Scalable and Consistent Virtual Worlds

The Proposed Time Management based on Constrained Communication Model

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Outline

- Introduction
- Previous Work
- The proposed Time Management approach
- Illustrations, Simulations, and Comparison
- Conclusions
- Future Work
- Questions

Introduction

- ***"A VE/Virtual World is an integrated/unified persistent 3D graphical simulation of real and imaginary contents, where avatars feel immersed through tele-presence in shared workspace, though geographically distributed both at infrastructure as well as application levels. Users collaboratively create and manipulate contents of the world they inhabit in."*** (based on definition of Rosedale et al. [1])

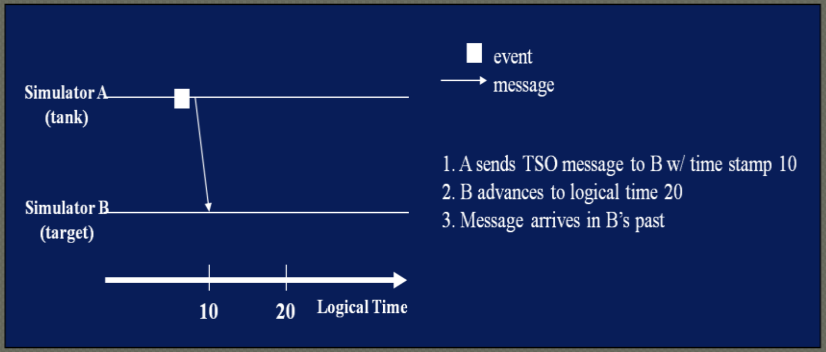
- A VE is an application of simulations (Fujimoto[2])

Introduction

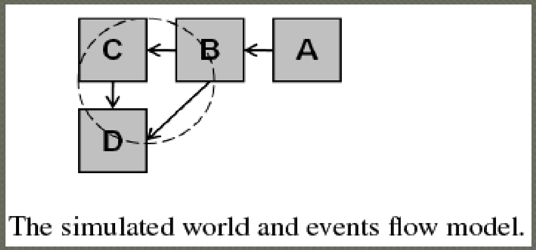
- Key Issues
  - Scalability : Splitting and distributing the world among a set of servers (has issues with conservative approaches)
  - Load Distribution
  - Consistency (Synchronisation/Time Management)

Synchronisation Problem

- Synchronisation maintains the temporal order of events in a system (called local causality constraint).
  - Examples: Flag Set Application, Fire/Destruction scenario
- Lookahead: determines a safe range of events to process
- LBTS (Lower Bound on Time Stamps) : to get a consistent environment time advance must be <= LBTS



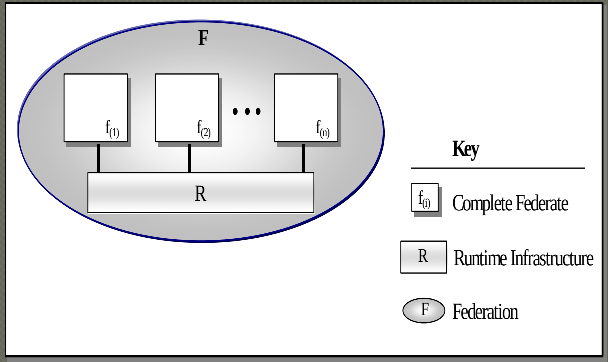
Violation of local causality constraint [3][4]



Flag Set Application

Synchronisation Problem

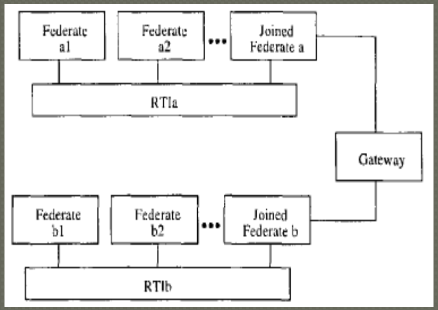
- The aim is to avoid receiving events in a federate past.
- The High Level Architecture (HLA) combines federates (individual simulator) into a federation (a collection of simulators).
- In HLA, the federates and RTI realise this together.



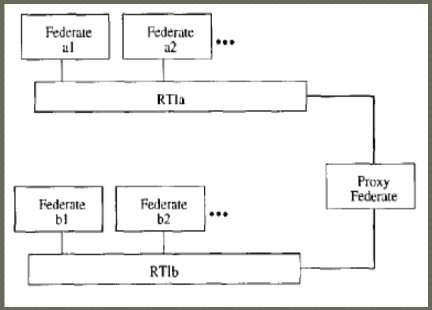
An HLA Federation [3][4]

Previous Work

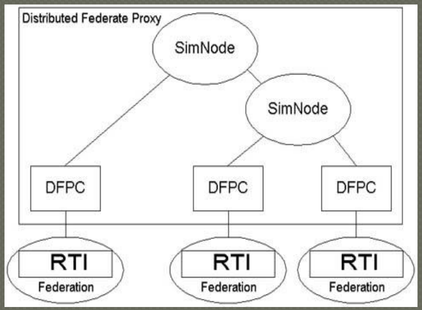
- Centralised Approaches
  - The HLA, for interoperability of simulators [2]
  - Interoperability among federations (a federation community)
    - Federation Gateway, Federate Proxy etc. [5]
- Distributed Approaches
  - Distributed Federate Proxy [6]



Federation Gateway



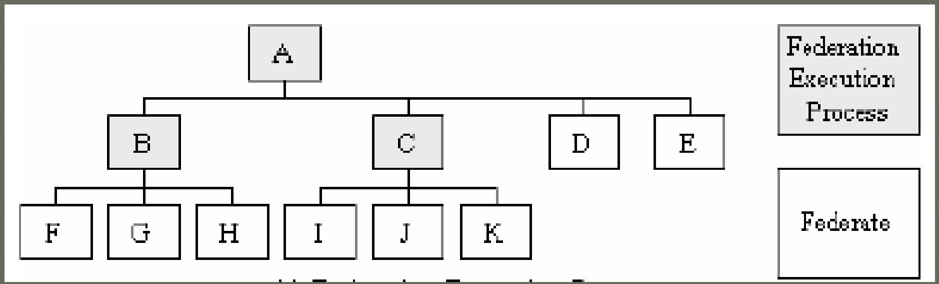
Federate Proxy



Distributed Federate Proxy
[Cramp et al. [6]]

Previous Work

- Hierarchical Approaches [7]
- Decentralised (Peer-to-Peer) Approaches [7]
- Not suitable for large scale virtual worlds with conservative behaviour.



Hierarchical HLA extension [Kim et al. [7]]

The Proposed Time Management Approach

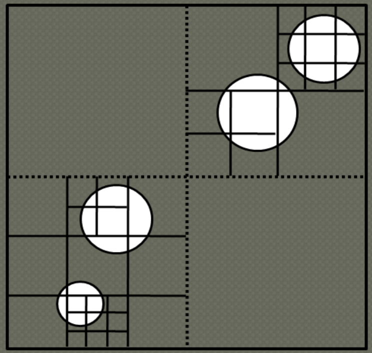
- Decentralised control, flat structure, and uses direct consultation with adjacent federates (sharing physical boundaries).

- It uses a restricted communication model based on inherent properties of virtual worlds (A region synchronises itself with regions that share boundaries with it).

- Objective:
  - To maintain local causality constraint.
  - To minimise number of intermediate hops and thus delay, complexity, number of messages communicated, and level of blockage.
  - To maximise scalability and interactive user experience.

The Proposed Time Management Approach

- A federate is a server executing a region.
- A federation (defined with respect to a federate) is a collection of federates that share boundaries with it.
- It uses a push strategy to reduce potential communication overhead and temporary blockage.
- A federate ensures that any destined messages are delivered (in sequence) before sending its LBTS value.



A hierarchical model based on JoHNUM strategies [8]

The Proposed Algorithm

```
Data: LocalQueue, LBTS, Lookahead, AdjacentLBTSValues
// Initialisations
// In general, the set of adjacent federates might change dynamically based on split and merge operations
int n = Number of adjacent federates;
int AdjacentLBTSValue[n];
for (i = 0; i < n; i++) do
|   AdjacentLBTSValue[i] = 0; // changes dynamically with the LBTS value sent by adjacent federate i
end
int LBTS = -1;// In order to force distribution of an initial LBTS value
int NewLBTS = 0;
Insert initial event(s) to LocalQueue; // used for synchronisation with other federates
// Main loop of program for safe processing
while (System is running) do
|   // Update LBTS value if necessary
|   NewLBTS = Min_{i=0}^{n-1}(AdjacentLBTSValue[i]);// determines minimum of LBTS values of adjacent federates
|   if (LocalQueue has Events) then
|   |   NewLBTS= Min(NewLBTS, Timestamp of earliest LocalQueue event);
|   end
|   if (NewLBTS > LBTS) then
|   |   LBTS = NewLBTS;
|   |   Send (LBTS + Lookahead) value to the adjacent federates;
|   end
|   // Check for an event that is safe to process
|   if (LocalQueue has Events and Timestamp of earliest LocalQueue event ≤ LBTS) then
|   |   Process Event; // Remove the event and may generate new internal and external events
|   |   Schedule internal and external events if any; // External events are sent to adjacent federates via messages
|   else
|   |   Go to Sleep;
|   end
end
```

Algorithm 1. The Proposed Decentralised Time Management Approach

Illustrations

- Simple illustration of a time advance
- Time advance for two independent federations without a common federate.
- Two federations with a common federate
- Temporarily blocking states of federates

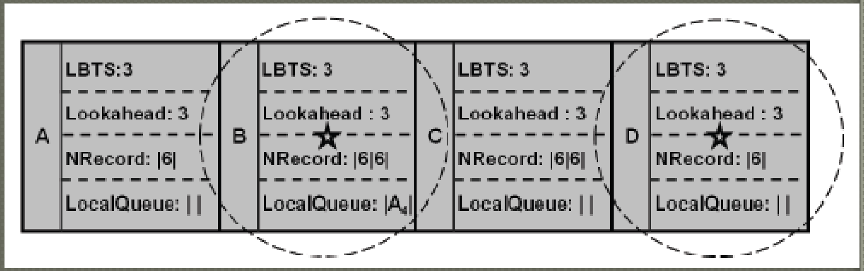
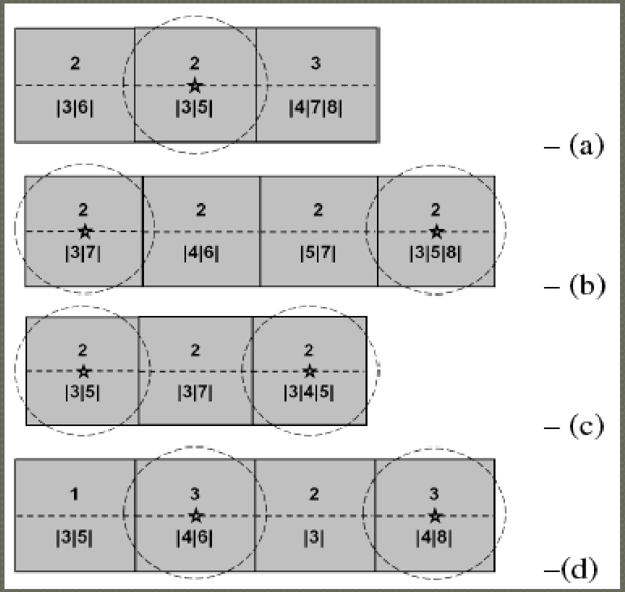


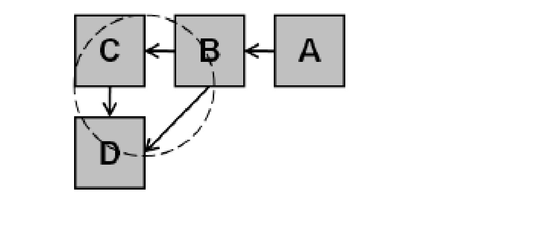
Illustration of a time advance



Illustrating the relevant concepts

Simulations

- Using a simple flag set application, randomly selected events, and delays in delivering messages.



The simulated world and events flow model.

Flag Set Application

Step	Region A					Region B					Region C					Region D (Observer)			
	Flag	LBTS	NRecord B	Local Queue	Event (s) Generated	Flag	LBTS	NRecord A,C,D	Local Queue	Event Generated	Flag	LBTS	NRecord B,D	Local Queue	Event (s) Generated	Flag	LBTS	NRecord B,C	Local Queue
-	0	-1	0	I_1	Empty	0	-1	0,0,0		Empty	0	-1	0,0		Empty	0	-1	0,0	
0	0	0	0	I_1	Empty	0	0	0,0,0	Empty	Empty	0	0	0,0	Empty	Empty	0	0	0,0	Empty
1	1	1	3	$[I_1]$	A_4	0	0	0,3,3	Empty	Empty	0	0	3,3	Empty	Empty	0	0	3,3	Empty
2	1	3	3	Empty	Empty	0	0	3,3,3	Empty	Empty	0	3	3,3	Empty	Empty	0	3	3,3	Empty
3	1	3	3	Empty	Empty	0	3	3,3,6	Empty	Empty	0	3	3,6	Empty	Empty	0	3	3,3	Empty
4	1	3	3	Empty	Empty	0	3	3,6,6	A_4	Empty	0	3	3,6	Empty	Empty	0	3	3,6	Empty
5	1	3	3	Empty	Empty	1	4	4,6,6	$[A_4]$	B_7	0	3	3,6	Empty	Empty	0	3	3,6	Empty
6-11	1	9	9	Empty	Empty	1	6	9,6,9	Empty	Empty	0	6	7,6	Empty	Empty	0	6	7,6	Empty
12	1	9	9	Empty	Empty	1	6	9,6,9	Empty	Empty	1	7	7,9	$[B_7]$	C_{10}	0	6	7,6	Empty
13	1	9	9	Empty	Empty	1	9	10,9,9	Empty	Empty	1	7	7,9	Empty	Empty	0	7	7,9	C_{10}
14	1	9	9	Empty	Empty	1	9	10,10,9	Empty	Empty	1	9	9,9	Empty	Empty	0	7	7,10	C_{10}
15-17	1	12	12	Empty	Empty	1	10	12,12,10	Empty	Empty	1	10	12,10	Empty	Empty	0	7	7,10	C_{10}
18	1	12	12	Empty	Empty	1	10	12,12,10	Empty	Empty	1	10	12,10	Empty	Empty	B	7	9,10	$[B_7]$, C_{10}
19	1	12	12	Empty	Empty	1	10	12,12,10	Empty	Empty	1	10	12,10	Empty	Empty	C	10	12,10	$[C_{10}]$

A simulation run of the proposed Time Management algorithm for flag set application

Simulations

- Non synchronised scenarios
  - D considering its own time information
  - D considering C (but not B) in addition to its own time information
  - Both violates the local causality, and allow C_{10} to process before B_7

Step	Region A					Region B					Region C					Region D (Observer)			
	Flag	LBTS	NRecord B	Local Queue	Event (s) Generated	Flag	LBTS	NRecord A,C,D	Local Queue	Event (s) Generated	Flag	LBTS	NRecord B,D	Local Queue	Event (s) Generated	Flag	LBTS	NRecord B,C	Local Queue
-	0	-1		I_1	Empty	0	-1		Empty	Empty	0	-1		Empty	Empty	0	-1		Empty
0	1	1		[I_1]	A_4	0	-1		Empty	Empty	0	-1		Empty	Empty	0	-1		Empty
1-3	1	1		Empty	Empty	0	-1		Empty	Empty	0	-1		Empty	Empty	0	-1		Empty
4	1	1		Empty	Empty	1	4		[A_4]	B_7	0	-1		Empty	Empty	0	-1		Empty
5-11	1	1		Empty	Empty	1	4		Empty	Empty	0	-1		Empty	Empty	0	-1		Empty
12	1	1		Empty	Empty	1	4		Empty	Empty	1	7		[B_7]	C_{10}	0	-1		Empty
13	1	1		Empty	Empty	1	4		Empty	Empty	1	7		Empty	Empty	C	10		[C_{10}]
14-17	1	1		Empty	Empty	1	4		Empty	Empty	1	7		Empty	Empty	C	10		Empty
18	1	1		Empty	Empty	1	4		Empty	Empty	1	7		Empty	Empty	B	7		[B_7]

A simulation run of non-synchronised scenario (Scenario 1) for the flag set application

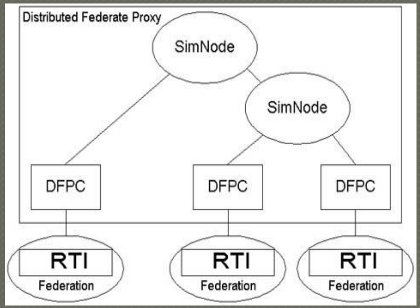
Simulations

- Decentralised/Peer-to-peer scenario
  - Achieves the same result and considers the entire set of LBTS values for an LBTS computation
  - Introduces longer delays and increases exchange of messages over network

An abstract Comparison

- Using Distributed Federate Proxy architecture as a reference, a number of potential parameters are highlighted for comparison in given table.

- The proposed approach is also well scalable and doesn't block the whole system.



Distributed Federate Proxy [Cramp et al. [6]]

Serial Number	Levels in Hierarchy	Algorithm	Number of hops	Complexity	Delay
1	2	Hierarchical/Decentralised	3	4*X	4*Y
		The Proposed Approach	0	X	Y
2	3	Hierarchical/Decentralised	5	6*X	6*Y
		The Proposed Approach	0	X	Y
3	4	Hierarchical/Decentralised	7	8*X	8*Y
		The Proposed Approach	0	X	Y

Comparison of existing hierarchical/distributed methods with the proposed Time Management Mechanism

Conclusions

- We proposed a Time Management approach and illustrated it with a number of examples.
- It is proved with a simple simulation model that it achieves the temporal order of events. An abstract model is used to compare it with the existing mechanisms.

Future Work

- Our future work includes the implementation of proposed Time Management approach together with JoHNUM infrastructure.
- It also include the detailed analysis and comparison with the help of further simulation and actual implementation.

References

[1] P. Rosedale and C. Ondrejka, Enabling Player Created Online Worlds with Grid Computing and Streaming, Gamasutra, 2003, 1-5.

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[5] W. Cai, S.J. Turner and B.P. Gan, Hierarchical Federations: An Architecture for Information Hiding, Proc. of the 15th Workshop on Parallel and Distributed Simulation, California, USA, 2001, 67-74.

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[7] J.H. Kim and T.G. Kim, Hierarchical HLA: Mapping Hierarchical Model Structure into Hierarchical Federation, M&SMTSA, 2006, 75-80.

[8] Umar Farooq and John Glauert, "Joint Hierarchical Nodes based User Management (JoHNUM) Infrastructure for the Development of Scalable and Consistent Virtual Worlds", Proc. of the 13th IEEE/ACM Symposium on Distributed Systems and Real Time Applications (DSRT'09), Singapore, 2009.

Questions?

Thanks!