



## A DEVS – Solution to ARGESIM Comparison C8 “The Canal-and-Lock System” with CSIM

Sabri Pllana, Vienna University of Technology  
 spillana@osiris.tuwien.ac.at  
 Thomas Fahringer, University of Innsbruck  
 thomas.fahringer@uibk.ac.at

**Simulator.** CSIM (Mesquite Software) is a process-oriented, general-purpose simulation toolkit, which supports the development of process-oriented, discrete-event simulation models, by using the standard programming languages C and C++. Because of the nature of compiled C and C++ programs and CSIM's dynamic memory allocation, developed models are compact and efficient.

**Model.** We have described the model textually by writing the corresponding C++ code. In order to model barges we have defined the class *Barge*. The methods of the class *Barge*, *proceedEastbound()* and *proceedWestbound()*, define the movement of the barge in the eastbound and westbound directions resp.

**Task a – Control Logic Modelling.** The behaviour of the barges during the movement through the system is modelled using CSIM *processes*. In a CSIM model a *process* represents an active entity. Furthermore, we have used CSIM *processes* to model the generation of the eastbound and westbound barges.

The control logic is constructed by using CSIM *events* and a set of integer counters. *Events* are used for the synchronization of CSIM processes, which in our model represent barges. When a *barge* is generated, based on the state of the system, either proceeds through the system or enters the *queue* and waits for the occurrence of a specific event. We have used the class facility, which is provided by CSIM, to model resources of the canal-and-lock system. The *west canal*, the *lock*, and the *east canal* are modelled as instances of the class *facility*.

The instances of the CSIM class *table* are used to collect explicit statistics on barge transition times. CSIM supports the automatic calculation of the *confidence intervals* (CI) for the mean of data stored in the table. The automatic calculation of commonly used confidence intervals (90%, 95%, and 98%) is enabled by invoking the method *confidence()* of the class *table* immediately after the table instance is created. Note that a minimum number of observations, which is determined by CSIM at run time, is required in order to automatically compute confidence intervals.

CSIM offers an interesting feature for controlling the length of the simulation run based on confidence intervals.

CSIM monitors the confidence interval during the simulation run, and when the desired accuracy is reached automatically terminates the simulation. Please note that this feature is not needed for solution of this *particular comparison*, but we consider that in general it may be a useful feature.

**Task b – Model Validation with Deterministic Data.** The deterministic model validation was a challenging and interesting task, because of the occurrence of multiple events at the same simulation time. Our model was valid for all specified datasets.

**Task c – Variance Reduction Experiments.** Table 1 shows the mean barge transition times for Activities 1, 2, and 3. The use of the Antithetic Random Variates (ARV) has not resulted in a significant change of the confidence intervals (CI).

Activities 1 and 2 90% CI [minutes]	Activity 3 (ARV) 90% CI [minutes]	CI Change [%]
497.58 +/- 31.66	454.67 +/- 34.46	-8.84
507.06 +/- 32.79	504.18 +/- 30.26	7.72
474.82 +/- 28.53	509.15 +/- 29.44	-3.19

Table 1. Mean barge transit times.

Table 2 shows the difference in mean transit times between the case in which maximally 5 barges and the case in which 6 barges are allowed to move in one direction before the movement direction is changed by the system control. The use of the Common Random Numbers (CRN) reduced significantly the confidence intervals (about 90%).

Activities 4 and 5 90% CI [minutes]	Activity 6 (CRN) 90% CI [minutes]	CI Change [%]
23.18 +/- 78.88	55.90 +/- 8.71	88.96
-0.85 +/- 73.99	54.32 +/- 7.42	89.98
98.89 +/- 79.58	50.80 +/- 6.82	91.42

Table 2. Difference between 5-barge and 6-barge mean transit times.

Based on results in the first column of the Table 2 it can not be inferred about the acceptance of the null hypotheses that the mean transit time for 5 barges is less than for 6 barges maximum, because it contains positive and negative values. However, CRN results in the second column show clearly that for 6 barges the mean transit time is decreased. Therefore, the null hypotheses can be rejected.

**C8 Classification: Object-Oriented Simulation Simulator: CSIM 18.3 for Linux**

