Global Journal of Computer Science and Technology
Software & Data Engineering
Volume 12 Issue 14 Version 1.0 Year 2012
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Virtual Construction Simulator

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Abstract - In the construction sector, computer simulation has been extensively incorporated to support complex decisions including automation of several different processes and also to design the novel machines or buildings. The changes inhabited in the work zone configurations are reflected in the animations as the work progresses. This also provides an opportunity to the construction workers, as well as agency personnel and general public to visually present the complicated information.

This projected work presents an overview of how simulation modeling can help in learning effective decision making while performing construction activities. The Virtual Construction Simulator provides a user interaction gadget through which user can feed in the inputs that addresses the system to implement those sequences of tasks. The tasks that do not violate certain specified constraints operate concurrently and the operation of these tasks can be viewed on the virtual construction environment as well as the intermediate status of all the elements is updated at the backend.

A comparative analysis of various available alternatives can be done, so as to determine the most optimal and most efficient sequence of operations that can be implemented. Here in the cost of translocation of the various vehicles is taken into consideration for efficiency deterministic. Some predefined constraints are accustomed to the system like the limit on the number of vehicles that can be used, also the parameters involved in evaluation of the efficiency of a plan is subject to some assumptions, they are an approximate to the real world attributes but they are subject to change and can be updated on demand as per the requirements of the system.

GJCST-C Classification : *I.6.0*

Strictly as per the compliance and regulations of:

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I. Literature Survey

Construction simulation is the science of developing and experimenting with computer-based representations of construction systems to understand and later on predict their underlying behavior. This field of operations and research applications in construction management has experienced tremendous academic growth over the past two and a half decades. The projected work provides an overview of advancements in construction simulation theory as reported in literature. It also summarizes the key factors that contribute to successful inculcation of simulation in the construction management sector, and it emphasizes on the key attributes of the problems that primarily make them more amenable to simulation modeling than opposed to other tools. It also provides an overview of long-term simulation initiatives leading the way to the next generation of computer modeling systems for construction sector; undoubtedly simulation plays an integral role in a futuristic vision of automated project planning and control.

II. Previous Work

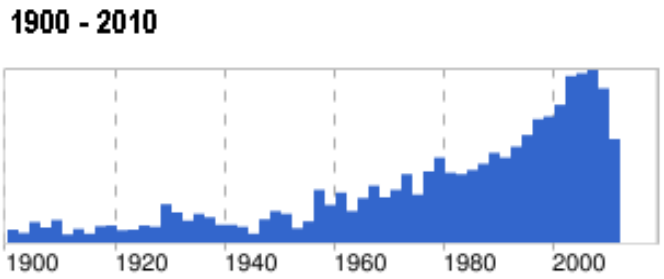

Figure 1 : Timeline Diagram of work done in Simulation

The initiative for the development of the simulators for construction management work took up from 1900. First successful model for simulator was built in 1969 by A.Gaarslev. Since then a considerable efforts were made to enhance the use of simulated tools for efficient modelling of realist construction environments as shown in Figure 3 [7].In August 1969, when A.Gaarslev & Stochastic proposed the model for estimating the production of material handling systems in Technical Report No.II at the Construction Institute, Stanford University.

In 1973, with the introduction of CYCLONE (CYCLic Operation NEtwork) methodology, the interest in the application of computer simulation in construction began. In Aug 1983 Paulson, BC, SA Douglas, A. Kalk, A. Touran and GA Victor published a paper on “Simulation and Analysis of Construction Operations” which emphasized that simulation analysis with disturbance scenarios not only identify critical disturbances but also can examine the dynamic system behaviour of construction operations.

Interactive Design Systems (IDS), which was founded in 1987, developed Bridge Engineering software that comprised of unique & important capabilities along with time-dependent construction simulation. Oloufa, AA published a paper on "A Framework for the Operational Simulation of Construction Projects” in Technical Report #13, at University of California in Berkeley in Mar 1988. Alciatore D, Hughes P, Traver A, and O'Connor J, published a paper on "Development and Simulation of an Ergonomic Control System for a Large Construction Manipulator" in the year 1989. A paper on "Computer-Based Process Simulation of Construction Activities" was published at ASCE Construction Congress, Minneapolis in Oct 1997.

In the year 2007, a French architect believed that he had finally solved one of the most puzzling

construction problems to reconstruct a three-dimensional simulation of how the granite blocks and great limestone of the pyramid were put together stone by stone. "A framework for real-time simulation of heavy construction operations" was published in the Proceedings of the 40th Conference on Winter Simulation Miami, Florida by Lingguang Song, Fernando Ramos, Katie Arnold. The paper described a framework of real-time simulation for simulation and modeling heavy construction activities. In comparison to the traditional simulation that uses static inputs, the capability of real-time simulation to dynamically embed new project data and the capability to adapt to the modifications in the operating environment to improve the accuracy of project forecasting.

In Sep 2009, a new construction training centre "the ACT-UK Simulation Centre" was set up in Coventry that was built to help construction managers develop their people management skills and enable them to fully develop their potential. Great turning point in the simulation field came out lately by 2010 when a sophisticated computer simulation program was used to develop an eight-phase construction plan to minimize disruptions.

III. Motivation

There has been extensive research done in the field of Construction Management through Simulation Process. Some of these studies have led to the production of practical computer-based simulation systems and various Simulation games that provide interactive games for various aspects of the management of construction projects to various firms and users learning the field. A review of the previous research and literature on these systems enlightened earlier showed that there has been very little research work aimed at producing a specific simulation system that tracks the totality of the decision making of site management at the user level. This projected work first presents the findings of the review and describes a logical model of a Construction system along with a prototype whose results can be justified on the Real Time Front. The research and development effort required to develop the prototype into a Working simulator to be further enhanced and then made use in industry is then elucidated.

The motivation of the projected work was extracted from various available Simulation Games like SimCity (The City Building Simulator) and Construction Destruction. The outlay of these games was blended in a system that provided the look and feel of these games, The innovative approaches and animation rends were taken as inspiration to give in an informative as well as an impressive appearance to the Simulator along with hat it was blended with the approaches of various Database Management Soft ware's to establish user interactiveness with the system and system's consistency with the database.

The parameters to define the efficiency of the software just in case to make it correlate with the Real World Scenarios are taken from the various Research and Development Projects like teaching construction management through games alone: a detailed investigation, Case Based Simulation of Construction Processes, CORBA, Using situational simulations to collect and analyze dynamic construction management decision-making data

a) VCS

The Virtual Construction Simulator – "A simulation game for construction engineering education" Understanding the dynamic nature of the construction process and the ability to make important decisions about resource utilization, sequencing, site layout, and project-related risks are critical skills for design and construction engineering students. The increase in projects complexity and shorter schedules pose pressure to develop more efficient construction methods, and also many challenges to educators to prepare students to manage these multifaceted processes.

The goal of this proposed project is to improve engineering education in building and construction through the use of interactive construction project simulation game. The goal is to create an experiential simulation environment where students can make decisions about resources, methods, cost/time trade-offs and related risks; and observe the impact of these decisions over time; thus actively learning to manage various factors that impact construction schedules. The immediate feedback will allow students to track their own progress, while the competition and scoring will introduce fun for more engaged, motivated and deeper learning of complex construction concepts.

IV. Methodology

In the initial study, it is determined that the work zone visualization and the simulation program could yield more benefits and expanded usage. The Simulation dataflow diagram is shown in Figure 2. The end user can select the sequence of actions to be performed at construction site. After that, the sequence is validated to check if some real time output could be generated.

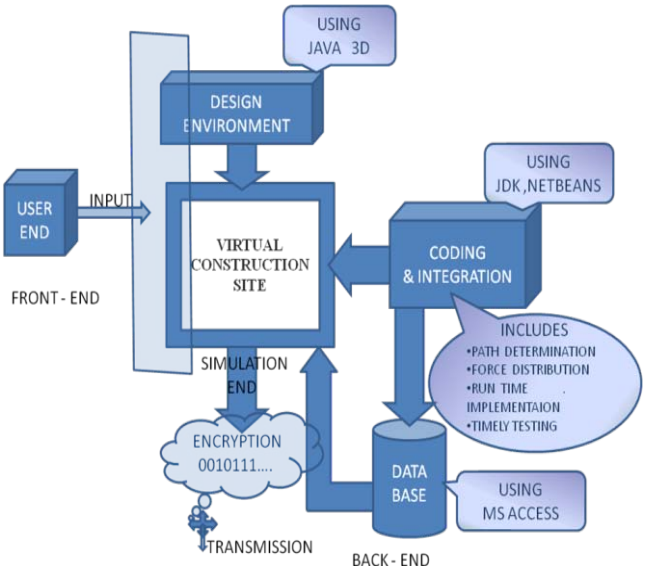

Figure 2 : Simulation Diagram

The simulator is closely integrated with JDK with the help of which it could easily determine the path and force distribution. The implementation is done at the run time and timely testing has been performed to ensure the feasibility. At the backend, MS-Access is used to store the temporary information regarding the motion of the bots, their path traversals, coordinate location of the static elements like walls, boundary and of the dynamic elements including the bots and the load. At the simulation end, the output of the calculations is transmitted to the robot in an encrypted form. The receptors received this output and accordingly gave instructions to the robot to perform the task required.

The construction site somewhat resembled a maze where bots are placed at different locations as shown in Figure 6. The bots actually imitated the vehicles present at the construction site for loading and unloading and various other tasks [9]. The simulator did the work of scanning this maze and identified the paths, bots and the load. Then calculations were performed to find out the optimal path to make the bots reach their respective destinations without colliding with each other.

The speed of the bots has been maintained by the simulator. Based on programmed algorithms, some vehicles increased or decreased their velocities if their conditions are met. As soon as all the bots reached their destination, work began according to the valid sequence of actions given by the end user. As the first task was completed, an event wss triggered for the next task to be accomplished after that.

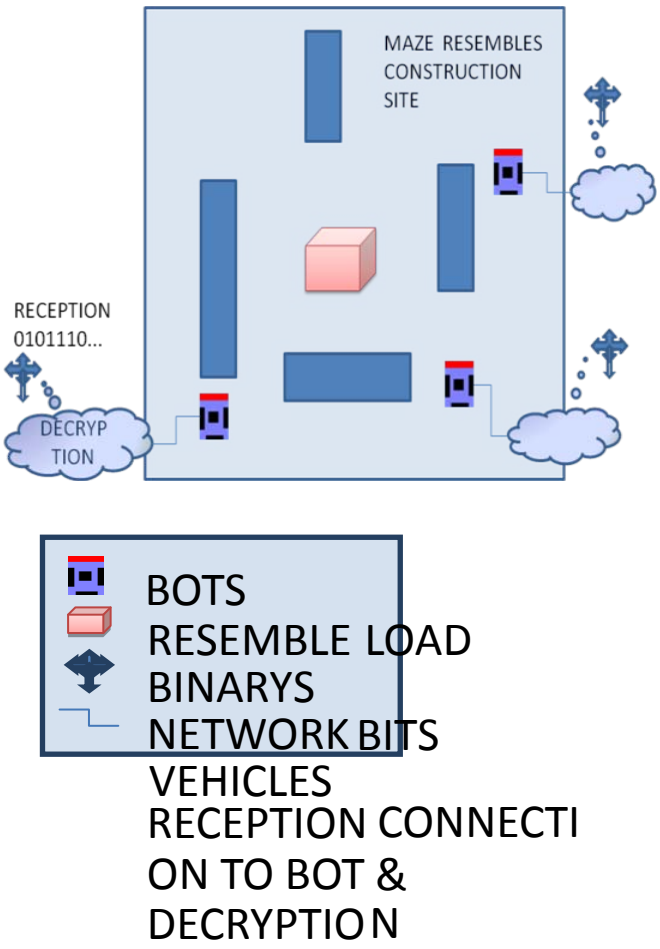

Figure 3 : Construction Site View Sensitivity Model [20]

After all the activities were completed in the simulator, the output was transmitted to the bots in encrypted form to perform the desired task where after the bots decrypted the binary information into necessary Kielcode to operate upon so as to accomplish the task of trans locating the load. Timely snapshots of the maze were taken to verify the desired operation of the bots and any necessary correction was heeded to [10].

V. Construction Plan

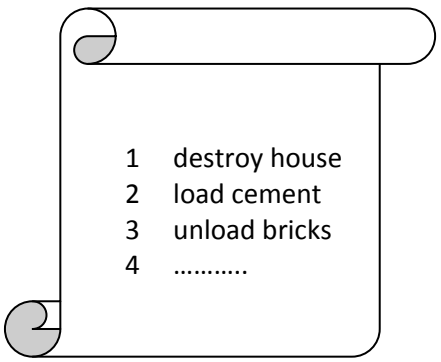

Figure 4 : A Sample Construction Plan

A construction plan is a sequence of steps that are to be performed to carry out a task with the

cumulative effort of various dynamic elements working cumulatively in a synchronous manner. Here in we assumed the task of creating a multistory building after destroying a house. So the task can be fragmented into various steps as in destroying the house, loading bricks and cement from Factory, unloading them at the construction site, constructing the Multi storey building, moving the waste to the recycler.

Now the job of the user is manage the construction mechanism so as to complete the task as soon as possible with most efficient use of fuel and with a certain constrained number of vehicles. To avoid the burden of management by hand or by any other tool this Simulator is developed where in the user can practice any number of Construction plan by merely feeding in the fragmented tasks as the input and then perform the comparative study analyzing the best plan amongst them.

Attributes involved in the Construction Plan:

- Process – ID
- Name of the vehicle involved
- Source location of the Vehicle
- Destination location of the Vehicle
- Task to be Performed by the Vehicle

VI. Construction – Simu

Construction Management is a hybrid, in which engineering analytical reasoning needs to blend with the real world business approach, hence it is logical to assume that teaching methods used in Schools of Business/Management can be brought to relevance. Both in construction and business programs there is a common goal of teaching professionals how to perform and succeed in real world situations.

This blended management approach to Construction Management instruction should involve the development of a set of philosophies, approaches, skills, knowledge, and techniques. This is best served by the Simulation method – a teaching approach that helps to provide knowledge and experience with techniques that can be displayed on a projector the operations can be minutely viewed and evaluated on demand. The simulation can be controlled by the user input and worked upon by extensive controls involving pausing the operation as well as rolling back the process to certain breakpoint for any sort of intermediate updation[20].

Certain characteristics of the Simulated System:

- Construction Simu is a 3-D virtual Reality environment of a Construction Site.
- It provides the users to employ their Construction Management Skills to design a Construction Plan.
- It interacts with the user to fed in the sequence of operations that control the flow of commands.
- The flow of information takes place between the user and the system as well as the system and the database that stores the intermediate status.
- The Simulator implements the Construction Plan in a Cascaded Representation where different Canvases are interconnected to transfer of information regarding Dynamic elements of the Simulator.
- It performs comparative study of the various Construction Plans can be made on the basis of Time Consumption, Net Distance traversed by the vehicles.

VII. Objective

Construction planning is a very fundamental and as well a challenging activity in the execution as well as in the execution of construction projects. The choice of technology, the identification of any interactions among the different work tasks, the definition of work tasks, durations of the tasks and the estimation of the required resources for individual tasks are involved in it's core planning objectives. A good construction plan is definitely the basis for developing the budget and the schedule for work. The most critical task in Construction Management is to develop a Construction Plan, even if the plan is not written or otherwise formally recorded. In addition to these technical aspects of construction planning, it is also necessary to make organizational decisions about the relationships between project participants and even which organizations to include in a project. For example, the limit to which laborers will be used on a project is often calculated during construction planning.

The primary objective of this simulated work is to design a Construction Plan for the user who intends to implement that plan on the Real world environment. There could be various sequence of events to processed in that Construction Plan and with lots of Permutations and Combinations of these events we design several Construction Plans to be tested in the environment.

So the ultimate objective of the user is obtain the most efficient and optimal Construction Plan evaluated by the System amongst the various available options to the user. Each alternative is implemented on the Simulator in minute details where in each fragmented subtask is viewed and the related information is punched in the database for evaluation and log purpose.

Using the information stored parameters(here in the cost induced by the user) are decided to compare the plans and determine the best amongst them to be transmitted to the Real World environment so as to be implemented.

VIII. Working

The construction simulator is a multi-cascaded environment with four canvases that can intercommunicate in terms of dynamic elements that are the vehicles travelling from one canvas to other and the information regarding them.

The Simulator is also inculcated with two gadgets one for demonstrating the status of the user as well as providing the information about all the dynamic elements being used by the user.

The other gadget provides the tools for the user to feed in commands for carrying out the operations like destroying the house, loading the bricks etc. It also keeps track of the progress of the commands issued indicating the measure of task completion.

Users can experiment various construction plans and implement them on the simulator and the task of simulator is to provide the comparative study of the various plans implemented on the basis of distance travelled or the fuel consumed and the time taken to execute the plan.

The user is equipped with two gadgets to interact with the system so as to control it and force it the way he wants the operations to be processed. The gadgets are named as Gadget1 and Gadget2. The former takes in the input from the user for the designing of the Construction Plan whereas in the later one the user addresses the name of the Vehicle to be queried and all the details about the vehicle is presented before him[20].

Now the System is also in correspondence to a Microsoft Access Database via JDBC driver to store the intermediate information to update the status of System as well as to compare and hence evaluate the most optimal option.

The key Features stored at the Back- End includes:

- Details about the Users evaluating the Software.
- Details about the Tasks being performed by the current Logged in User.
- Details of the various Vehicles in action or in Passive State.

IX. Diagramatic Flow of Data User View

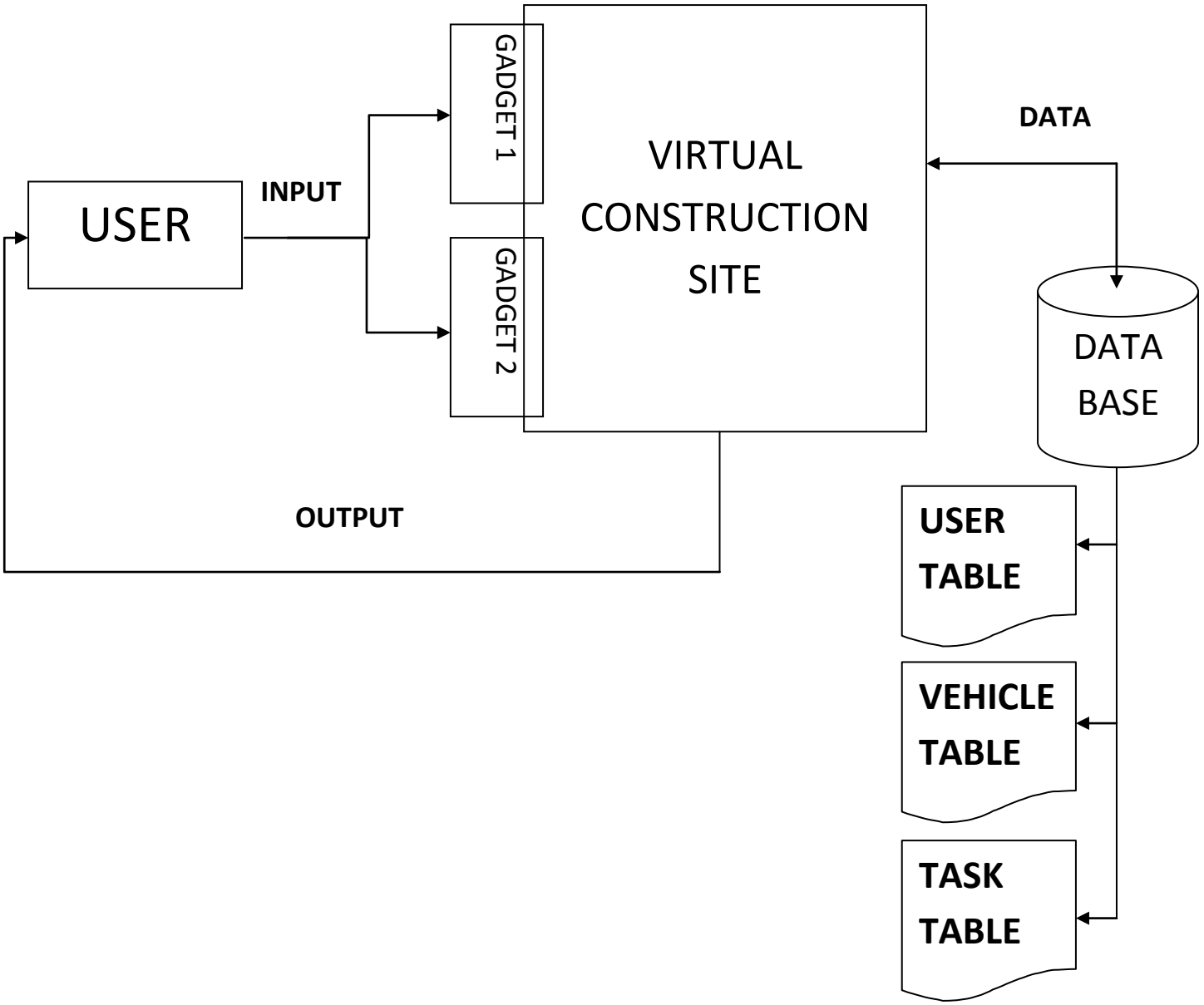

Figure 5 : Diagrammatic flow of data user view

- Virtual Construction Site is the VDU of this simulated system, which interacts or communicates with the input units hat is the gadgets, the back end repository as well as the design Mechanism[20].
- The input units are the two Gadgets that are a part of the Visual Site and are deeply integrated with them and connected to the Database internally, The former gadget is a interaction `tool that feds in all the necessary details regarding the task to be commenced, the details include name of vehicle undergoing the task, source location and the destination of the vehicle and the task to be performed.

A series of inputs can be combined to form a construction plan such that all the tasks defined in that plan work concurrently to execution. One thing to be kept in mind is that no two tasks can be performed on the same vehicle simultaneously, if so forces the system to issue an error message. Also certain constraints regarding the nature of task have been inbuilt such that a truck can only be used for loading and unloading purpose whereas the crane for destroying the house etc. and no task that does not correspond to its vicinity can be issued if done so again an error message is issued. Once the plan has been submitted it can be started, cleared and stopped as per the need of the user

The later gadget is an information tool which interacts with the user to input the name of the vehicle and displays all the records regarding that vehicle including its name location, fuel contained and its distance from the petrol Pump.

- The output of the System is recorded in the database in the form of cost inculcated by the user initially in the form of vehicles bought by him and additional cost of refilling the tank of vehicles.

The Database used is a Microsoft access repository that comprises of three tables namely:

- User Table: Storing the details of the user including his name his password and his net worth and expenditure done till that moment.
- Task Table: Storing the information about each task whether queued, accomplished or in progress, the intermediate status of each task is updated in intervals. This information is tracked for the VDU to display the execution of task on the Monitor screen as well as to evaluate the final results of the comparative study made by System [20].
- Vehicle Table: This table is primarily designed for the second gadget, all the information about each vehicle including I's ID, Name, Fuel and Fuel capacity it's Mileage and location are stored in this table. The values of second gadget are updated from the intermediate values stored in this table.

X. Diagramatic Flow of Data Site View

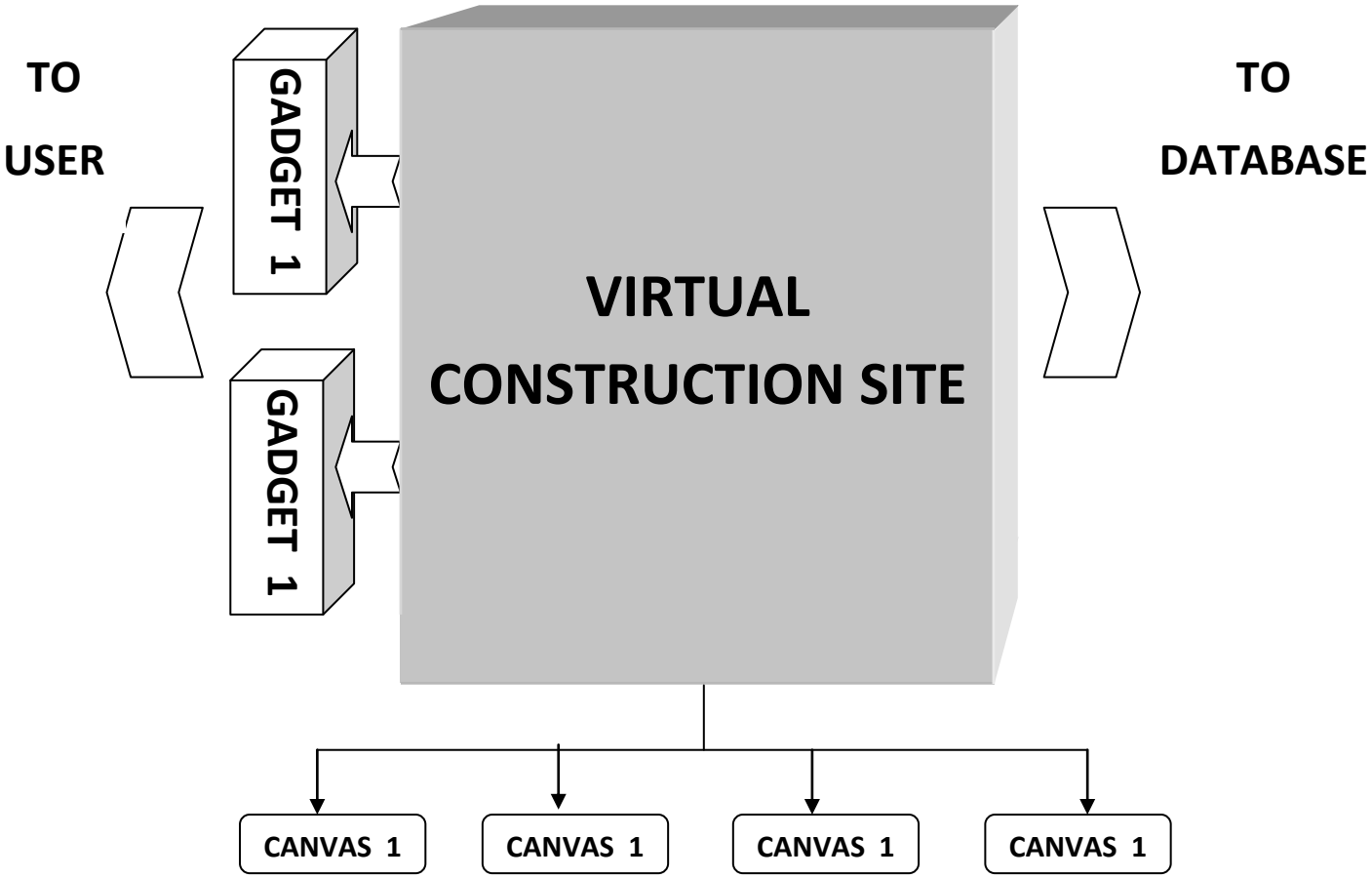

Figure 6 : Diagrammatic flow of data Site view

Going into depth of the Virtual Construction Site, we come across that the main Visual Environment is defined and designed in Disp class, embedding The two Gadget classes ad the four Canvass classes.

a) Inside the Code

DISP : Disp is a java class which extends the Frame class of Java. Swings Package [20]. This class presents the base of the Visual System with the black Background, this class embeds the four canvases for displaying the four different locations of the real time environment in a multi cascaded format. Each canvas can communicate with each other and share information in a consistent manner. The updates made in one canvas are to be updated in the others as well.

When a vehicle moves from one vehicle to other the data also is transferred from that canvas to other canvas along with the updation in the global database about the updation of the information.

The dynamic elements that is the various vehicles are embedded as labels in the main base class but their location is stored relative to various canvases in the back end.

CANVAS : There are for canvas classes namely Canvas1, Canvas2, Canvas3 and Canvas4. Each canvas represents a different location of the real world. The Canvas class is Java class that extends Jpanel Class in Java.swings package it consists of all the static elements embedded as images on the labels.

Canvas 1: this is the representation of the construction site displaying house to be destructed and then a multi storey building to be construced at its place.

Canvas 2: this is the representation of the Factory where in the trucks are used to load and unload various building materials like cement and bricks.

Canvas 3 : this is the representation of the Petrol Punm where in any vehicle can drive in to refill it's tank.

Canvas 4 : this is the representation of the Recycler Plant where in the waste cressure generated can be brought out over here and Recycled.

GADGET : There are two gadgets invoked in the base class, they can be slidded and brought into focus by the two side buttons available. The Gadget class is again a JPanel class purely designed by labels, TextFields and Buttons in Netbeans to give a user Interactive interface to the user. The user can fed in the details of the tasks and view the information of the vehicles in these gadgets.

XI. Sample execution

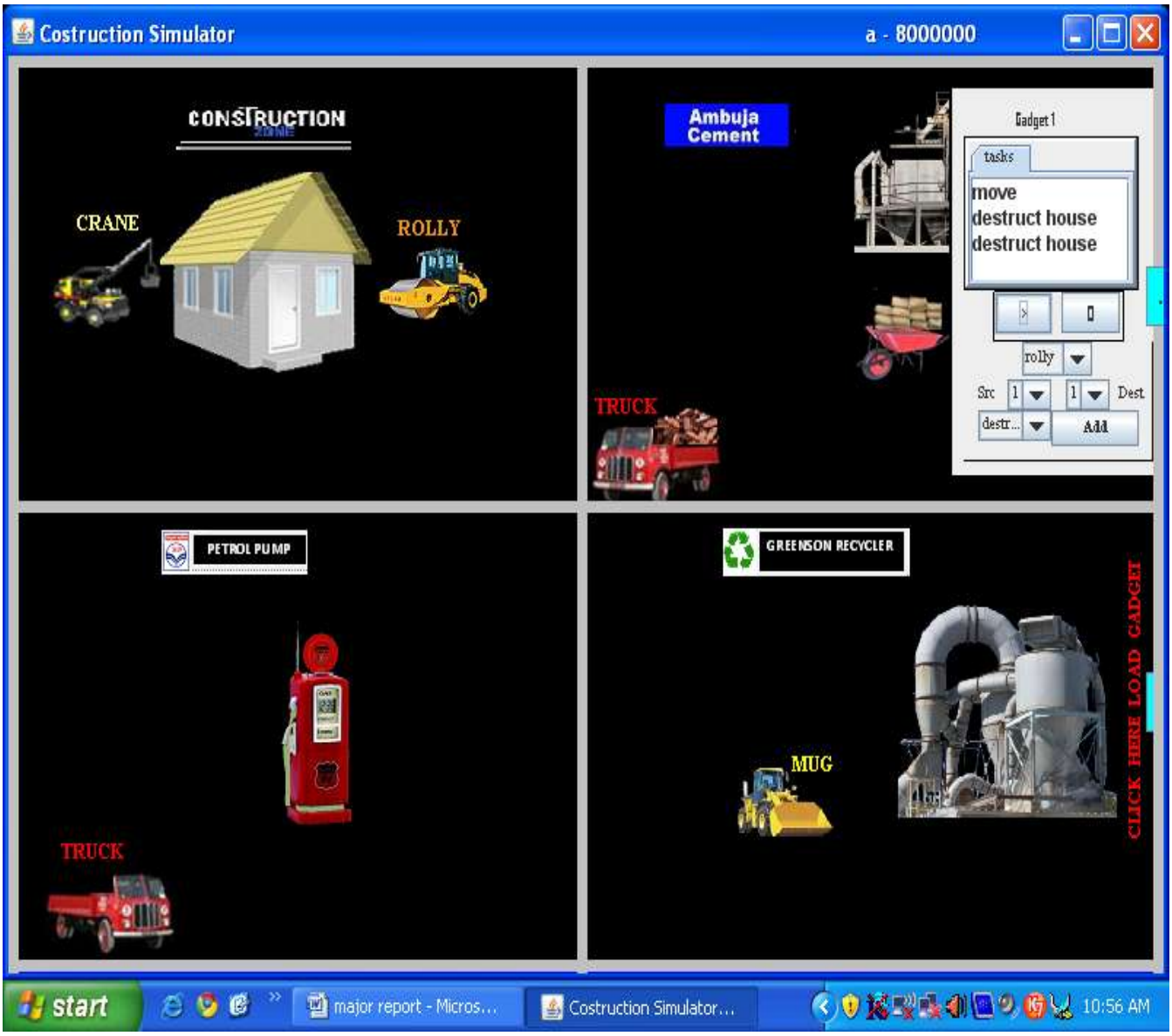

Figure 7 : Screen Shot Construct-Simu [20] (Sample Execution)

XII. List of Inputs

Vehicle	Task	Source	Destination
Truck1	load bricks	2	2
Crane	destroy house	1	1
Rolly	destroy house	1	1
Truck2	move	3	4
Truck1	unload bricks	1	1
Truck1	load cressure	1	1
Truck2	load cement	2	2
Truck1	move	1	4
Truck2	move	2	1
Truck1	unload cressure	4	4
Truck2	unload cement	1	1
Mug	recycle	4	4
Truck1	move	4	3
Truck2	load cressure	1	1
Truck1	refill fuel	3	3
Truck2	move	1	4
Truck2	unload cressure	4	4
Mug	recycle	4	4
Truck2	move	4	3
Truck2	refill fuel	3	3

XIII. Conclusion

a) On the Basis of Results

The results suggest User A had to spend more cost due to another extra vehicle where as User B cutting his cost wasted lot of time which when multiplied to a factor for implementing in Real world would indeed be a greater loss.

Also the sequence of tasks were restricted to testing perspective in real time operations the number of tasks performed at the site is much larger in number and hence the cost of an extra vehicle will be fruitful as we can see using two trucks we needed two refills each while using one truck it required 5 refills.

Undoubtedly User a employing Multi-Tasking by using an extra vehicle is a better and efficient manager of Construction events.

b) On the Basis of Use

Computer simulations can provide students in construction management the opportunity to experience management and business decision making. Simulations allow the users to analyze the results, discuss different strategies, and see the result of planning and implementation of business bid strategies. This simulation is a work in progress and continued development is being done to date.

Additional functionality in the area of obtaining negotiated work, increased complexity of the project management piece, and expanding the types of projects to include other segments of the construction industry; i.e. heavy civil and highway construction, are the next pieces to be completed. It is anticipated that this simulation will be available to the Associated School

of Construction programs on a measured access basis in early 2003. The simulation has under gone thorough testing and is working up to expectations, but as with any work in progress, it will greatly benefit from input from the anticipated new users and individual instructors.

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