Adaptive Distributed Multimedia : A Concept for Characterising Co-cognitive Virtual Reality Systems

N. SESHAGIRI

Abstract

Proposing the concept of adaptive distributed multimedia as an essential next step in the evolution of multimedia C&C systems, it is forecast that it will become the building block for the second generation of Virtual Reality Systems. Introducing the term 'Co-cognitive Virtual Reality' as a consequential generalisation and unification of the various alternative concepts of virtual reality and cyberspace propounded and developed by Lanier, Rheingold, Robinett and Henderson, among others, functional characterisation and basic design imperatives of such systems are examined. It is argued that such a design would call for substantive elaboration of not only the design principles of tele-presence described by Pehrson, et.al into adaptive tele-presence and adaptive flexible trading, but also the design concepts of spacio-temporal composition of distributed multimedia objects developed by Little and Ghafoor into relative spacio -temporal composition and adaptive synchronisation. Some of the beneficial applications of co-cognitive Virtual Reality like cybernetic situated co-learning and cooperative tele-research are described.

1. INTRODUCTION

Since 1989, persistent demands have been made for developing realistic 4-dimensional multimedia solutions for certain environments that a learner can 'enter' with a view to lead to technologies which can enable him 'Virtual Participation' in the simulated environment he has entered. This emerging technology was called, 'Virtual Reality' by Jeron Lanier of VPL Research Inc. [1]. Virtual Reality is basically an integration of several well developed technologies like 3-D Stereoscopic displays, Holography, sophisticated graphic chips, large memory capacity parallel processors in conjunction with a number of user-computer interface gadgets like fibre-optics data gloves, 3-D LCD goggles, tactile feedback system, cybernetic body suit, tread mill, pressure feed-back etc., all of which have been developed in the past for entirely different applications. Some elementary forms of Virtual Reality are known to have been used for robotic control, scientific visualisation and medical imaging [2]. Virtual musical instruments have been designed using this technology by Trubitt [3]

The author is with National Informatics Centre, New Delhi, India

and Markoff [4]. In Virtual Reality, user enters the computational space instead of merely observing the computer screen by interacting through a Mouse or key-board or voice recognition unit. The next generation of interactive units are special electronic sensor gloves and cybernetic body suit which are linked through a computer to a set of 3-D LCD goggles mounted in a head-set which has two micro-video screens filling the entire field of fiew. With this, the user can see the simulated, yet realistic, representation of 3-D objects in 3-D space. With the time sequence simulation, the representation becomes dynamic.

Computer animated image response to a programmed stimulus-response characteristics with respect to the movement of the user's hands or body which are linked to the computer by fibre optic glove and body suit act as data transceivers. It has been demonstrated that this, in conjunction with the 3-D profile of the user, will enable the user to participate in the simulated environment, but as his own virtual image in the computer and controlled by his real movements. David Zelter of MIT and Wheeler [9] advocate the use of the phrase 'Virtual Environment' as Virtual Reality is seen as the liimiting case of the former. The technology of Virtual Reality has opened up new levels of sophsitication of training of air plane pilots, nuclear power plant operators, etc.

Henderson [5] introduces Virtual Reality through his concept of cyberspace. Our experience in designing interactive multimedia simulation is applicable for designing Virtual Realities; similarly, work in multimedia database is applicable for designing cyberspace environment. Thus Virtual reality is considered as the next step in the technological evolution of Interactive multimedia. Using this concept, Henderson successfully designed his special purpose computer called, 'Traumabase Simulator' which he demonstrated for training battle-field doctors in a 'Virtual' real-life audio-visual environment. Here he simulated Virtual Realities as a multimedia environment to provide the apprentice battle-field doctors scenes of realities different from their own.

The concept of Virtual Reality developed first by Lanier was in the nature of a single user technology. It should not only be made multi-user, but also adaptive. However, neither the concept of multi-user nor that of adaptive control connote the familiar term in computer and control technology. An entirely new way of looking at this is called for. A first attempt at this is made in this paper.

2. ADAPTIVE DISTRIBUTED MULTIMEDIA

Designing Distributed Multimedia (DMM) as a system for which the user must be able to perform the same things from any of the nodes of the system and access multimedia information stored anywhere in the system, adaptibility is introduced as a built in process by which the system continuously optimises its behaviour in state-space to dynamically come into homeosthatic equilibrium with the user-computer interaction within the ambit of structural or externally imposed constraints. In the adaptive DMM, the system is itself responsible for finding the Multimedia data by a dynamic optimal strategy homeosthatic with an interactive user-computer environment. In this frame-work, adaptive 'computational' control is exercised for providing identical homologous treatment of the

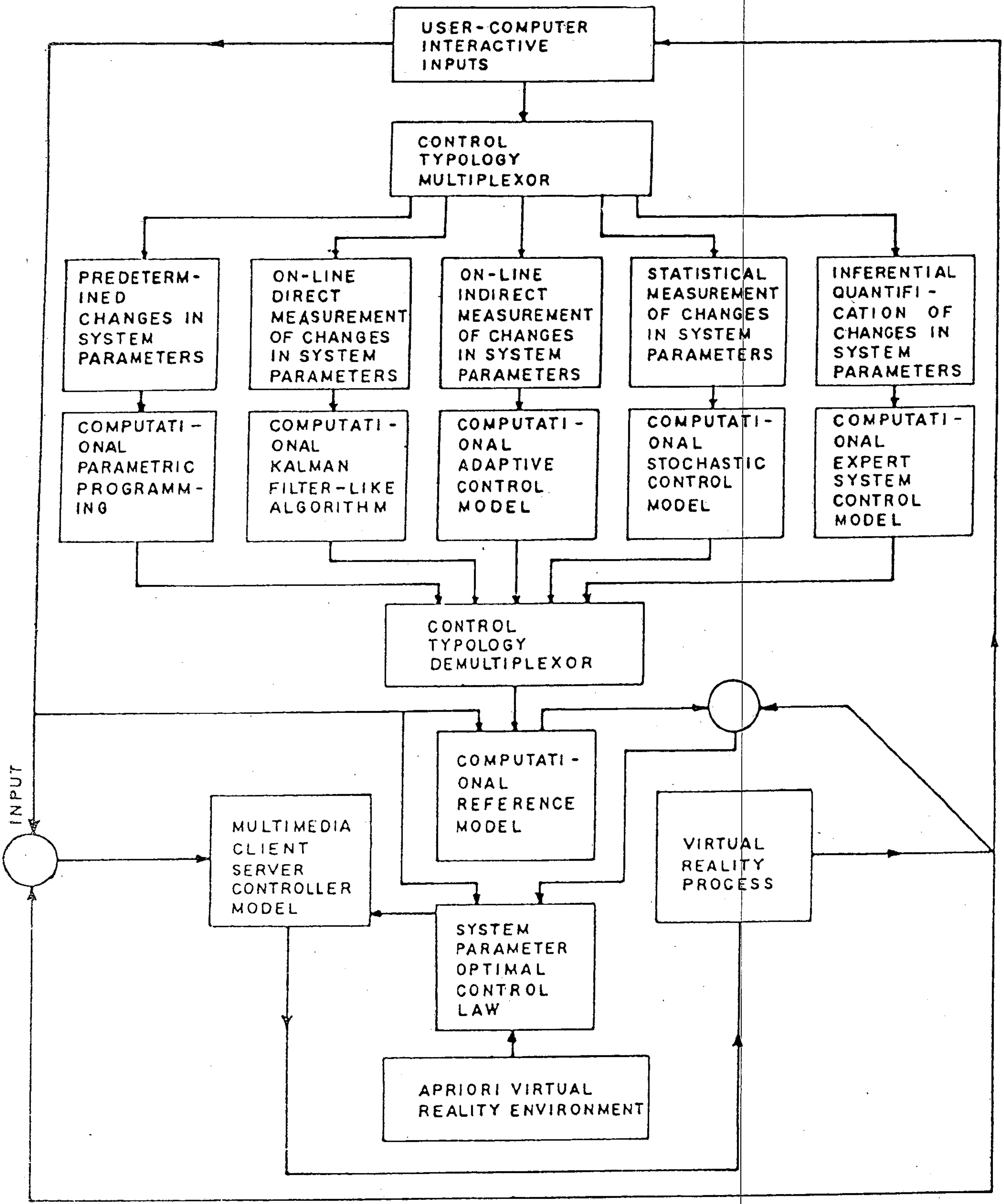

Fig. 1 : A GENERAL FRAMEWORK FOR OPTIMAL 'COMPUTATIONAL' CONTROL IN DISTRIBUTED MULTIMEDIA SYSTEMS

overlapping priorities of data media and the deployment of multiple media in some mutual relations like, for example, browsing through video display with sound and animation objects on the fly.

Such adaptive locational transparency of not having to know where the objects or users are, pre-supposes global animation of objects as the basis of global sharing, i.e., system wide agreement on animation, object invocation and security. This also pre-supposes a high level of structuring of multimedia information accessible in a type-dependant way.

Adaptive computational control, in the face of dynamic client/server interaction, requires a proper remote-procedure call which can compile communication code directly from interface-description languages which can cope with adaptive computational control. Integrating communication subsystems for Isochonous multimedia data streams, remote procedure calls (RPC) and reliable causal broadcast capability. For adaptive real-time multimedia RPC and broadcast (like for example, window manager, drawing and freedom on the screen as demanded by the user-computer interaction at some precise moment), scheduling the mixture of adaptive real time, non-adaptive real time, non-adaptive non-real time is also essential. Optimal system control for the above is described in Fig. 1 in terms of the following five situations.

1. The optimal control law is pre-programmed for compensating tractable changes in the system parameters by parametric programming.

2. The optimal control law is centralised for compensating online systems generated by direct adaptation algorithms like the computational analogy of the Kalman's Filtering Algorithm.

3. The optimal control law for compensating indirectly measured changes in the system parameters by algorithms which are computational controlled analogies of the adaptive reference models like the method of Liapunoff.

4. The optimal control law for compensating statistically measured changes in the system parameters which are computational controlled analogies of the Stochastic Control models.

5. The optimal control law for compensating the inferentially described changes in the system parameters by algorithms which are computational controlled analogies of the expert system control models.

In what follows in this paper, the above five optimal control laws are assumed to be necessary and sufficient within the overall frame-work of a Tetrad of Optimal 'computational' control outlined in Fig.2. and broadly described below:

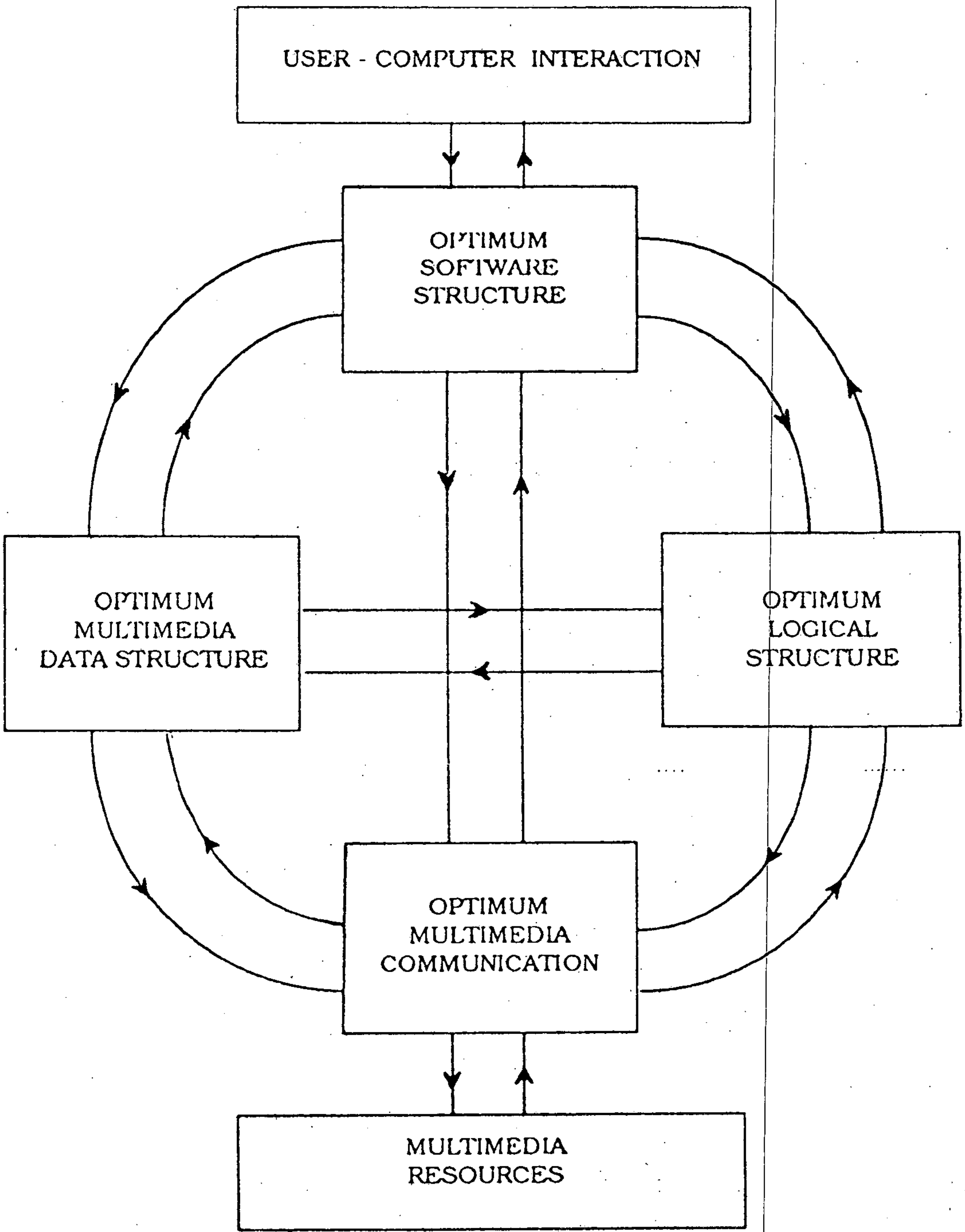

Fig. 2 : The Tetrad of Optimal 'Computational' Control in Distributed Multimedia Systems

2.1 Optimum Distributed Multimedia Data Control

For the client/server adaptive frame-work described in Fig.1, a queuing data theory model is described here to illustrate this category of optimum multimedia data controlled and managed by a network server. The data is distributed over many servers in the network with previously defined access to the data or work with distributed data residing on the discs of the servers. Here one works on element of the distributed data-file, record, field, etc. One occupies the element until processing of the data in the element is completed after which he releases the element for another user. A model has been developed on the basis of a request structure of the network server. Mathematical expression for the characteristics of the evaluation of the access to the data is derived. Each task distributes requests to the designated server, where the data of the request is placed. The data for the application is distributed in the network on the basis of some user considerations and principles like meaning of the data, where to use the data and the placement of the users of the data.The structure of such requests consists of two main parts - distribution of the requests to the server where the requested data is placed and the processing of the data which includes the lock, read modify, unlock operation, etc. This request structure is used as a basis for developing queuing theory model for modelling the work of applications with distributed multimedia data. The basic elements of the queuing system are, input request flow, service mechanism and queue discipline. Within the framework of Fig.1, adaptive control methods are deployed for input request flow, service mechanism and the queuing discipline. The states of the system and the transition probabilities are derived adaptively within a broad mathematical template. In this, a facility for adaptive location transparency is also built in.

2.2 Optimum Logical Structure of DMM

From the software point of view, DMM logical control is viewed as a distributed facility for locational transparency in sharing of multimedia facilities, resources and information. Depending upon the types of multimedia resources, DMM system has a number of functionally demarcatable DMM subsystems linked together by multimedia Input-Output ports. These are viewed as a complex system of cooperative algorithms or processes. During the task realisation a user creates a virtual network of processes which, in turn, consist of a set of logically connected co-processes. Each of the co-processes for the given virtual process is executed in a distinct virtual process of the DMM system.

A frame-work is given for the automatic generation of synchronisation and communication mechanism such that the execution of processes will be feasible as optimall to certain criteria. One method of optimal allocation of tasks to particular subsystems is to minimise the inter-communication of co-processes. The method of traces which is a general technique for software specification is used for this in a modified way to describe the processes in the DMM.

2.3 Optimum Multimedia Integrated Communication

For the purpose of illustrating the types of methods used in the optimal control of integrated multimedia communication systems, we consider the limited case of the optimal control of the integrated voice and data multiplexing system. The system is dynamically and adaptively controlled according to the scheme of Fig.1 by accepting or rejecting a new arrival voice call according to its state. Undiscounted Markov decision process characterises the control problem[6] . One possible multiplexing technique is the time division scheme in which each fixed duration frame is partitioned into M-Time units called, Slots. Appropriate time slots in the frame are allocated for transmitting the digitised voice. The voice calls arrive according to the independent Bernoulli trials with probability λ of an arrival during each frame. The accepted voice calls wait in gate queue until the beginning of the next frame. The service time for voice call is geometrically distributed with probability μ of service completion during each frame. The remaining time slots in the frame are allocated for the transmission of the data packets with a fixed size of time slot. Each packet arrives in Poisson process. If no time slots are available for packets, they wait for transmission in a buffer of size L. We modify the methods developed by Shioyama, Konheim and Pickholtz [7] to come within the ambit of the general control scheme of Fig.1.

The rejection cost α is incurred by a rejected voice call and a loss cost α_p incurred by a packet loss incurred by a fully occupied buffer. The holding cost incurred by a packet is taken as one unit cost. The system is controlled by accepting or rejecting a new arrival voice call so as to minimise the expected cost.

The state of the system is observed immediately before the slot assignment at the beginning of each frame and then control action is taken depending upon the observed state. The state described by $i = (i_1, i_2)$ where i_1 is the number of voice calls in service or in the queue and i_2 the number of packets in the buffer. The state space S is given by the set of $\{i = (i_1,i_2);\ i_1=0,..,M;\ i_2 = 0,..,L\}$. The control action 'a' is chosen from 1 or 0 denoting acceptance or rejection of a new voice, call arriving during the frame. It is assumed that action 'a' is 0 at state i such that $i_1 = M$. A policy is defined as any rule $\{a(i) =0 \text{ or } 1;\ i\in S\}$ depending on the observed state i.

Define r(i),L.(i),q(k) and q.(k), respectively, as

$$r(i)=(i_1+i_2-M)^+,\ L.(i)=L-r(i) \qquad \text{for } i=(i_1,i_2)\in S,$$

$$q(k)=\lambda^k \exp(-\lambda p)/k! \qquad \text{for } k=0,1,..., \qquad \text{..... (1)}$$

$$q.(k)=q(k) \qquad \text{for } k=0,...,L.(i)-1 \text{ and}$$

$$= \sum_{m=L.(i)}^{\infty} q(m) \qquad \text{for } k = L.(i)$$

where, $(x)^+ = \max(0, x)$.

Let P(i, j, a) denote the transition probability that the system moves from state i to state $j = (j_1, j_2)$ assuming that an action 'a' is taken in state $i \in S$. It is assumed that the probability is i_1, μ for one of i_1, voice calls for services to complete its services during one frame, i.e., $i \in S$, $j_2 = r(i),..,L$

$$P(i, (i_1 - 1, j_2); a) = (1 - \lambda a) i_1 \mu q \cdot (j_2 - r(i)),$$
$$P(i, (i_1, i_2); a) = (\lambda a i_1 + (1-\lambda a)(1 - i_1 \mu)) q \cdot (j_2 - r(i)) \text{ and} \qquad .... (2)$$
$$P(i, (i_1 + 1, j_2); a) = a (1 - i_1 \mu) q \cdot (j_2 - r(i)).$$

When the system is in state i and an action 'a' is taken, the expected loss cost C_L for packets and expected rejection cost C_r for voice during one frame are given by

$$C_L = \alpha_p \sum_{K=L.(i)+1}^{\infty} (K - L.(i)) q(k) \text{, and, } C_r = \alpha \lambda (1-a) \qquad ... (3)$$

When an action 'a' is taken in state i, the expected waiting cost C_W for packets can be proved to be

$$Cw = r(i) + [\sum_{k=0}^{L.(i)} kq(k) + L - (i)\{1 - (L-(i)+1)/\lambda p\} \sum_{k=L.(i)}^{\infty} (i) q(k)$$
$$+ (L.(i)+1) q(L.(i) - 1) + L.(i) \sum_{k=L.(i)+1}^{\infty} q(k)]/2 \qquad .... (4)$$

From these, the expected minimum cost C (i, 'a'), $i \in S$, 'a' $\in \{0,1\}$ during one frame is given by $C(i, a) = C_W + C_L + C_r$.

Since the transition probability matrix {P(i, j, 'a")} has a single chain for any policy, there exists a stationary optimal policy that attains the minimal cost rate G independent of the initial state. In the same way, as Derman [8] has derived the optimality conditions, we derive that applicable in the frame work of Fig.1 for g^* and the relative value v.(i), $i \in S$ satisfying

$$v.(i) = \min_a [c(i,a) - g^* + \sum_{j \in S} P(i,j; a) v.(j)], \; i \in S.; \; v.(0) = 0; \qquad .... (5)$$

A policy minimizing the right-hand side of equation (5) in the framework of Fig.1 is determined.

2.4 Optimum Software Template

For the adaptive DMM systems essential for Virtual Relaity, the design of the entire software has to be in template form giving scope for modification of the software structure by itself in an adaptive manner within the framework of Fig.1. This necessarily calls for software design methods based on Graph Theory. The optimization of the software structure within the degree of freedom afforded by the template structure requires multi-step positional game of pairs of players.

The minimising player chooses at every step a statement which generates the associated programme unit, while the other player determines the conditions for unit termination. Formally the problem statement is as follows. A finite algorithm is presented as a graph G(X,U) - a finite directed graph with the set of vertices X and a set of edges U which is free of cirquetes. Each vertex $x_1 \in X$ presents one of the conditions of vector of variables and each edge (i, j) (epsilon) U presents an operand allowing us to obtain the jth conditions of this vector by means of ith conditions. A sub-graph $G_q(X_q,U_q)$, $X_q \subseteq X$, $U_q \subseteq U$ presents a single program unit $\{G_o\}$ - the set of subgraphs, connected with different realisations of the main programme and $\{G_q\}$, $q \neq 0$, - the set of subgraphs, presenting different subroutines. Each edge $(i, j) \subseteq U$ becomes vector $r(i,j) = \{ r_1(i,j), r_2(i,j)\}$; $r_1(i,j)$ is a function of the operand, associated $(i, j) \subseteq U$, realisation, $r_2(i,j)$ - the set of used variables.

Let the Virtual Reality environment which the user enters for sub-objective functions V_1 and V_2 over the software template. When finding the optimal strategy of realisation of the algorithm, the subgraph Gq (Xq,Uq) serves as a general instrument of adaptation. The problem is how to cover all the surfaces of graph G(X,U) with the set of subgraphs $\{G_k\}$ k= 0, 1, 2,.., minimising the goal function. If the goal function minimises the upper bound of computational function, the formal problem statement can be presented as follows:

$$\max_t \max_d \sum_q \sum_{(i,j) \in L_d(s,t)} r_1(i,J) s_q(i,j) \rightarrow \min; \qquad \ldots\ldots \qquad (6)$$

$$\forall (i,j) \in U, \sum_q s_q(i,j) = 1; \qquad \ldots\ldots \qquad (7)$$

$$\forall q, \sum_{(i,j) \in U_q} sq(i,j) = |U_q|, \prod_{(i,j) \in U_q} s_q(i,j); \qquad \ldots\ldots \qquad (8)$$

$$\forall q, s_q(i,j) = 1,0; \ (i,j) \in U_q; \qquad \ldots\ldots \qquad (9)$$

$$\sum_{q} \left| \bigcup_{(i,j)\in U_q} r_2(i,j) \right| \prod_{(i,j)\in U_q} s_q(i,j) \leq v_2; \quad \ldots\ldots \qquad (10)$$

$$\sum_{G_q\in\{G_o\}} \; \sum_{(i,j)\in U_q} s_q(i,j) r_2(i,j) + \max_{G_q\notin\{G_o\}} \left| \bigcup_{(i,j)\in U_q} r_2(i,j) \right| \prod_{(i,j)\in U_q} s_q(i,j) \leq v_1 \qquad (11)$$

This approach can give a structure within the software template for adaptation to the user-computer interaction in equilibrium with the Virtual Reality environment. The input includes the user's strategy and the computer parameters while the output is a modified software adapted to the Virtual Reality environment in which the user-computer interactive interface is imbedded. Initial inputs and the decision on the optimisation is realised in ån interactive mode, but as time progresses, adaptive 'computational' control takes over within the framework of Fig.1.

3. CO-COGNITIVE VIRTUAL REALITY SYSTEM

Cooperative research in any area involving continuous inter-play between experiment and theorisation by a number of researchers is likely to benefit substantially with the help of Virtual Reality Systems[9]. When several users 'enter' the Virtual Reality environment, there is need for synchronisation for co-cognition of the Virtual Reality environment. All the users have to share the same stimuli of the Virtual Reality environment while their response may be different depending upon their perceptive ability, knowledge base and their motivation at that point in time. A researcher has to not only learn from the VR environment, but also contribute to its adaptive course. Sharing of experience, knowledge base and motivation of one another should be facilitated by the VR system. Such VR stimulated cooperative research is the next logical step in a research methodology. We call this complex multi-user adaptive distributed multimedia based Virtual Reality environmental system as 'Co-cognitive Virtual Reality (CVR)".

Before describing the technical details of the CVR we will review a concept of situated learning proposed by Henderson in 1990 with specific reference to the possibility of application to airline pilot training in a Virtual Situated environment. Henderson situates Virtual Reality in the context of interactive multimedia as a training tool. In his Traumabase Simulator, when a text window appears for the learner, sound track keeps playing the realistic sounds and video plays the simulated environment. The simultaneous and integrated display of information can be in terms of texts and numbers, images, sounds and models. John Seely Brown [10,11] introduced the term 'situated learning' in 1989 while examining certain useful examples of teaching skiing which reduced learning time from two years to two weeks and identified the features of such successful applications shared in common. He lists six successful strategies for learning as: Apprenticeship, Collaboration, Reflection, Coaching, Multiple Practice and Articulation. All these strategies can be naturally embedded in a Virtual Reality based training system. According to Brown, knowledge is situated in the sense that it is the product of the activity, context and culture in which it is developed and used. Activity and situations are integral to cognition and learning. Therefore, this knowledge must be learned in the context of the actual work setting or a'Virtual Surrogate' of the actual work environment.

A study of accidents conducted by Boeing Aircraft reveals that most of the accidents could have been avoided if the non-flying pilot in the cockpit had promptly taken action. The traditional pilot training methods, including that in a conventional simulator, do not really address the problem that crews encounter thereby resulting in accidents. The LOFT training programme was devised to provide practice, team building and crisis management for the pilots. In LOFT training, the goal is to replicate as realistically as possible, the actual flight environment complete with delays, adverse weather etc. By having pilots practice such situations in sophisticated Virtual Reality environment simulators, they prepare themselves for real-world emergencies. In the LOFT simulator, there is no instructor intervention and pilots are allowed to follow their own course as they like. In the quest for more and more real life simulations, knowledge of the above six critical situated learning components outlined above can be accommodated. The LOFT simulator is inadequate because each pilot gets trained in the system as a single user even though he learns how to cooperate with a fellow pilot. Yet, the two pilots do not share a common Virtual Reality environment. It is in this sense that the co-cognitive adaptive Virtual Reality simulation proposed in this paper will be the ideal direction to take for not only applications like situated learning by two or three pilots, but also for more complex applications like cooperative research.

Virtual Reality provides a high degree of sensor realism like 3-D visual display that the user actually appears to enter into using a head-mounted display, electronic glove and body suit. Virtual Reality provides a user with an opportunity to practice activities requiring refined motor skills using the hands, like surgery or molecular chemical synthesis. If the present development of virtual reality are a guide, it can be forecast that within the next one decade, it is possible to teach a surgeon how to handle a scalpel without drawing blood by monitoring the fine motor skills involved in carrying out this sensitive procedure. This Virtual Reality training system would provide ongoing feedback considering the accuracy of the learner's movement by means of a tactile glove that applies pressure on the palms of the hand. If used in a research laboratory with Virtual Reality training systems, the reality of the high technology work place can be simulated.

A broad schematic of a co-cognitive Virtual Reality system is outlined in Fig.3. N users interact together in Virtual Reality environment. Each user interacts with a single user virtual reality system of the type described in Fig.1 for creating a VR environment through the user-computer interaction. The user-computer interface while acting as the bridge between the user and the computer also receives inputs from a-priori virtual reality environment as well as online final output of the co-cognitive virtual reality system fed back as input to each user. The output of the single user VR system is fed as N inputs to the corresponding systems of all other users. In addition there is a distributed multimedia multiplexer for N users and M multimedia resources. The output from each user which may

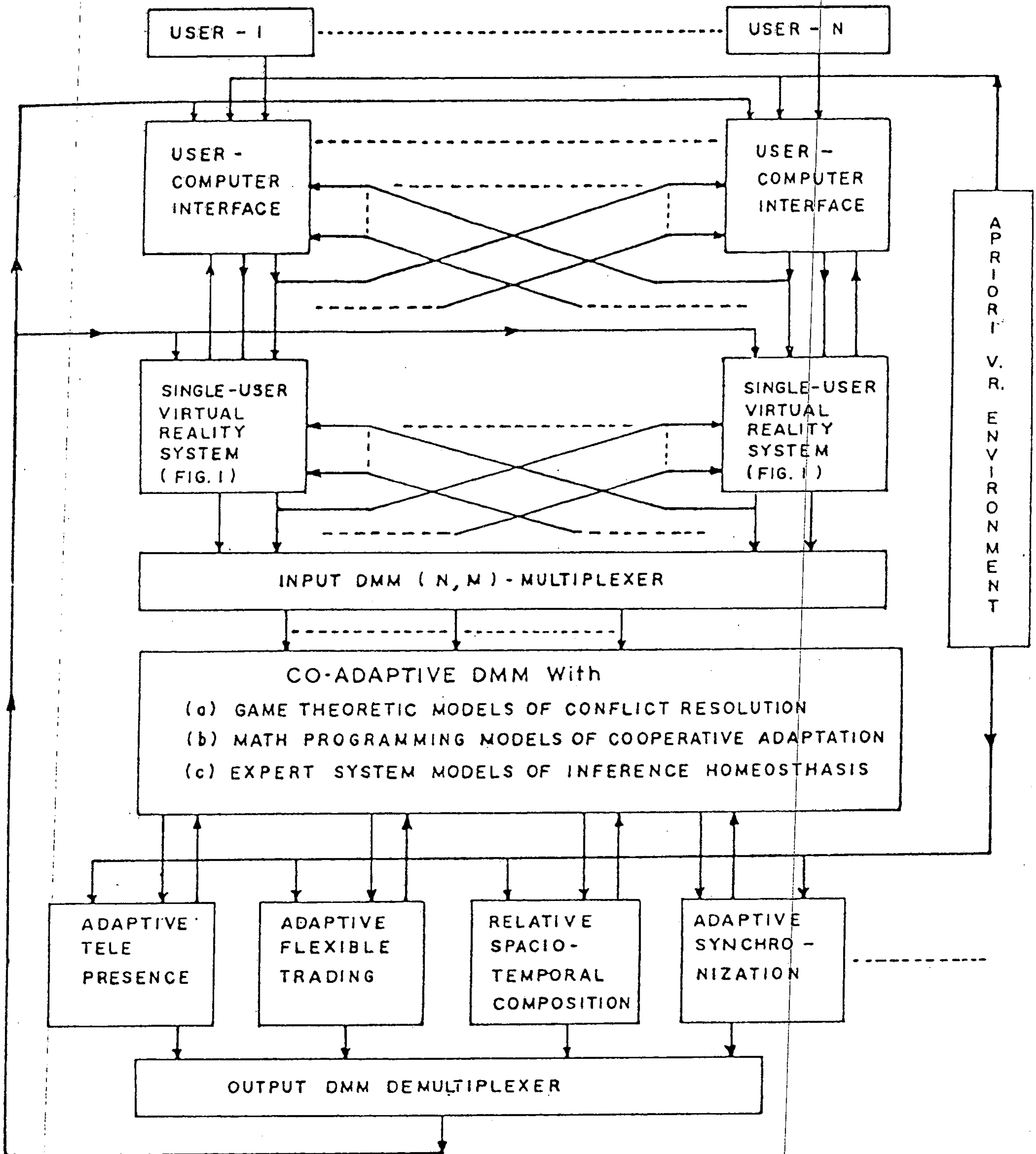

Fig. 3 : BROAD SCHEMATIC OF A CO-COGNITIVE VIRTUAL REALITY SYSTEM

be in the form of text, audio, graphics and video of his VR environment, are fed in as inputs to the other users while they are adaptively evolving their own VR environment. A facility for co-cognitive distributed multimedia information and knowledge processing assists in correlating and integrating the individual VR environment into co-cognitive virtual reality environment. The direction of integration is such that a global objective of the cooperative research by the N users can be accomplished in the shortest possible time and in the best possible manner. When N users enter the CVR environment together for a common purpose, co-cognitive DMM requires methods and models for conflict resolution, cooperative adaptation and inference homeosthasis. These are respectively carried out utilising game theoretic models, mathematical programming models and expert system models. In addition, the co-cognition DMM controls the various attributes of co-cognitive like adaptative tele-presence, adaptative flexible trading, relative spacio-temporal composition and adaptive synchronisation among others which are briefly described below. The totality of outputs of these CVR attributes constitute the output fed back to the individual users. The output DMM de-multiplexer has the function of integrating these attribute outputs in a form and sequence that is optimal for feeding back to the N users.

3.1 Adaptive Tele-presence

Tele-presence is the concept developed by MultiG Research Group in Swedish Insitute of Computer Science at the Royal Institute of Technology and Electrum, Sweden. Pehrson et.al and Fahlen [12] have chosen virtual world as a user interface and communications medium in their tele-presence project. The main issues are visualisation interaction and distribution. The visualisation in a simulated 3-D world uses a head-mounted stereoscopic display, data gloves, electronic wands and other interfaces to make the interaction as similar as possible to the interaction in the real world. The personal workstation turns into the mobile workstation where display, microphone and ear-phone are integrated with a pair of goggles which are semi-permeable to allow the user to absorb both the virtual and the real worlds. Instead of a Mouse, there is a tracker of body movement. Instead of the key-board an electronic wand is used. The mobile workstation has a wireless interface network. In a virtual world, the user has a feeling of part of the workstation world. The MultiG Telepresence prototype allows several users to share and interact with an object in a separate set of virtual world between which the users can move via gateways. The objects can be processes that represent other users, clocks, 3-D video screens, among others. The virtual world is displayed on a pair of conventional miniature screens on the head-mounted display. The user can select an object, including another user, to perform operations on it. The communication and computer architecture of the MultiG Project are given in Fig.4A and B[12, 13].

MultiG neither has adaptive Distributed Multimedia nor it has any facility for permitting co-cognition of a correlated and integrated virtual reality environment as shown in Fig.3. While the developments in the MultiG project can form necessary hardware and software platforms, they are far from being sufficient. For accomplishing sufficiency, it is necessary to implement the framework equivalent to or similar to Fig.3, over the MultiG tele-presence prototype.

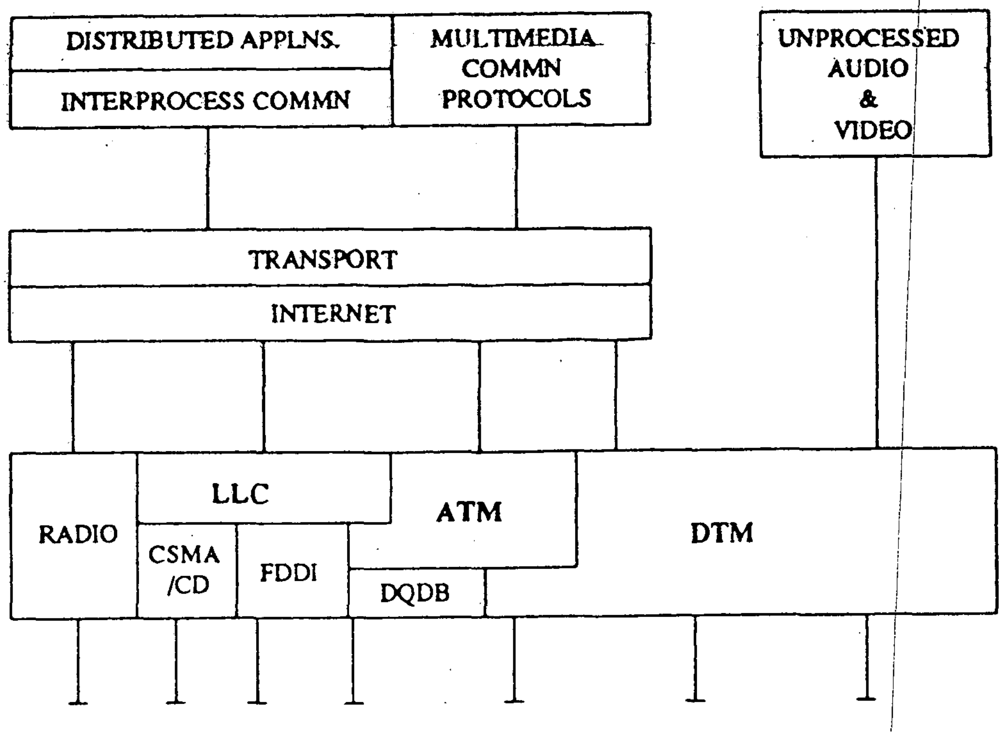

FIG.4 (a): DMM COMMUNICATION ARCHITECTURE BASED ON MULTI.G OF PEHRSON et al

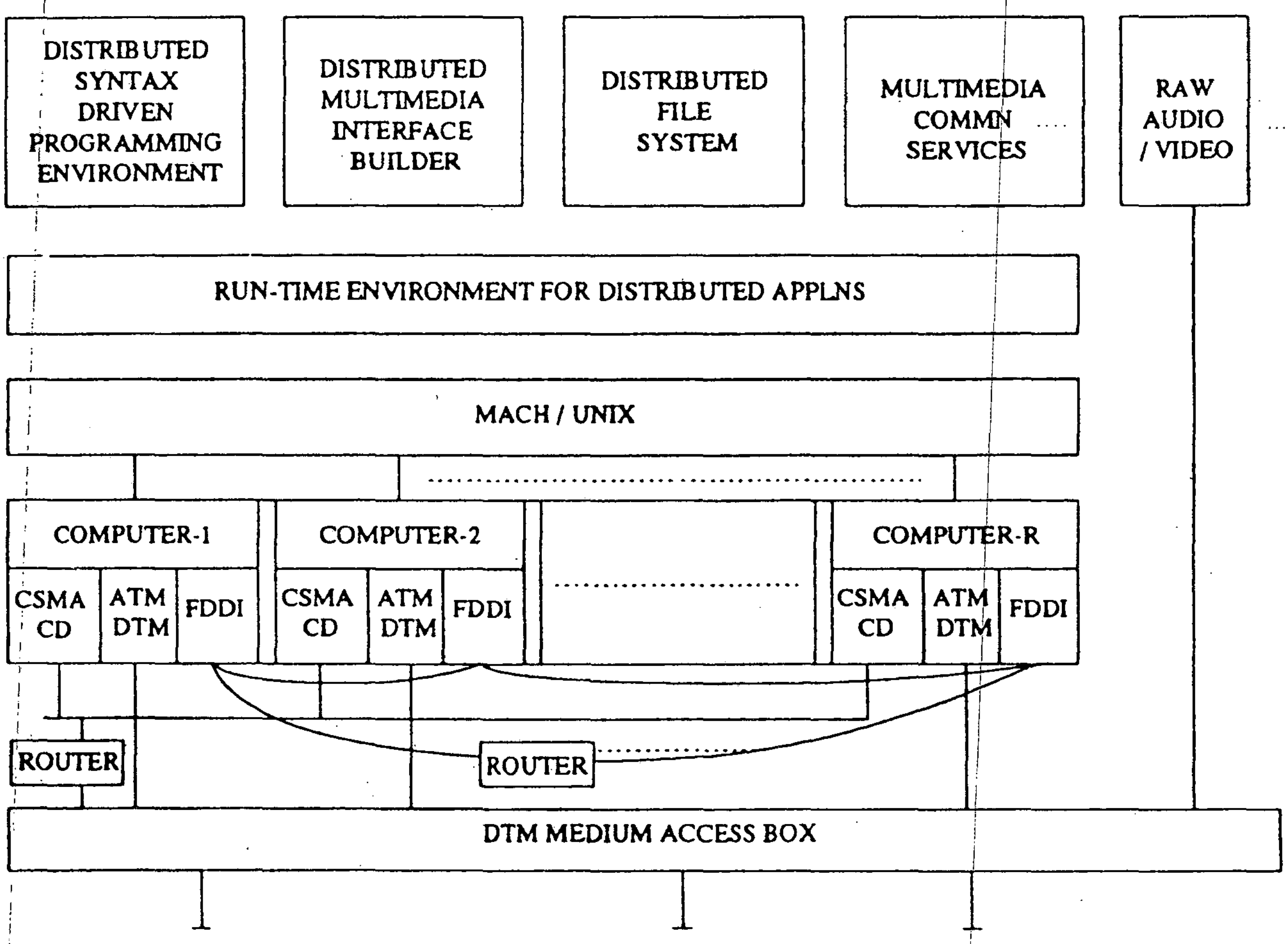

FIG.4(b) DMM COMPUTER ARCHITECTURE BASED ON MULTI-G OF PEHRSON et al

3.2 Adaptive Flexible Trading

The concept of trading has been found to be important for structuring of distributed systems. Trading for services has been intelligently exploited in the Advanced Network Systems Architecture (ANSA) and by the open distributed processing (ODP) standards community. Attempts have been made to extend the concept of trading in the design of distributed multimedia systems. Of particular importance, is the method suggested by Macartiney and Blair[14] for the construction of multimedia trading which can co-exist with standard ANSA traders. This is an object oriented approach for designing and building distributed systems utilising the concept of a trader in which all objects (services) are registered wtth the trader and subsequently carried out and used by the clients. A trader is a mechanism of matching the services required with the services actually available. The object oriented approach fuses the objects as instances of abstract data type along with procedural interface consisting of the messages that an object can understand to give respective arguments and resolutions. Such an encapsulated approach makes the object model amenable to distribution

The ANSA project funded under the UK ALVEY Programme aimed at producing a coherent model for distributed systems. The ANSA team identified five projection that encapasule all the different issues and needs of distributed systems ranging from the requirements of user organisations to hardware and software considerations. The main function of ANSA trader is to match the clients' request against available resources by comparing import and export statements. In addition, the trader has four management interfaces for dealing with the other aspects of the trading databases. These are given in the top portion of Fig.5. The TrType Interface allows for the addition and deletion of types to and from a trader. TrCtxt is an Interface for context management in which the context is a container for registering services. TrFed is an inteface for federation management for the inter-working of different traders by binding the context tree of one trader with that of another trader for a given context with the proviso for de-federation by un-binding the context trees. TrShut is an interface used to shut down a given trader.

With the emergence of multimedia computing, distributed systems have to contend with various types of media as well as give a flexible approach to trading. With multimedia, it is necessary to support continuous media types like video, voice and moving raster images. Quality of services is a major issue in distributed systems especially for DMM for virtual reality systems. DMM also requires the ability to express synchronisation constraints across different types of media. Both continuous synchronisation and event based synchronisation are essential.

Addition of multimedia to ANSA based system increases the number of services for handling such service mechanisms which require flexibility to discriminate between closely related services without sacrificing the open nature of the ANSA architecture[15]. When using such flexible mechanisms, it will be possible to interrogate the trader in a number of ways: explicitly by services; using sub-typing; trading by signature (operation); trading by

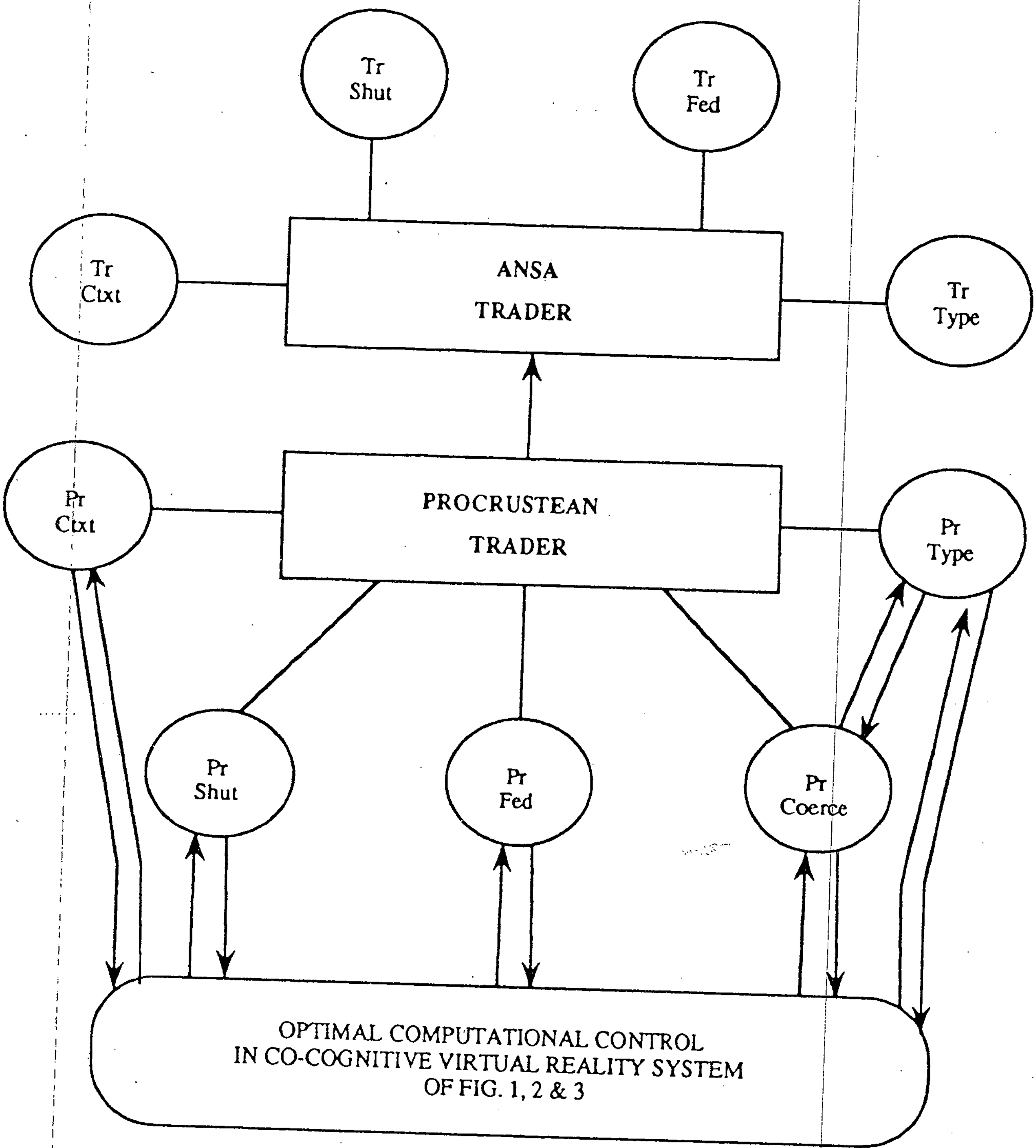

FIG.5: A GENERAL SCHEMATIC FOR ADAPTIVE FLEXIBLE TRADING

extended signature (operations and attributes); trading by extended signature and attribute values; trading by extended signature, attributes and range of values; using attribute coercion feed services within the quality range required; and, using the type of coercion to convert between different services. Apart from the first two, the other six are not available in ANSA and form part of a flexible or Procrustean trading [see middle part of Fig.5], where, similar to the ANSA counterparts, PrType, PrCtxt, PrShut and PrFed are introduced. In addition, an interface called, PrCoerce for coercion management is introduced for ensuring that services just outside the client specified ranges are coerced so that they may be suitable for client use. PrType interface also performs an important role in the composition of multimedia services.

The above described flexible trading mechanism is necessary, but not sufficient for which design of a co-cognitive adaptive Virtual Reality System is proposed. It is proposed here that optimal computational control in Fig.5 is introduced by inbedding the flexible trading into the structure of Figs. 1, 2 and 3 for realising adaptive flexible trading.

3.3 Relative Spacio Temporal Composition

In their pioneering work, Thomas Little of Boston University and Arif Ghafoor of Purdue University have characterised the spacio-temporal composition of distributed multimedia objects along with network considerations for DMM object composition and communication. [16,17,18]. A distributed multimedia information system requires integration or composition of multimedia objects retrieved from databases distributed across the network. Their composition depends on the spacial and temporal characteristics of the multimedia elements. Spacial composition of the multimedia data which is unique for each medium, is quite complex in a CVR environment. For achieving device independence in the integrated environment, we can use storage, processing and communication tehchnology along with open system applicability. Temporal composition on the other hand, calls for the evaluation of relationship among component elements and scheduling their retrieval and presentation accordingly. As multimedia objects are time dependent, they must be synchronised appropriately not only for static objects like still images, but also for continuous streams of audio and video in the presence of random network delays. The synchronisation can, in principle, be extended to multiple streams and non-stream data such as still-images and texts. The application synchronisation protocol and network synchronisation protocol allow communication of complex multimedia presentations from distributed sources for play out at a single site. The protocols utilise the petrinet type of temporal specifications of a multimedia object which specifies precedent relations among all sub-objects in the form of a partial and strict ordering. Little and Ghafoor have accomplished a combination approach for performing temporal and spacial composition of DMIS as a service provided by the network.

The technique developed by Little and Ghafoor needs conceptual and procedural modifications for applicability to CVR environments. The spacio-temporal composition (STC) will be optimised relative to the CVR set. In other words, in CVR state space, there

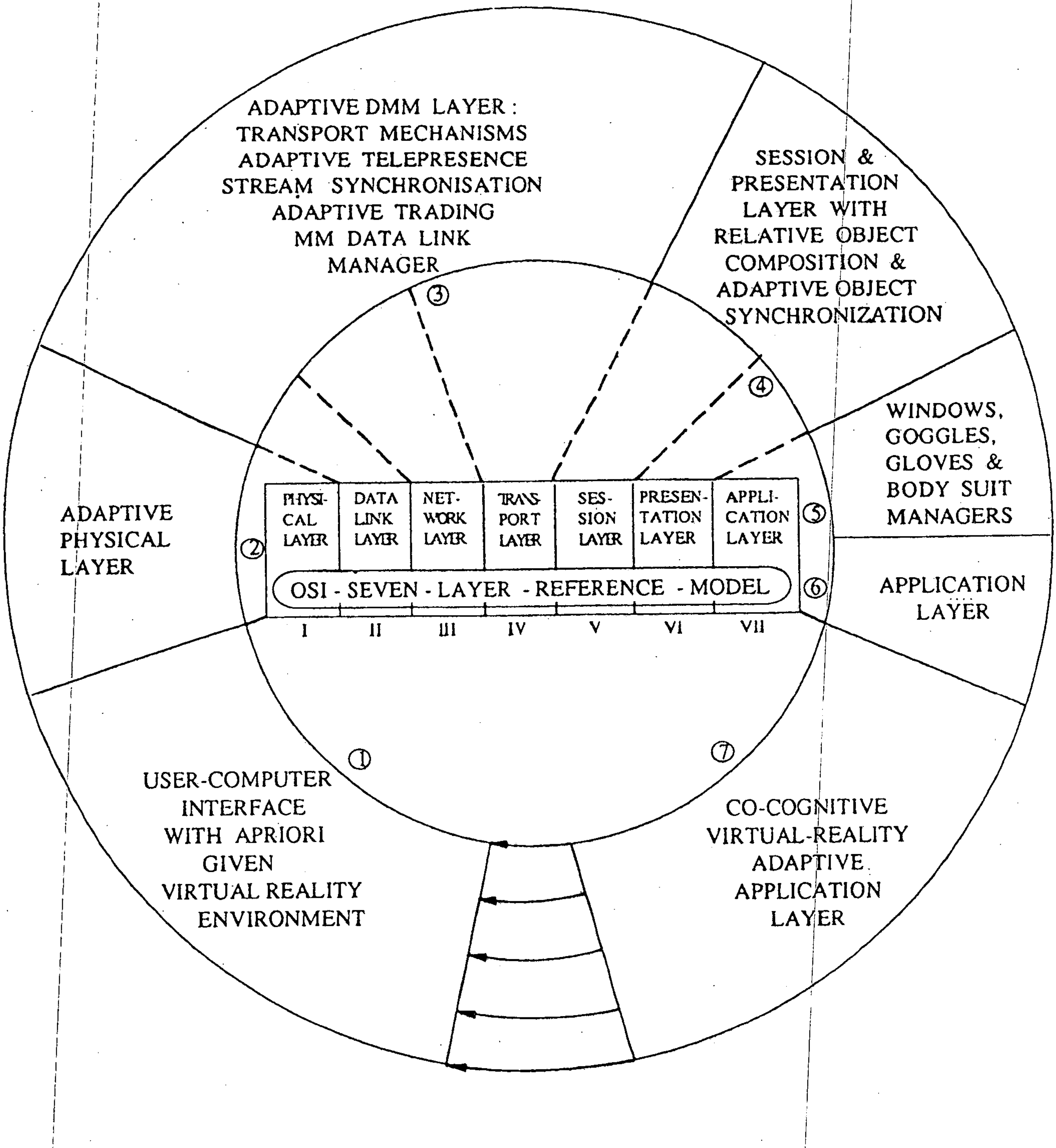

Fig. 6 : Proposed Co-cognitive Virtual Reality Seven Layer Ring Model

is a single valued mapping of the spacio temporal composition which itself forms a state space. Spacio temporal transformation will be designed over this state space in conjunction with the CVR state space. As the STC state space is relative to the CVR state space, we propose the concept of 'relative spacio temporal composition'.

4. THE CO-COGNITIVE VIRTUAL REALITY 7-LAYER RING MODEL

In the background of the new concepts and designs outlined above, a proposal for a 7-layer ring model is presented for the design of co-congitive adaptative VR systems. This ring model is compared with the OSI 7-layer model for reference purposes. While the physical layer is basically and intrinsically adaptive, there is a layer below this which is not so in the OSI reference model. In the CVR environment, when several users start 'entering' the system, there is an a-priori given virtual reality environment in the form of a knowledge base, and hardware, software and netware embodying the constant input to the user at the user-computer interface. This is taken as layer-1 for reasons to be made explicit below. This constitutes the first layer while the adaptive physical layer is the second.

The data link layer, network layer and transport layer in the OSI 7-layer reference model are given in the proposed ring model as an adaptation of distributed multimedia layer integrating all the three OSI layers. However, the adaptive DMM layer, which has the transport layer corresponding exactly to that of the OSI model, has other features which cannot be so seggregated in view of the adaptive integrated nature of this layer. Adaptation tele-presence, stream synchronisation, adaptive trading and multimedia data link manager described in the foregoing, are so integrated that the OSI layers II, III and IV are necessarily fused together into one adaptive DMM layer.

The session and presentation layer of the OSI model also cannot be treated distinctly in view of the integration attributable to the relative objects composition and adaptive object synchronisation.

The application layer in the OSI model is split into two layers in the ring model. Not only the managers for windows, but also those for photonic and electronic goggles, gloves and body suits are also important in the CVR system in so far as they relate to applications. A separate application layer corresponds entirely to layer-VII of the OSI model.

Beyond the application layer, we introduce a new layer called, CVR adaptive application layer. The newly introduced concept of 'adaptive application' in the context of the foregoing sections is inevitable, because, while layers V and VI refer to a-priori introduced applications, the new layer embodies new applications which are precipitated within the system in the co-cognitive virtual reality environment evolving adaptively with intrinsically built in learning imperatives. This builds up a knowledge-base as well as hardware, software and network characteristics in an online, dynamic and evolutionary mode. At any point in time, the state of the system becomes the a-priori given virtual reality environment for the user-computer interface in layer-1. In other words, layer-7 feeds into layer-1, thereby forming a ring. Such a ring model is convenient for adaptive and evolving systems which is a pre-requisite for co-cognitive virtual reality.

5. CONCLUSION

A co-cognitive virtual reality 7-layer ring model is proposed as a necessary and sufficient frame work for enabling several users to simultaneously 'enter' the virtual reality environment and adaptively evolve a co-cognitive environment. It is apparent that the traditional concepts of information technology and control technology have to be modified substatively for bringing about co-cognitive virtual reality[19]. This calls for entirely new lines of inter-disciplinary research and development involving disciplines like distributed computer systems, distributed communication systems, multimedia C&C, optimal and adaptive control system, AI and Expert system, Opto-electronics, Game theory, Mathematical programming, Software engineering, Man-machine interface, applied psychology, transport mechanisms, network design, among others.

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