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Merging Assistance Function with Task Distribution Model to Enhance User Performance in Collaborative Virtual Environment

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ABSTRACT

Collaborative Virtual Environments (CVEs) falls under Virtual Reality (VR) where two or more users manipulate objects collaboratively. In this paper we have made some experiments to make assembly from constituents parts scattered in Virtual Environment (VE) based on task distribution model using assistance functions for checking and enhancing user performance. The CVEs subjects setting on distinct connected machines via local area network. In this perspective, we consider the effects of assistance function with oral communication on collaboration, co-presence and users performance. Twenty subjects performed collaboratively an assembly task on static and dynamic based task distribution. We examine the degree of influence of assistance function with oral communications on user's performance based on task distribution model. The results show that assistance functions with oral communication based on task distribution model not only increase user performance but also enhance the sense of co-presence and awareness.

1. Introduction

In real life when a task (simple, complex) is to be performed then it will be either performed in a group/combine or will be carry out individually, that's why scientist start the development of VEs which support single as well as collaborative work. "Collaborative Virtual Environments (CVEs) are virtual reality systems that offer digital landscapes where individuals can share information through interaction with each other and through individual and collaborative interaction with data representation" [1]. CVEs have been used as a mediation tool to facilitate the human-human collaboration across different spaces. Moreover, the concept of CVEs include the collaboration between human participant and virtual entities such as Intelligent Virtual Agents (IVAs). CVEs have been used in multiple fields such computer added design, training, virtual science experiments conduction, visiting of virtual museums, business, medical, entertainment, education and tele-operation [2-7]. CVEs have gained a lot of interest due to the evolving growth in networking and telecommunication technologies.

Interaction in CVEs with different synthetic objects may occur in synchronous and asynchronous form [8]. In synchronous form of interaction the simultaneous manipulation of distinct or the same attributes of an object are carried out, e.g. if a subject in VE holding an object and his/her collaborator painting it or to displace or lift a heavy object cooperatively/collaboratively is a synchronous activities in CVEs. While in asynchronous interaction the sequential manipulation of unique/distinct attributes of an object are performed in CVEs. For example if a subject paint an object and his/her collaborator will change position of the objects in VE. Similarly if a subject displace an object to a place in VEs and his/her collaborator moves it further.

To perform the collaborative task smoothly and efficiently the users of the VEs need presence and co-presence of other users and to find an easy way of communication with each other's. Mainly two types of communication are used i.e. verbal and non-verbal. In verbal communication audio modality are used whilst in non-verbal communication in the form of gestures or facial expressions are adopted. Also to execute a task in CVEs the users need a common protocol. To design such a system and their implementation for remote collaboration is really a challenging job for the developers and researchers in field of VR. Whenever the remote collaboration strategy is adopted for which the client server architecture is implemented the network delay in the form of jitter and latency will produced. Also whenever the replicated architecture is used then need to addressed the consistency issues.

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In this paper a VE is designed for the implementation of collaborative work using the replicated framework and try to search the use of oral communication with assistance function to feel the presence and co-presence of the user to work in collaborative environment easily and efficiently. We tries to investigate the effect of oral communication and assistance functions (lighting, arrows and color changes of the avatar) to accomplished the collaborative assembly task in CVEs and got better user performance based on task distribution mechanism [9, 10].

In section 2 and 3 background study, system description, Task distribution model and the specification required for conducting the experiment are discussed. In Section 4 the oral communication and assistance function with audio modality based on task distribution are discussed to check the user performance in CVEs to conduct assembly task. Conclusion and future direction are given in section 5.

2. Related Work

In field of CVEs a lot of work has been done to improve the user performance and provide efficient collaboration between the members of the CVEs. The MASSIVE collaborative environment is used which provide the teleconferencing facility between the collaborative users [11]. In this collaborative work, general software and network architecture were used [12-15].

The role of force feedback in CVEs to perform a collaborative task was investigated by Bastogan et al., in which the two station and their associated devices in the form of two monitors and haptic to a single machine was connected [16]. Also Evalotta et al. have described the effect of force feedback to improve user performance based on presence and awareness modalities in CVEs [17]. A lot of work have been done to support the haptic interaction in CVEs to perform a collaborative task [18]. Other significant works have been done in field of CVEs which support the collaborative work i.e. navigation, selection and manipulation of different synthetic objects in VE include [19-22]. In all these system to maintain the consistency among them heavy data are exchanged. So modality in the form of visual, audio and tactile cues has been used for the single user VE and tele-operation systems as a substitute for haptic feedback [23, 24]. Another approach in the form of sensory feedback has been used to avoid the possible force feedback instabilities due to the presence of the small network delay in the form of network latency.

3. Task Distribution Framework

3.1 Description of the System

We will conduct the experiment on two users based on task distribution model as described in section 3.3. The users will be connected via LAN, to collaboratively perform the assembly task in CVEs. Secondly we present how oral communication and the assistance function in the form of visual aids (textual display and textual boards label, lighting, arrows and change of color) may assist the user in assembly task accomplishment in VEs to navigate, select and manipulates objects of the CVEs.

The VE for collaborative manipulation has a simple cubic objects in different rooms in a scattered virtual environment.

The objects in shape of cube are randomly placed in CVE. The collaborative users of the group will search the objects and bring it to the central room for completing the assembly of making the word ‘UNIVERSITY’ based on C1, C2, C3, C4, C5, C6, C7, C8, C9 and C10 conditions as mentioned below. The collaborative assembly task process is depicted in Fig. 1.

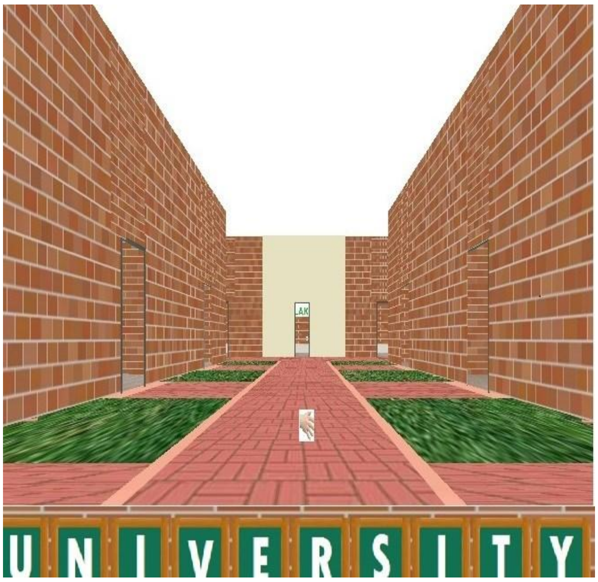

Fig. 1: CVEs scenario

When users of the collaborative environment execute a task based on dynamic distribution then the names of the objects are communicated using audio/oral and visual aids in each conditions i.e. C1, C2, C3, C4, C5, C6, C7, C8, C9 and C10. In making the assembly of word “UNIVERSITY”, whenever the group user pick up the object ‘U’ then he/she will inform his/her collaborator that object ‘U’ is picked and you search the object ‘N’. The same mechanism will be used for the rest of the objects to complete the task of making the word “UNIVERSITY”. To use this type of mechanism for task execution and completion is dynamic task distribution. As for as the static task distribution is concerned the objects i.e. ‘U’, ‘N’, ‘I’, ‘V’ and ‘E’ are assigned to user1 of the group and ‘R’, ‘S’, ‘I’, ‘T’ and ‘Y’ objects are assigned to his/her collaborator in the group to complete the task. In static task distribution the coupling and dependency level of the objects are low. The task will be completed independently by the users of the group. Less communication is used due to low dependency of the objects of the task among the group users.

To represent the user in the collaborative/ cooperative task in CVEs avatar are used [8, 25, 20] or can also represented the users with simple virtual hand or sphere/ball [17, 16, 21, 26]. In our CVEs setup we used two simple virtual hands which are identic in size and have same colors, so that the users may feel the presence of others.

3.2 *Use of Assistance Function and Audio/Oral Communication in Cooperative / Collaborative Work*

To perform work collaboratively in CVE is emerging research area and a lot of challenges will face the users to perform the task. When the work is done via intranet or extranet then a number of points to be addressed. Firstly to feel the presence of the collaborator, and have awareness that where is the collaborator? What are they doing? Are the important factors should be consider to provide better coordination among them, Also the partner of the CVEs should know that when to start the task, when to leave and whenever the interruption occur what strategy should be adopted. For better coordination, Awareness is essential for which communication is vital. For this purpose visual channels in the form of assistance function (lighting, arrows, and color changes) and audio/oral communication between the users are used.

If any user moves towards the rooms in which the objects are lying then the specified object outside area of the room become lighted. The users easily recognize the object room and goes straightly there for picking the objects. Similarly when users navigate in the environment then arrows appears which shows the direction for movement to the specified target. The users easily move in environment by the help of arrows to find the specified objects. Also to bring the object to the central room and the users loose the object control then the arrows color will changes. The third assistance function "color changes of the avatar" is concerned, then whenever the user avatar in the form of simple virtual hand in our CVEs moves towards the target then its color will become green and when he/she move away from the target then his/her color become red. When the object is told to the user in CVEs then he/she start navigation in VE. When he/she moves towards the specified object hen his/her color will be green and when he/she moves in wrong direction then his/her color will become red. The oral communication is used with each of the assistance function.

Oral communication is frequently used to perform task in CVEs. To achieve the cooperative/collaborative task in CVEs in realistic manners and to increase the user performance and to increase presence and co-presence of the CVEs users' awareness modalities like audio/oral communication along with assistance function are used. For communication over the intranet or extranet we use TeamSpeak software which enable the users of the CVEs to communicate easily and real time fashion with the help of headphone equipped with microphone over the network [27]. The audio/oral communication modalities along with assistance function allows the users to make conversation and also to inform each other about the events(moving towards or away from central room, losing control of the objects and increase or decrease speed) occurs in CVEs.

3.3 *Task Distribution Model*

CVE is a computer generated world where two or more user can simultaneously interact with synthetic objects to perform a task. The CVEs consist of tasks (T), objects (O) and users (U). Task is further divided into sub tasks T_1 to $T_{i,}$ Objects consists of O_1 to O_j and the Users set are divided from U_1 to U_m.

To describe the task distribution model, consider a CVE scenario, in which multiple parts/objects of a task/product assembly is carried out. The task will be carried out in two ways. Firstly, the assembly task from different constituent synthetic object in CVEs will be performed sequentially i.e. to completes task (T) which consist of sub tasks T_1, T_2….T_i will be completed one after another by a single group of users. Secondly, task will be completed/performed by multiple group of users. In which each group of users, a specified task ($T_{i)}$ will be assigned. The first step in CVEs task execution is the selection of the task as described in Fig. 2.

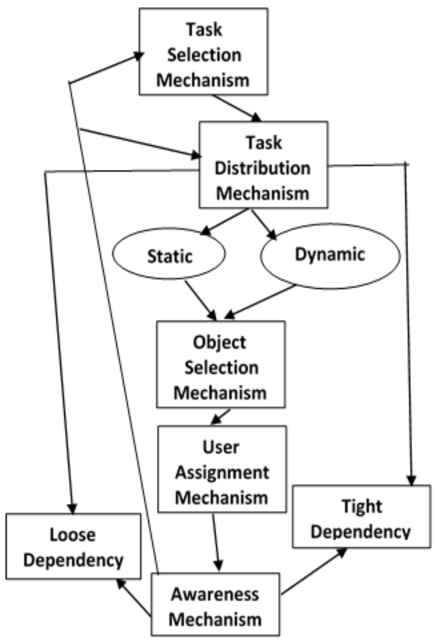

Fig. 2: Task distribution model [28]

After selection of the task the next step is to realize the task in CVEs by the group of users. In the model it can be proposed in static and dynamic task distributions as explain below.

3.3.1 Static Task Distribution

In this type of task distribution mechanism, users of the group know in advance that which sub task he/she will be performed in CVEs. Also the user of the group know in advance about the objects of the task which they are going to execute e.g. if the task set T is divided into sub tasks from T_1 to T_i, and the users are divided from U_1 to U_m, then T_1 will be assigned to U1, T_2 to U_2 of the same group. In static task distribution the awareness level is low, in this context less communication is required.

3.3.2 Dynamic Task Distribution

In this task distribution mechanism the objects of the tasks which are going to be execute will not be divided in advance i.e. in start of the program execution. In this mechanism all users of the group will first complete the sub task (T_1) collectively then the sub task T_2 will be completed and so on until sub task T_i is completed. In this task distribution mechanism when users of the group start sub task T_2 then they will be aware that task T_1 is completed. Similarly for starting the sub task $T_{i+1,}$ users of the group involve in task execution will know that task Ti is completed. All the information will be communicated among the users of the group in real fashion. The same procedure will be used in sub tasks, if the sub tasks further consists of sub subtasks. In this mechanism of task distribution, high awareness for which high communication are used [29].

***Awareness**:* - To feel the presence of the other users in a VE is called awareness [29]. For awareness communication is vital. Visual/textual, audio/oral and haptic communication modalities are used for awareness.

Audio/Oral Modality: - The audio/oral communication modality are used in a CVEs to achieve a high performance and increase the co-presence of users in CVEs. During navigation, selection and manipulation of the objects in CVEs, audio/oral communication are used for the exchange of the information among the collaborator users.

Textual/Visual Modality: - To increase the awareness level of the collaborative users in CVEs, lighting, arrows and color changes of the avatar visual aids are used. These visual aids will increase the user performance level in CVEs [30].

Task Dependency: -Coupling refers to the degree to which task in CVEs are dependent upon each other. In this regard we defined three type of tasks. (1) tightly-coupled task (2) loosely coupled tasks (3) decoupled tasks. In tightly coupled tasks there exist a strong relationship between two or more tasks/subtasks and hence the dependency will increase due to which high awareness is required during the accomplishment of tasks/subtasks. In a loosely coupled task/subtasks there exist weak relationship between two or more tasks/subtasks having low dependency. Loosely coupled task/subtasks require low degree of awareness and hence less communication is used. In a decoupled tasks/subtasks, operations on the objects can be performed separately and independently. In static distribution there exist loose dependency and required less communication during task realization while in dynamic distribution users are more dependent on each other and thus require more communication.

4. Experiment and Analysis

4.1 Architecture for CVE

In CVE application the architecture play a vital role in its efficiency and success. It is related to that, how data will be accessed and which protocol (TCP, UDP) are used for data transmission to keep consistency of data [31]. For this purpose, in our experimental setup we use a complete replicated approach and install the same copy of the VE on two different machines. As the Fig. 3 depicts each VE station has a module which acquires the input from the local user. This input is not only applied to the local copy of the VE, but is also sent to the remote station where it is applied to same VE in the same manner. The same module receives the input from the remote station which is applied to the local copy of the VE. It means that a single user simultaneously controls the movement of two pointers (in our case a simple virtual hand) at two different stations, so if this pointer triggers any event at one station, it is also simultaneously applied at other station. In order to have reliable and continuous bilateral streaming between the two stations, we use a peer-to-peer connection over TCP protocol.

Here it is also worth mentioning that the frequently exchanged data between the two stations is the position of the two pointers where each is controlled by a single user.

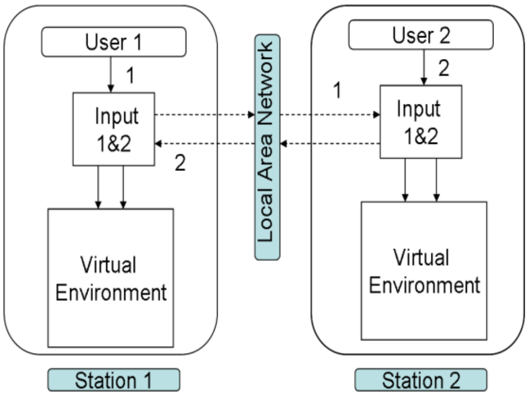

Fig. 3. Architecture/Framework of collaborative virtual environment

4.2 Experimental Setup

We installed the software on core i3 laptops having 4GB RAM, which are connected with each other via LAN. Each station contains standard graphic and sound cards. We used WIIMOTE for input data to the stations.

4.3 Task

The users will search the cuboid objects which are placed randomly in CVE and bring the objects to the central room for making the word "UNIVERSITY" under the given conditions C1, C2, C3, C4, C5, C6, C7, C8, C9 and C10 collaboratively based on task distribution model as described in section 3.1 (description of the system) and shown in Fig.1.

4.4 Procedure

To investigate the effect of assistance function (lighting, arrows, color changes) with audio communication for objects manipulation on user performance in a CVE based on task distribution model to evaluate the system, we conduct experiment. For this purpose twenty students/participants consisting of ten males and ten females, most of them were undergraduate having ages from 13 to 16 were selected. All the students' performed the experiment in a replicated virtual environment collaboratively.

First of all the participants in the experiments was given a short briefing about the experiment and also to make them familiar with the system a pre-trials were conducted. The participants were seated on two remote station and a successful network connection were established between them. The users were represented by simple virtual hand and the replicated environment of the objects scattered in VE were displayed on each side. They were required to bring the scattered objects from rooms to the central room and make the words "UNIVERSITY" assembly task from them, based on static and dynamic distribution under the oral communication and visual ads i.e. the assistance function (lighting, arrows and color changes of the avatar). We conducted the experiment based on static and dynamic task distributions under the following conditions:

C1= Static with audio

C2= Dynamic with Audio

C3= Static with lighting

C4= Dynamic with Lighting

C5= Static with Arrows

C6= Dynamic with Arrows

C7= Static with Color changes of the avatar

C8= Dynamic with color changes of the avatar

C9= Static with lighting + arrow + color changes of the avatar

C10=Dynamic with lighting + arrow + color changes of the avatar

All the above condition will be tested with oral/audio communication.

The twenty participants were divided into ten groups of two users each performed the experiment using distinct counter balanced combinations of the ten mentioned conditions. In this experiment the task completion time was recorded for each condition based assembly task. The time will start when the VE is loaded and end when the assembly task is completed. Also we recorded the number of errors made in each condition based experiment when they picks up the wrong object and also to place the object in other location rather than the central room. All the participant completed the experiment four times.

In the subsections given below the results of task completion time and errors made by the students are analyzed during the accomplishment of the task. Similarly the feedback collected from students through questionnaire are also thoroughly examined and discussed.

4.5 Task completion time

For the time completion the ANOVA ($F(9, 19) = 13.03$, $p < 0.05$) is significant. Comparing the task completion time of C1 to C10, We have C1 (means time 156.76 sec having 39.41 std), C2 (means time 185.7 sec having 40.24 std), C3 (means time 141.45 sec having 37.75 std), C4 (means time 160.23 sec having 38.03 std), C5 (means time 136.8 sec having 32.20 std), C6 (means time 153.60 sec having 34.69 std), C7 (means time 149.80 sec having 35.75 std), C8 (means time 157.60 sec having 36.03 std), C9 (means time 122.80 sec having 28.2 std) and C10 has 141.6 sec having 30.69 std. From the task completion time the static task under the oral communication with different assistance function have influence and increase user performance as compare to the dynamic task under the oral communication with different given assistance functions. Also the assistance function arrows under both task distribution i.e. static and dynamic, increase user performance as compare to other assistance function (lighting, arrows and color changes of the avatar) as given in condition C5 and C6. In C9 and C10 when the assistance functions were used in combination, then it exponentially increase user performance as compare to other conditions. From task completion time C3, C4, C7 and C8 i.e. the lighting and color changes of the avatar have very low difference which give a low changes in the user performance level. The overall process as shown in Fig. 4.

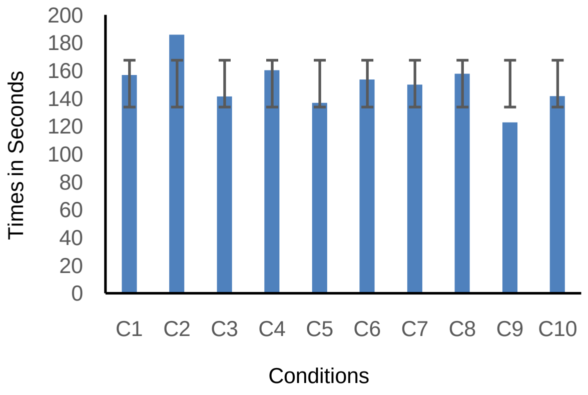

Fig. 4: Task Completion Time based on Various Conditions

4.6 *Error in task completion*

When the user picks up the wrong objects from the VEs and also when release the objects in some other location rather than the central room are considered to be errors. So the number of errors are recorded under each condition based experiment and we give a global error analysis under each conditions as shown in Fig.5. Here C1 has 0.88 mean error with 0.39 std, C2 has 1.87 with 0.85 std, C3 has 0.70 with 0.36 std, C4 has 1.65 with 0.72 std, C5 has 0.45 with 0.27 std, C6 0.87 with 0.52 std, C7 has 0.49 with 0.38 std, C8 has 0.73 with 0.67 std, C9 has 0.30 with 0.21 std and C10 has 0.42 with 0.37 std. The number of errors reduced in static task distribution as compare to dynamic task distribution under each and every assistance functions specified in each condition as shown in Fig. 5.

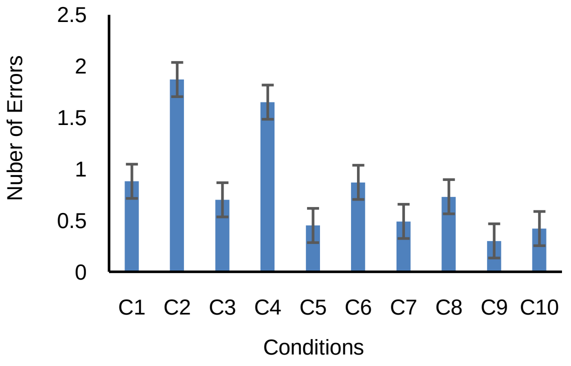

Fig. 5: Mean errors based on various conditions

4.7 *Subjective evaluation*

Questionnaires were given to all participants in the experimental process and feedback was taken. The questioners contain different option based on the specified conditions. The subject has to choose options in their order of precedence basis.

Q1: Which condition did you prefer? Classify in order of preference.

(a) C1 (b) C2 (c) C3 (d) C4 (e) C5 (f) C6 (g) C7 (h) C8 (i) C9 (j) C10

For question 1, 70% student select C9 is their first choice for task execution. 60% choices comes for option C10, Then next higher choices comes for option C5 and C6 which are 50 and 45% respectively. The remaining choices are marked 35, 30, 27, 25, 23 and 20 % for options C3, C4, C7, C8, C1 and C2 respectively.

Q2: To accomplished the task which assistance function is more useful and helpful? Organize on basis of priority.

(a) Audio communication (static and dynamic) (b) Lighting (static and dynamic) (c) Arrow (static and dynamic) (d) color changes (static and dynamic)

Arrow (static and dynamic), was marked by 60, 25 and 15 % students' as first, second and third precedence respectively. Only 30 % students' marked lighting (static and dynamic) on first position while 40 and 50 percent users placed it on 2nd and 3rd position respectively. Audio/*Oral communication* was ranked for second position by 30 %, while first and third position each got 35 percent votes. And the color changes of the avatar (static and dynamic) got 40, 35 and 25 % as first, second and third choices for the students.

Q3: Under in which condition, the action of the collaborator is more perceived? Classify in order of preference.

(a) C1 (b) C2 (c) C3 (d) C4 (e) C5 (f) C6 (g) C7 (h) C8 (i) C9 (j) C10

For question 3, 70% students' select C7 and C8 at their 1st precedence while 30% put it on the 3rd. C5 and C6 got 50, 30 and 20% opinions for first, second and third precedence positions respectively. C1 and C2 was marked by 30 and 70 percent users for 2nd and 3rd position respectively, similarly C3 and C4 was marked by 40 and 60% students' precedence for 1st and 3rd choice. Option C9 and C10 was selected by 80% students for their first option and 10% as a 2nd and 3rd choice respectively for task execution to perceive better the action of their collaborators.

Q4: Under which condition the collaborator presence is more sensed? Classify in order of preference.

(a) C1 (b) C2 (c) C3 (d) C4 (e) C5 (f) C6 (g) C7 (h) C8 (i) C9 (j) C10

For question 4, 80% students' select C9 and C10 at first priority while 20% put it on the 2nd. Similarly C5 and C6 receive 50, 30 and 20 % opinions for 1st, 2nd and 3rd priority respectively. C3, C4, C7, C8, C1 and C2 got 50,40, 40,50, 10 and 40% students' marked for first choice option while 25, 30, 30, 25, 45,and 30 for 2nd and 3rd position respectively.

Q5: In which condition, coordination between the collaborators is more established? Classify in order of preference.

(a) C1 (b) C2 (c) C3 (d) C4 (e) C5 (f) C6 (g) C7 (h) C8 (i) C9 (j) C10

To this question the precedence positions are same as that for question 4.

In concluded remarks we can say that C9 static (Audio + arrows + lighting and color changes) and C10 dynamic (Audio + arrows + lighting and color changes) is the most preferable condition and users placed it on first and second priority position. In C9 and C10 condition students' better collaborate with each other and also sensed their collaborator bitterly. While audio communication enhanced awareness and realism. Furthermore (C5 and C6), (C3 and C4) and (C7 and C8) were placed on 2nd, 3rd and 4th position respectively.

4.8 User Learning

To execute the task under condition C1 the students' completed the specified task in 188 seconds in first trial and took 144 seconds in fourth trial. Under condition C2 they took 204 sec in first trial and 175 sec in his/her fourth trials. Similarly under conditions C3, C4, C5, C6, C7, C8, C9 and C10 they took (170 sec and 135 sec), (195 sec and 161 sec), (150 sec and 123 sec), (180 sec and 140 sec), (168 sec and 131 sec), (192 sec and 152 sec), (135 sec and 115 sec) and (133 sec and 120 sec) in their first and fourth trials respectively as shown in Fig. 6.

Therefore, the percentage performance improvement are 23.40, 14.21, 20.58, 17.43, 18, 22.22, 22.02, 20.83, 14.81 and 9 percent for conditions C1, C2, C3 C4, C5, C6, C7, C8, C9 and C10, respectively.

From the results shown in Fig. 6, the assistance function in the form of arrows with audio communication based on static and dynamic task distribution enhances user performance in manipulation of the objects in CVEs. The arrow is useful in collaborative manipulation of objects in the CVEs due to its feedback.

5. Conclusion

In this paper the assistance function in collaborative tele-operation assembly task based on task distribution model is investigated. Two subjects via local area network with different stations was connected to performed the assembly task of making the words "UNIVERSITY" from different constituent scattered objects in CVEs. The use of assistance function (lighting, arrows and color changes) with audio communication was examined, to check their special effects on collaboration/cooperation and subjects performance. Twenty subjects voluntarily performed an assembly task collaboratively with static and dynamic task distribution.

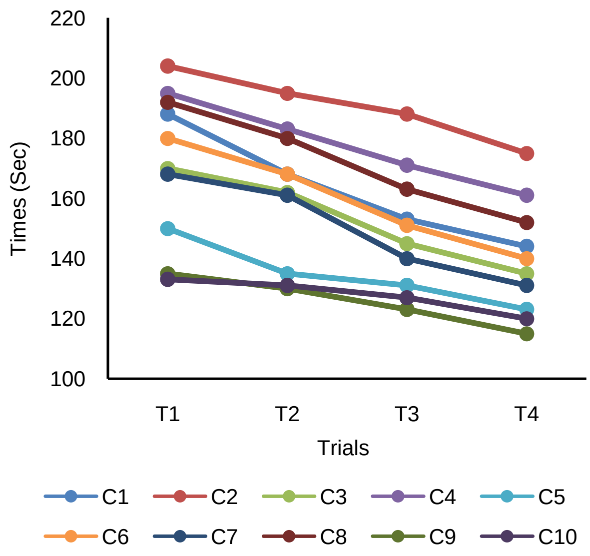

Fig. 6: User learning in various trials

Results revealed that assistance function (lighting, arrows and color changes) with audio/oral communication helped subjects to manipulate objects collaboratively in VE. Also these assistance function with audio, based on task distribution model when used collectively increases users performance in CVEs. Future work will be carried out to integrate the force feedback modality and examine its effects on collaborative task. For future direction, a CVEs system will be implemented for long distance geographical network i.e. WAN and the effect of network delay in the form of network latency will be investigated based on the task distribution model.

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