history of objects is very difficult task in CVEs and an extra overhead is created.

Greenhalgh *et al*. [13] used another approach, which integrates "third-party objects". The "third-party objects" provide support for awareness calculation by using the contextual factors, which enhance scalability. Third party objects may represent features of interaction context, such as crowds, common objects, rooms/ buildings or more abstract factors such as control of the chair or membership of a group. Third party objects are defined in terms of their activation and effects. It means that what they do and when they do it. There are two classes of effects used in "third-party objects ". Firstly is the adaptation, which is basically used to modify the existing awareness relationships i.e. suppression or amplification. Secondly, the secondary sourcing, which basically introduce new indirectly forms of awareness. The combine effects of adaptation and secondary sourcing is mainly useful to realize the group effects. The group effects include abstraction and aggregation of the whole group [9, 13].

There is a need to make control over the interaction more accessible to users (e.g. via manipulation of focus and nimbus). In each direction and in each medium (e.g. graphics, audio and text) the awareness may be different. In "third-party objects" among the communicating bodies, simultaneous interactions are required, which creates extra overhead. Also using "third party objects" interaction will be changed dynamically.

A model of presence was proposed by Rodden in 1996 [14] for cooperative and/or collaborative applications. This model is also represented as awareness model for interaction for multiuser applications. The model is basically focused on to exploit the shared nature of the pool of objects. Shared objects and their relationship form a common 'space" onto which the users of the environment project their action. The actions which they performed are publically available through the objects which form the space. The model of presence's basic goal is to allow a sharing workspace of cooperative application based on presence and the notions of awareness.

The model of dynamic management of interests Ding & Zhu in 2003 [15] deals with the problem of presence management in collaborative virtual environments between different users. This model is focused on a dynamic interaction of environments. The model describes user's behaviors and more precisely the changes of their center of interest over time. In this approach when all the users go to a single common of interest, then remaining objects of the task become idle as no one are taking interest. Therefore problem will occur and the task will not be completed. Also with passage of time when some users of the CVEs change their common of interest, then user's performance will be affected.

To ensure awareness in heterogeneous environments, Bharadwaj *et al.* in 2005 [16] proposed a model based on Benford spatial model of interaction and allows a user to have more focused on providing an easy choice of sources. Access rules are used to allow or reject certain sources.

Otmane *et al*. [17] proposed a more recent model, which is fully dedicated to 3D interactions for collaborative virtual environments. In this model a conceptual framework have established that is based on 3D interaction functional aspect i.e. navigation, selection and manipulation called "functional clover of 3D interaction". This model enable users to have knowledge about the system state and also provides information to assist users to interact.

The workflow based model is used to help users to interact in CVEs. They highlighted the ability of the system to provide assistance to improve performance in single-user interaction (to navigate and select) as well as in multiuser setup (in the case of more users manipulate the same object). Workflow based model consists of two components: a shared and a motor component. The shared component is presented as the shared data space that symbolizes the behavior of users and sources in the CVE. The motor component is presented as a set of assistance functions that deal with data processing from the shared space and provides tools to assist the users during the 3D interaction process. It uses the shared data and applies them via assistance functions (navigation, selection and manipulation functions) on particular sources (focus, aura, nimbus, assistant and avatar) in the CVE [18].

More recently Ullah *et al.* [19] proposed a model for cooperative and/or collaborative task in CVEs which is based on the Benford spatial model of interaction [11]. According to this model two users qualify for interaction if their auras collide with same object. According to Ullah *et al.* [19] all the users of the aura set of an object will be able to communicate with each other and therefore will have mutual awareness. In this concept the user awareness is increased and ultimately increase the user's performance in CVEs.

Up to the authors knowledge no one has discussed about the task distribution strategy. In this paper a new model is proposed for task execution/distribution in CVEs by using awareness modalities for communication and will increase user performance. Also in the proposed model the effect of tight and loose coupling are described to check user performance in CVEs. The proposed task distribution model will be checked for its better user performance in future via various experimental studies.

3.0 TASK DISTRIBUTION MODEL

CVE is an environment in which interaction occurs between the users and virtual objects which are selected and/or manipulated.

In this study, the CVE is represented by a set of virtual tasks, virtual objects and a set of users that can manipulate these objects.

$$\mathrm{CVE} = \{\mathrm{T}, \mathrm{O}, \mathrm{U}\} \quad (1)$$

$$\mathrm{T} = \{\mathrm{T}_1, \mathrm{T}_2, \mathrm{T}_3 \ldots\ldots \mathrm{Ti}\} \quad (2)$$

$$\mathrm{O} = \{\mathrm{O}_1, \mathrm{O}_2, \mathrm{O}_3 \ldots\ldots \mathrm{O}_j\} \quad (3)$$

$$\mathrm{U} = \{\mathrm{U}_1, \mathrm{U}_2, \mathrm{U}_3 \ldots \mathrm{Um}\} \quad (4)$$

where 'T', 'U' and 'O' represent the set of Tasks i, Objects j and Users m respectively.

The task distribution is carried out in two ways i.e. static task distribution and dynamic task distribution.

In static task distribution a free defined task is assigned to each user in advance, while in dynamic nature of task distribution the user is informed via awareness mechanism in real time to perform the specified task which needs to be completed. In static task there exists loose coupling among the users as each and every user performs his/her work independently. In dynamic task the coupling level among the users is tight as the work of one user is depended on the work of remaining users.

The proposed model is depicted in figure 1.

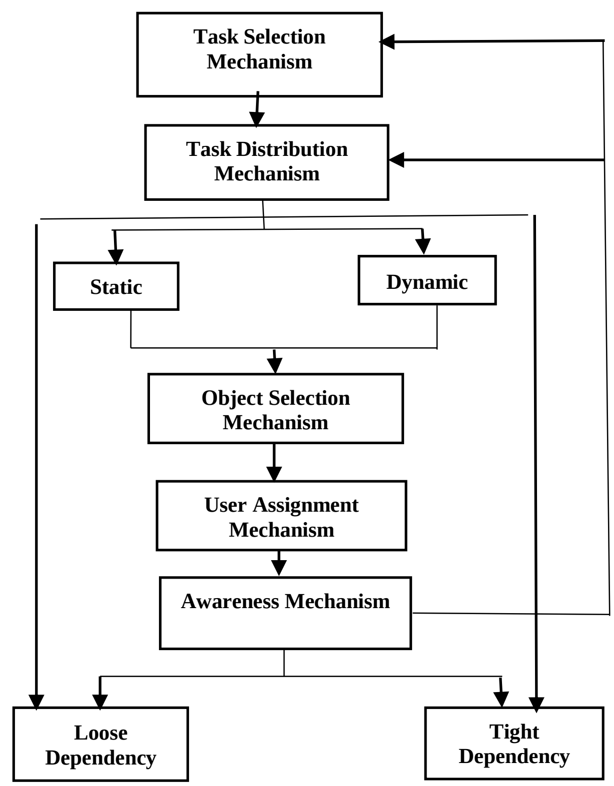

Figure 1 Task execution new model

3.1 Task Selection Mechanism

The first step in CVEs is the task selection. It means that what type of task should be carried out in CVEs. For example to design a CVE for painting a building wall, for assembling a transformer, humanoid skeleton assembly etc. In task selection process it should be decided that how many users will be involved to perform the said task i.e. two or more users. Also in large CVEs the task may consist of sub tasks as described by eq.1. For sub tasks selection in CVEs, communication and coordination are adapted to complete the task successfully.

Consider the humanoid skeleton construction VR assembly environment as depicted in figure 2, where the users are represented by means of spheres along with multiple humanoid skeleton parts. Initially the parts which are to be assembled are randomly placed in VR environment. The users picks up the parts and assemble it collaboratively. In skeleton assembly in figure 2, the task is divided into sub tasks i.e. skull (maxilla, mandible, vertebrae etc.), trunk (ribs, vertebrae, sacrum etc.), upper limbs (clavicle, scapula, humerus, elbow, radius, ulna, wrist etc.) and lower limbs (pelvis, femur, knee, patella, tibia, fibula, metatarsals, Tarsals etc.). The users will select one of the sub task and perform its assembly. Whenever the sub tasks assembly are completed, then combining it, the task is completed.

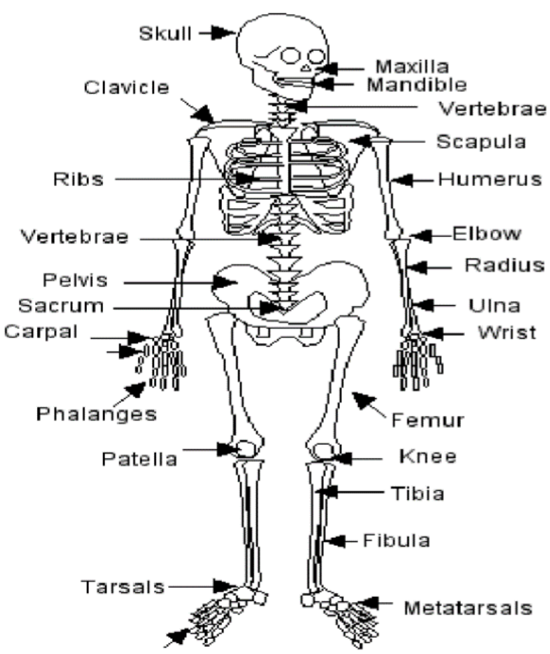

Figure 2 Humanoid skeleton [10]

3.2 Task Distribution Mechanism

In CVEs when performing the complex task, it is divided into subtasks. Solving the sub tasks independently and combining the results the main task is solved. Consider a CVE for assembly of humanoid skeleton construction as described by figure 2. The humanoid skeleton assembly task is divided into sub tasks i.e. assembly of the skull, trunk, upper limbs and lower limbs. When the subtasks assembly is completed, then it can be combined to get the whole skeleton. The task distribution is mainly divided into static and dynamic nature of the task.

Static Task Distribution: - In static task distribution, selected sub tasks are assigned to users of the CVEs in advance. It means that users of the CVEs will know in advance that what he/she will carry out. The users are informed at start about the division of the task. Therefore less communication is required among the collaborative users during task execution.

In humanoid skeleton construction as described by figure 2, the skeleton assembly is performed collaboratively. Task of skull assembly is assigned to user 1, Trunk assembly assigned to user 2, and so on. This type of task distribution of the skeleton is called static distribution.

Dynamic Task Distribution: - In dynamic task distribution, No division is carried out in advanced i.e. at start level. For dynamic task distribution high communication and strong awareness are required during task execution. For example to construct the humanoid skeleton as depicted in figure 2 using dynamic task distribution mechanism, the parts of the human body are assembled dynamically. For example if one part like maxilla is placed by any user from the users set, then the remaining users will be informed to search the next part for example mandible. Now all the free users will search the mandible. When anyone found and placed it in the skeleton, then next part vertebrae will be told and the searching of vertebrae will be continuing and so on until the task is completed.

3.3 Object Selection Mechanism

Object has been selected from object set as described by eq.2. If Oj is assigned to one of the free user from user set, then that user become busy. The rest of free users will search object in the remaining objects O_{j-1}.When the object released by the busy user, then that user will be included in free user set. The same process is repeated for the remaining objects.

For example in figure 2 if maxilla is found by a user from the users set, then that user will be included in the set of busy users and the remaining free users will search object from the rest of the objects of the human skeleton. When the busy user release the object, then he/she is included in the free users set. The same process is used for the rest of the objects of humanoid skeleton construction.

3.4 Assignment Mechanism to Users

The users set in CVEs is described by eq.(4) is divided into two sub list i.e. Free Users (U_{Fm}) and Busy Users (U_{Bm})

$$U = \{U_1, U_2, U_3 \ldots\ldots\ldots\ldots\ldots Um\} \quad (5)$$

$$U = \{U_{Fm} + U_{Bm}\} \quad (6)$$

where $U_{Fm} = \{U_{F1}, U_{F2}, U_{F3} \ldots\ldots\ldots\ldots\ldots U_{Fm}\}$

and $U_{Bm} = \{U_{B1}, U_{B2}, U_{B3} \ldots\ldots\ldots\ldots\ldots U_{Bm}\}$

The objects are assigned to free users among the free users set. When the object is pick up by the user from free users set, then the user become busy. The free users will search remaining objects from the object set. When the busy users release/place the object, then it will be included in free users set and so on. The whole process is depicted in figure 3.

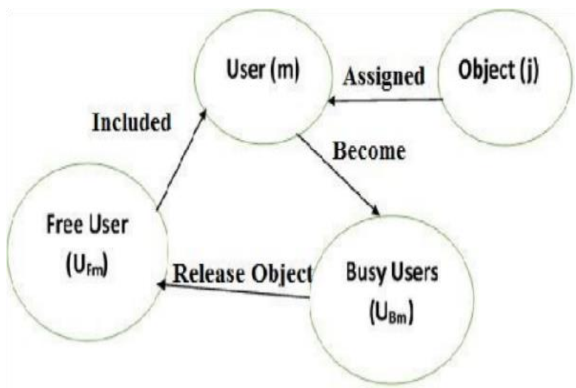

Figure 3 Objects assignment mechanism to users

3.5 Awareness Mechanism

It is the feelings of a user about the presence of other users in shared space. Simply it is the knowledge of a user about the status, action and intensions of other users. It deals with the degree, nature or quality of interaction between two objects or users [9]. Communication is required among the users of the CVEs to provide awareness. Various communication modalities are used for awareness like audio, visual and haptic. These modalities will provide assistance and coordination to users in collaborative and/or cooperative work. The awareness play a vital role in CVEs to provide a better result. Awareness modalities are required for both static and dynamic task distribution.

Audio Modality: - To accomplish collaborative and/or cooperative task in the virtual environments in more realistic manner and to achieve high performance and increase co-presence of users, oral/audio communication may be used. It allows users to negotiate and exchange information on various events, such as increasing or decreasing speed, losing control of the objects.

Visual/Textual Modality: - Textual/Visual modality for communication allow users to exchange information on various events, such as picking the objects or releasing the objects. Other visual guides like shadow, change of colors, arrows and lightning are also used in CVE to increases user awareness [20]. To achieve high performance and increase co-presence of users, textual modality is used for data transfer between the collaborative users in CVEs to increase awareness. Awareness are categorized into two types i.e. targeted and global awareness.

Targeted Awareness: - In CVEs where selective users will be informed about each other activities is called targeted awareness. For example if there are more than two groups of users involved in collaborative work. Suppose group 1 is responsible for task T1 and group 2 for T2, where the latter is dependent on the former. In this case if group 1 completes its task, then there should a mechanism to inform or make aware group 2 only, so this kind of awareness is called targeted awareness. In figure 2 if skull section assembly is assigned to group 1 and trunk section to group 2. When group 1 completes their task, then they will inform group 2 via modalities. When group 2 users complete their task collaboratively, then they will inform next group to start their task and so on. In targeted awareness users will be informed about each other activities.

Global Awareness: - Global awareness, meaning he is always able to view any part of the environment from any perspective, through any available medium, at any time [21]. In global awareness process the users of the collaborative virtual environment are aware of each other individual activities, For example in humanoid skeleton assembly if there are more than two groups of users involved in collaborative work. Suppose group 1 is responsible for task T1 (skull assembly), group 2 for T2 (trunk assembly) and group 3 for T3 (limbs assembly) and so on. No group is dependent on each other. When all groups executing their assigned task then they should be aware of each other activities whenever they want from any location. This kind of awareness mechanism is called global awareness.

3.6 Task Dependency Mechanism

The act of joining two things together is called coupling. To make assembly in CVEs coupling refers to the degree to which objects of the task in CVEs are dependent upon each other. For instance, in a tightly-coupled dependency, each object of the task and its associated objects must be present in order for completion of assembly task. In a loosely coupled dependency, objects can remain autonomous and allow a mechanism in the middle to manage communication between them. In a decoupled dependency, the objects can operate completely separately and independently.

There are many situations where a task accomplishment requires tight and loose coupling among users of the CVEs. For both kind of coupling awareness is required to complete the task. For example, if two or more persons lift a heavy object and change its place in the virtual environment. The collaborators must be aware of each other's status and actions. They should also be able to negotiate on how to lift and manipulate the object. In addition if any user detaches during task execution, then the rest should know that who has lost control.

In this case the awareness can be formalized in the following way.

Set of users (U) subscribed to perform one or more operations (T) on object (O).

$T = U \leftarrow O$

If $T(t) = U_m \leftarrow O_j$ and $T(t) = U_{m-1} \leftarrow O_{j-1}$. It means that user U_m and U_{m-1} will collaboratively perform an operation on object O_J. They should have mutual awareness. $U_m \leftarrow > U_{m-1}$ is 1.

For humanoid skeleton construction in figure 2, if object "maxilla" is picked up by one user among the users set, then remaining free users will search the next object suppose the "mandible". When "mandible" has been picked up by any one of the free user from users set, then the next object supposes the "vertebrae" will be searched and so on. This mechanism of object selection is tightly coupled. As for as loosely coupling is concerned if objects like "skull" of the skeleton is assigned to one user, trunk of the skeleton to other user and so on or if selective objects are assigned to users from users set, then it is loosely coupled. So in CVEs task will be performed by considering the two levels of couplings.

4.0 CONCLUSION

In the fields of Human-Computer-Interaction and Virtual Reality a lot of technological advancement occurred. In spite of this technological advance, a few models and formalisms exist for the collaborative interaction. In this paper, a new task distribution model for collaborative interaction is proposed in which the task selection, task distribution, task assignment, object selection, user awareness and task dependency mechanisms among users in CVEs are discussed. The aim of the proposed formalism is to define the task distribution strategy in the virtual space so that the system can inform each user about the presence of other users and to collaborate and/or coordinate their interactions for increasing user performance. Also the model allows an easier and more effective group interaction basis on static or dynamic nature of task distribution which will enhances user performance via spatial awareness modalities. The effect of coupling on task distribution and user performance in CVEs is also discussed.

In the future work, an adaptive strategy for coordination of collaborative 3D interactions based on the proposed model will be designed and implemented. Experimentations will be carried out on basis of this model and the result will be pictured in multi-users set up (co-located/distributed).

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