ICONIC ANIMATION OF CONSTRUCTION SIMULATION

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ABSTRACT

This paper presents a continuous research effort the animation function in the development of the Activity-Based Construction (ABC) modeling and simulation system. ABC animation uses the constructed ABC simulation model as the animation background; and pre-created images of simulation entities move around along individual execution paths on the ABC model. A library of icons consisting of common construction entities has been created in the ABC system. To perform animation function in ABC only involves one simple additional task for the user to select an appropriate icon for a simulation entity.

1 INTRODUCTION

To simulate a real-world construction process is to execute a simulation model specifically built for the process on a computer (Hill 1996). Simulation has achieved many successful applications in construction. However, some practitioners have criticized simulation as a "black box" beyond their understanding since they cannot see what is going on during simulation and they usually have problems understanding the simulation technology. One effective way of overcoming this problem and further improving construction simulation is to animate the process so as to enable the user to visualize the dynamic interactions during simulation.

Literally, to animate means to bring to life. In practice it means to define changes of parameters over time. As an effective tool for understanding and evaluating the functioning and behavior of a real system in real time, animation technology can be integrated with discrete simulation technology. The dynamic characteristics and discrete change of information over time of a construction process can be visualized on a computer screen. Through visualization of operational progress over time, animation enables the user to verify the simulation model and to validate simulation results.

Communicating information via images is the principle shared by various types of animation technology. Conventional animation seeks to re-create "life" through the artistic skills of an animator who transforms his or her observations, experiences, and intuition into believable objects. In this computer age, visual reality technology creates a 3-dimentional environment to allow animation close to the real world. However, most of the developed tools provide manual control over images, shapes, and movements. The complexity of re-creating real live images (e.g. a construction site) as well as the difficulties of graphically updating complex changing information in the animation environment have led to limited capabilities of such animation tools. Moreover, cost and time considerations make this type of animation impractical for engineering simulation (Earnshaw and Watson 1993).

Many simulation systems that support 3-D animation can import 3-D images created in other computer graphic tools, such as AutoCAD, 3D Studio, Authorware, and Photoshop. In addition to the difficulty of mastering these additional tools, the time requirement and complexity involved in modeling and simulation have caused practical problems for the ordinary end user to make use of such animation functions. Considering the uniqueness of a construction project, such effort for one project may hardly be rationalized in the industry.

The major purpose of animation is to enable the user to visualize the dynamic interactions during the real construction process. Comparably, a 2-D iconic animation technique provides an alternative for achieving the objective with much less effort needed. This paper presents a continuous research effort of the animation function in the development of the Activity-Based Construction (ABC) modeling and simulation system.

2 A BRIEF OF ACTIVITY-BASED CONSTRUCTION (ABC) MODELING AND SIMULATION

Many simulation systems are available in the market, including AweSim, AutoSim, GPSS, etc. Extensive professional training is always required to master any of these simulation systems to achieve effective use. As having been noted by construction simulationists (Ibbs 1987, Shi and AbouRizk 1997), difficulty-in-use and time required have greatly hindered the application of simulation in the construction industry.

Activity-Based Construction (ABC) is a recently developed construction modeling and simulation method (Shi 1999). It requires one single element, the construction activity, to model a construction process and to simulate the randomness and dynamics of the process. The modeling element has the same meaning and attributes as used in the critical path method (CPM). Employing ABC to model a construction process is similar to constructing a CPM network diagram consisting of activities and specifying attributes of these activities such as resource requirement.

In the ABC modeling environment, an activity either be in an "idle" or "active" state. If an activity meets all required conditions for execution, it is in the active state; Otherwise, it is in the idle state. Therefore, it is not necessary for an activity to differentiate its activity state from its idle state in the model. Instead it is left to be handled in simulation process. Resources can wait at an idle activity as necessary until the activity gets started. Meanwhile, other modeling functions can also be achieved through activity as attributes. Table 1 compares the approaches of achieving the common functionality needed for modeling a construction process in ABC and existing simulation systems.

Table 1: ABC versus Existing Simulation Systems

Functionality	ABC-Mod	Existing simulation systems
Generate entities	Entities can be generated by an activity, see Example 2.	Additional element for generating entities, e.g. CREATE
Terminate simulation	Simulation time or production cycle of selected activity	Simulation time or entity count on given nodes, e.g. COUNTER, TERMINATE
Idle state	An idle resource or entity waits at an activity.	Waiting elements, e.g. QUEUE, AWAIT
Active state	Activity	Regular or service activity
Resource location	Activity or pool	Waiting location, activity, other elements, or pool
Multiply entity	Given number of entities to be released to a following activity	Specific modeling elements for splitting an entity, e.g. GENERATE, UNBATCH
Combine entity	Given iterations needed for the release of an entity	Specific element for combining multiple entities into one, e.g. COMBINE
Matching between resources	Directly specify matching units of resources	Split or combine entities to balance the matching
Production	Count iterations of selected production activities	Elements for collecting production entity
Utilization of resource	Trace the life cycle of a resource entity	Collect time at all idle states

The above contrast suggests that the needed modeling functionality that is realized through various additional modeling elements in existing simulation systems can be achieved through activity attributes in ABC. Because activity attributes are directly related to an individual activity, it is easier for an engineer to describe them at the local environment of the activity than to model them independently from the activity through foreign elements. In conclusion, it is practical to use one single element (i.e. activity) to model a construction process without sacrificing functionality or complicating the modeling process.

A pub example has been used here to illustrate the construction of the ABC diagram as shown in Fig. 1. In the example, a customer arrives at the pub and is served a drink of beer by a bar attendant. After the customer drinks the beer, s/he may leave the pub or go for another round. The bar attendants also wash dirty glasses.
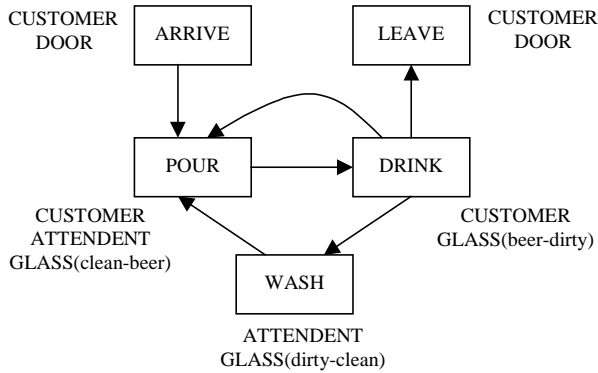
Figure 1: A Pub Example Modeled in ABC

An ABC model is a static representation of a construction process whose dynamic behaviors are simulated by movement and interactions of simulation entities, which include the resource entity and processing entity. Activities are the basic elements that ABC simulation directly deals with in simulation. The dynamic behavior of a construction process is simulated by detailing the status of activities. ABC simulation executes the ABC Model by manipulating activities in three stages: a) select activity, b) advance simulation, and c) release simulation entities.

In summary, ABC is a general–purpose modeling and simulation method with an emphasis on construction. It has all the features required for modeling and simulating the dynamic and random behaviors of a construction process. But the significant point is that it does not require any more knowledge to use it than an activity–on–node network does. A detailed description of ABC can be found in the reference (Shi 1999).

3 ABC ICONIC ANIMATION

An ABC model provides an abstract description of a construction process under study. During simulation, both resource and processing entities move around from activities to activities (and resource pools) by engaging in the execution of activities and waiting at pools or activities. If all entities are displayed on the ABC model with appropriate icons and change of position and status of entities can also be updated in a real-time manner, then the dynamics of the construction process are animated on the ABC model.

Therefore, ABC animation uses the constructed ABC model as the animation background, which can assist the user in visualizing the construction progress of the process under study. Pre-created images of simulation entities move around along individual execution paths on the ABC model in a real-time manner. With the library of common construction entity images, the user only needs to select an appropriate icon for an entity during modeling. Basically, there is no additional work needed for the user to achieve animation. This section describes how ABC iconic

animation is achieved. The involved issues include the creation of iconic images and dynamic movement of icons in a real time manner during simulation.

3.1 Iconic Bitmaps

As previously mentioned, a library of common construction icons has been created in ABC. During animation, each simulation entity is represented by one or more icons to model the change of shape of the entity over time (e.g. movement in different directions). An icon frame of an image is built in Photoshop or Microsoft Photo Editor environment. Each icon contains an image with a black background.

An icon frame is in rectangular bitmap form. All required icons are loaded from the library and are saved into the memory of device context, and are copied to the destination over time. When an icon is displayed over an animation background (e.g. activity), the frame will cover the background that causes the loose of some of the image. To prevent this happening, the mask image method is adopted. The method first copies the single-colored mask image in SCRAND raster operation mode over the background, and then copies the bitmap with black background over the mask image in SCPAINT raster operation mode. Mask images are automatically generated during animation by changing the RGB values of the icon, i.e. to change icon's black background to white and change other colors of the image to black.

3.2 Managing Animation

ABC iconic animation uses post-process mode, which means that simulation is executed first and simulation process information is stored for animation. The animation process is controlled by a framework named OnTimer( ), which calls a member function after each time interval specified in the member function SetTimer( ). During animation, an activity may be in either active or idle state. In order to display the active state, a small active icon with multiple frames of animation images appears at the top-right corner of the activity during the whole active period, which stands for the activity duration. When an activity is in active state, the engaged resource and processing entities should stay with the activity until its completion.

It should be noted that the connection arrows in an ABC diagram only indicate the logical sequences. To animate the entire movement of all entities, icons consume real time to pass through arrows before reaching their destination activities, and the time cannot be rationalized in the construction process. To fulfill the real time animation requirement, the activity duration is divided into two portions 80% - 20%. From the start to 80 percent of the

activity duration, all engaged simulation entities of an activity are displayed at the activity; the remaining 20 percent of activity duration is allocated to release entities passing through relevant arrows to their destinations while the activity is still displayed with an active icon.

Before an image is copied to a destination, the destination area must be saved in order for the area to be recovered when the next frame of the image is copied to another destination. Multiple entities may be released and multiple activities may be in active state at the same time. Therefore, multiple images may appear on the same animation background simultaneously, and can cause overlaps of images - collision among images. It is very important to detect and avoid collision of images, which may confuse of the appearance of involved images during recovery.

3.3 Object-Oriented Animation Method in ABC

The ABC simulation system was implemented using Object-Oriented programming technique with VISUAL C++ (Aitken 1995). Activities are treated as objects. The activity class contains resource class because an activity has the information of its required resources. In addition to other methods, an activity object has an animation method.

The animation class has following methods such as: initialization of animation, display of iconic images, collision detection, handling of multiple images, timer control, position updating of images, switch on and off operation, speed adjustment, and display of additional simulation results.

The existing class CBitmap provided with MFC is hardware dependant in handling images, and would cause compatibility problems for the developed ABC system. It becomes very important to create a new class to resolve these problems. The new class has the method to open and load the icon bitmaps independent of hardware, the drawing method for copying images to the memory device, and other methods for handling the DIB operation and palette process. The new class (AniDIB) provides the basis for the animation class. The relationship between the activity object and classes is shown in Figure 2.
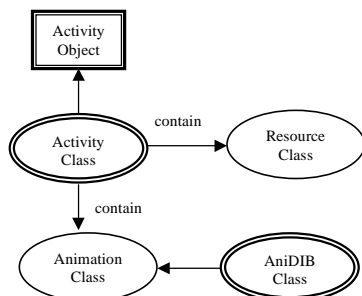

Figure 2: Relationship Between Activity Object and Classes

4 ABC ANIMATION FUNCTIONS

Employing ABC involves constructing an ABC diagram for a construction process consisting of activities. For each activity, a dialog box is presented to the user to ask for the attribute values of this activity including resource requirement, activity duration, etc. In the same dialog box, an icon should be selected from the icon library to associate with a resource.

The ABC model will be executed first so that the real time construction progress information can be obtained and saved. The animation function is performed next. With the interactive user interface, animation process can be easily controlled, including starting/stopping animation, adjusting animation speed for best visualization effect. Simulation time is displayed on the status bar. Other important information can be displayed on the screen depending on the user's needs including operation count of activities, production rate of selected activities, and utilization of resources over time. Moreover, a zooming function is implemented to allow the user to select view size.

5 EXAMPLES

Two examples are presented to illustrate the ABC animation function. The first example is the crane operation in a building construction process with four activities: pick up object, lift object to position, drop off object, and return to pick up position for next cycle of operation. This is a closed loop network, in which a simulation entity starts from and ends up at the same activity. The ABC model as well as the animation view are shown in Figure 3.

At the present simulation time (19 minute) in Fig. 3 when the animation view is taken, the two activities: "pickup object" and "Lift object" are in an active state and each of them has an active icon on the top right corner. A crane is on the arrow toward the activity "Lift object", and a crew is on the way to its pool. This suggests two cranes in the process. Crane 1 is engaged in lifting the object. Crane 2 is still engaged in picking up another object but 80% of the time needed for picking up object has elapsed.

The second example is a concreting process in building construction (Halpin and Riggs 1992). In the process, the concrete is produced at the off-site bath plant, and transported to site by transit mix truck. The fresh concrete arriving at the job site is moved to placement area by a hoist, held temporarily in a storage hopper and then distributed using rubber tired buggies. The operation process consists of 11 activities and requires 6 kinds of resources, namely plant, truck, hoist, hopper, buggy and crew. The 11 activities form four loops. Following the logical sequence, the four loops can be linked into an
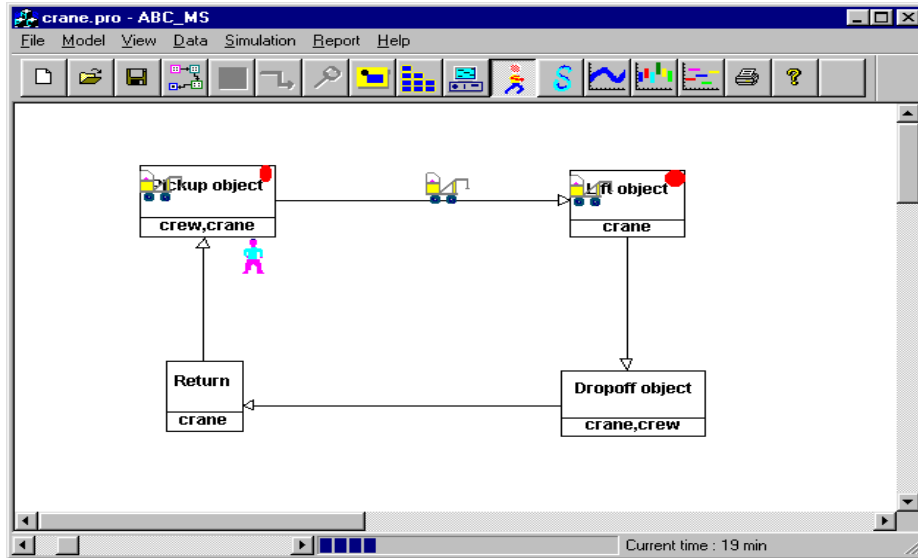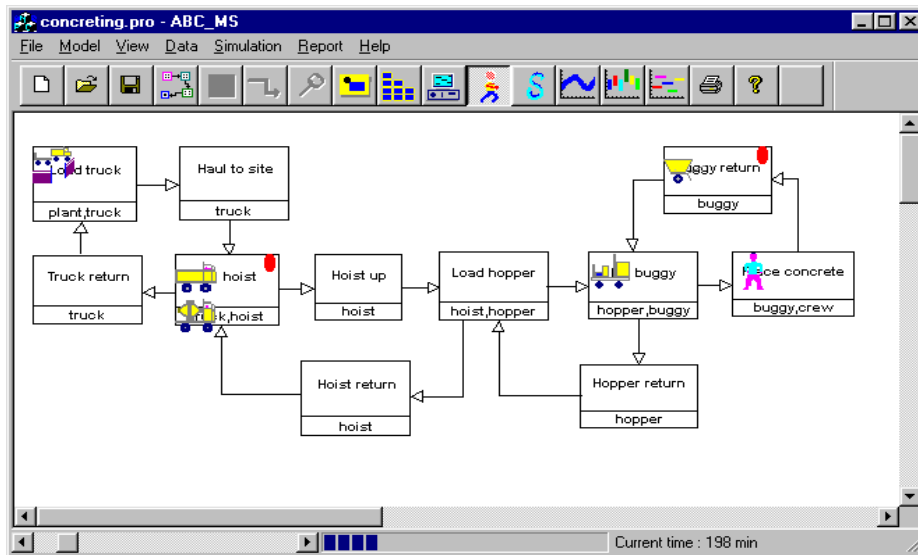
Figure 3: Animation View of Crane Operation

Figure: 4: Animation View of Concreting Process

ABC model as shown in Figure 4. For the best effect of visualization, only one concrete truck, one hoist, one hopper, one buggy and one labor crew are initialized during simulation.

The animation view shown in Fig. 4 is taken at the time when 198 minutes had elapsed. The active icons at the top-right corner of activities show that the "Fill hoist" and the "Buggy return" activities are at active state at the time 198. One truck and one hoist are working at the activity "Fill hoist", and one buggy is returning at the

activity "Buggy return". Moreover, the concrete plant, hopper and concrete crew are in idle at relevant activities.

6   CONCLUSION

Because animation can bring a construction process to "life" to the user on a computer screen, it has been recognized as an important aspect of construction simulation. However, real world construction processes and site situations are so complex that it is hardly possible to achieve the best visualization effect of 3-D animation

under reasonable effort considering the uniqueness of aconstruction project. Comparably, the iconic animation provides an alternative for achieving the compromised visualization effect.

This paper presented the continuous research effort of animation function in the development of Activity-Based Construction (ABC) modeling and simulation system. No additional effort is needed from the end user to perform animation in ABC besides selecting an appropriate icon for a resource entity. The ABC model provides the animation background, and icons representing simulation entities move around on the background to enable the user to visualize the dynamic behavior of the construction process.

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