G54SOD (Spring 2018)

Workshop 09

Output Analysis + Client Engagement

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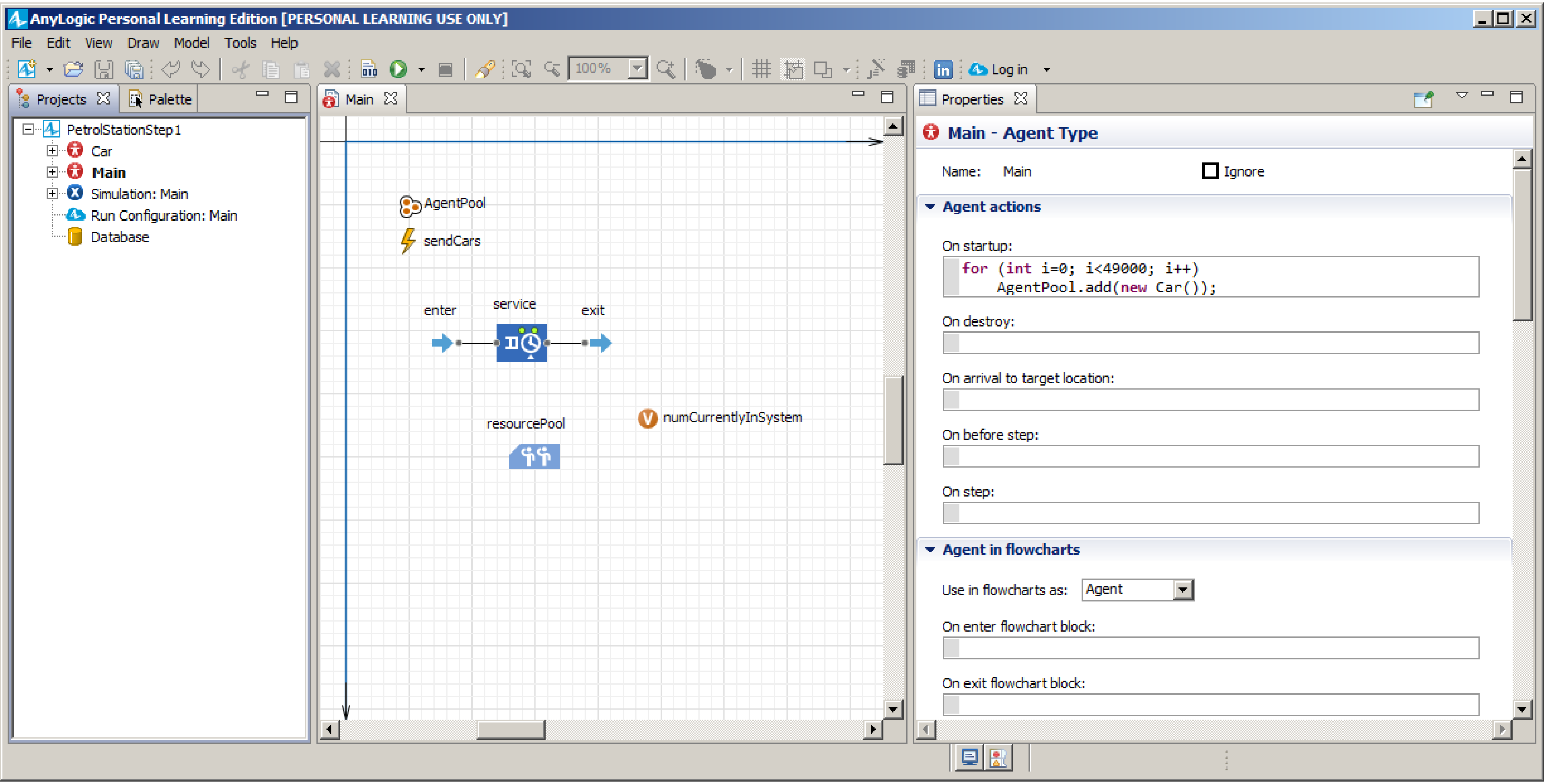
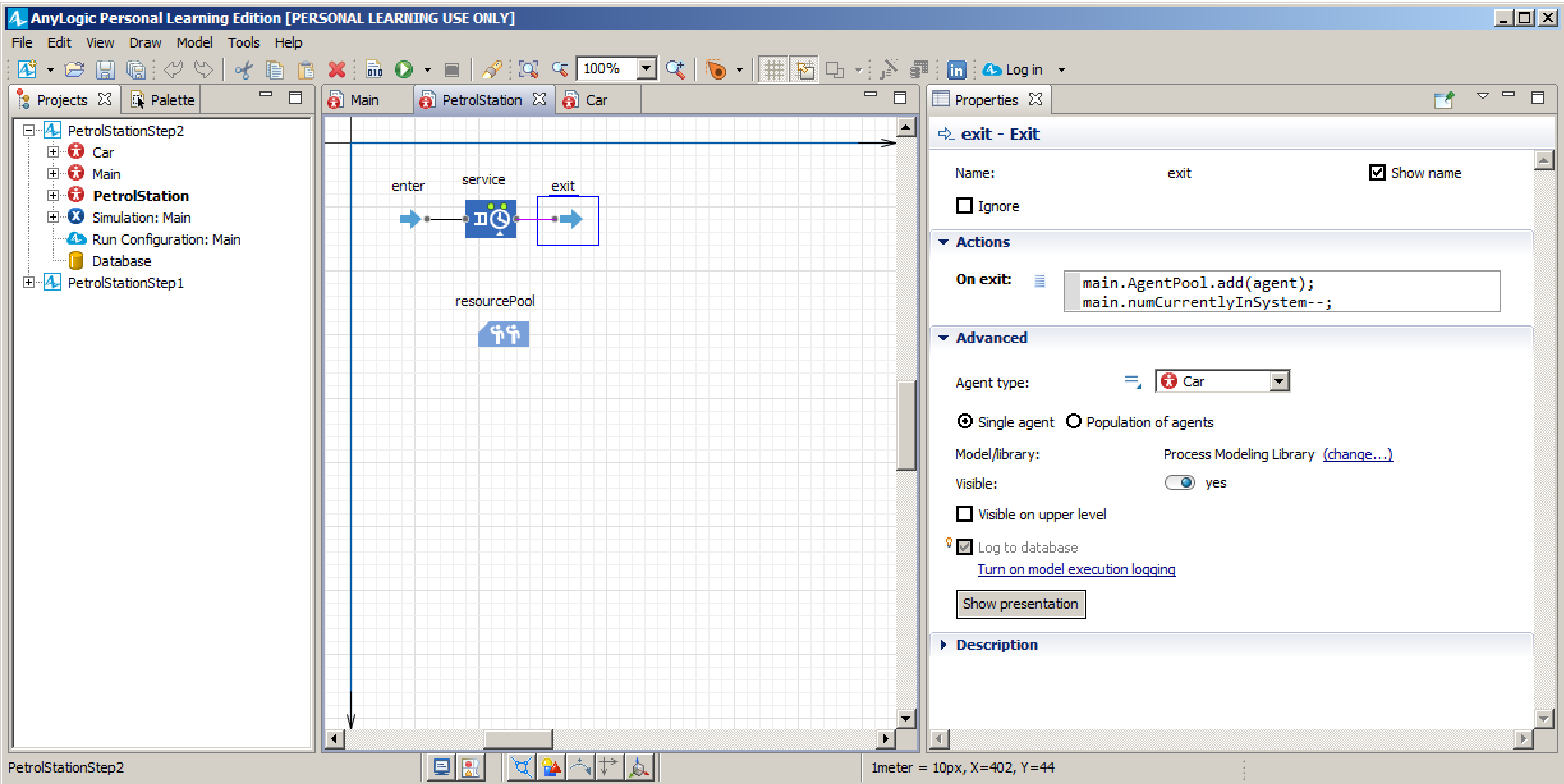
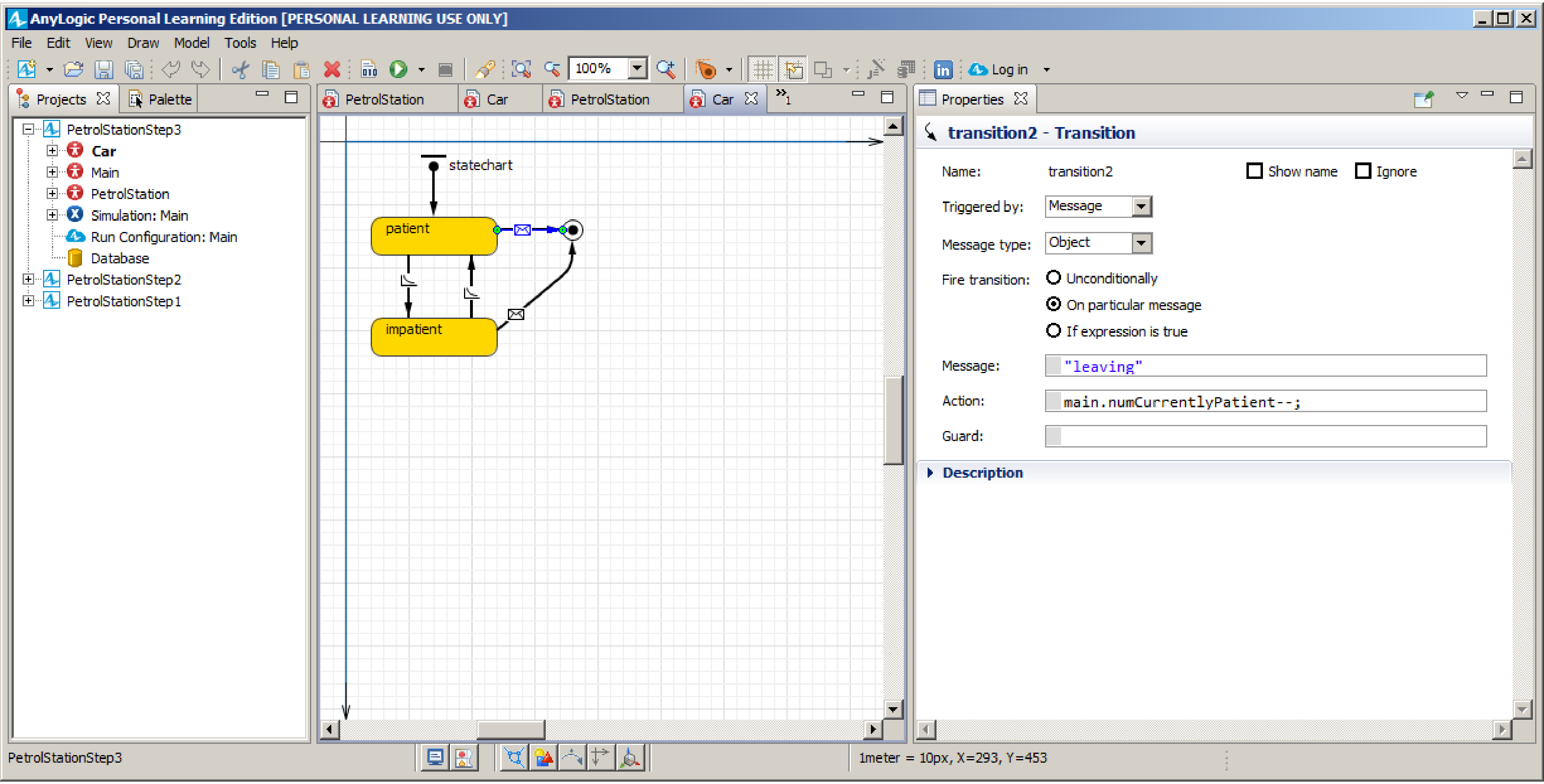
Coursework Help



Coursework Help

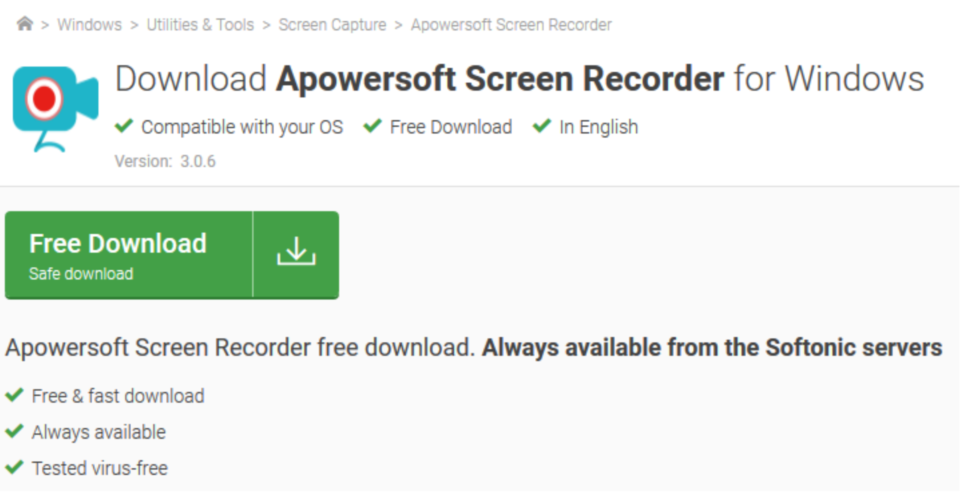


Coursework Help



Coursework Help

- Apowersoft Screen Recorder (https://apowersoft-screen-recorder.en.softonic.com/download)
  - Good alternative to OBS (much easier to use)



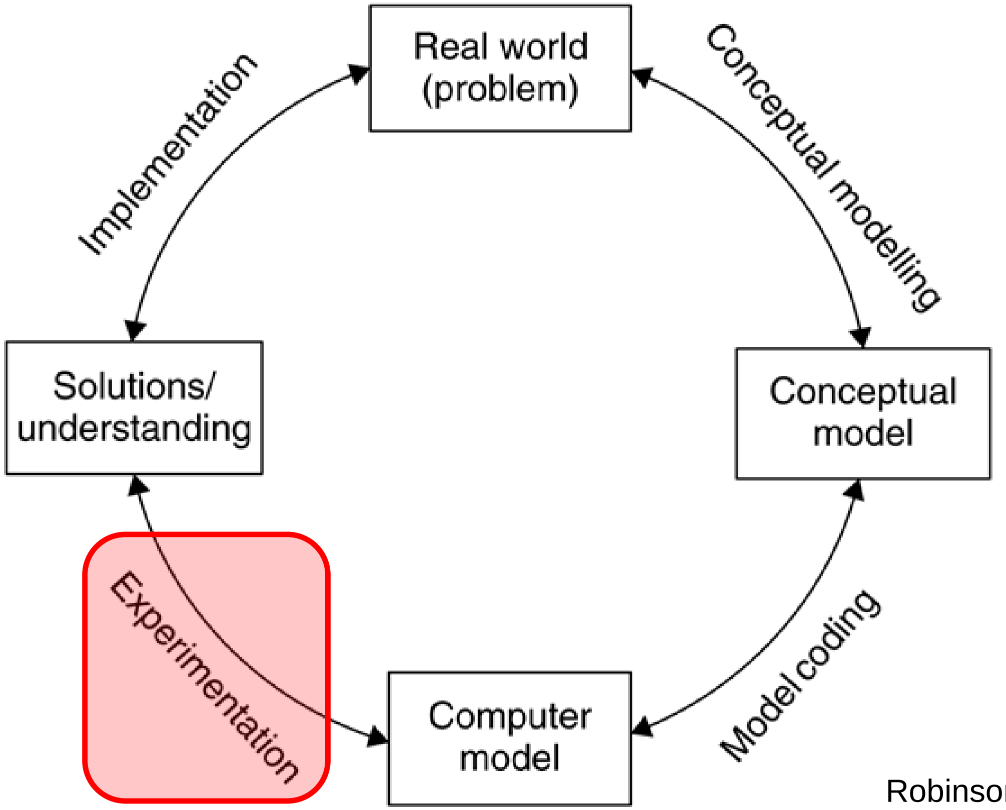
Motivation

- Last steps in the simulation life cycle
  - What kind of simulation experiments one can run
  - How to deal with the output data produced by the simulation
  - How to pass on the results of the study to the clients

- Reflecting about the project
  - Project analysis

Experimentation

- Simulation study cycle



Robinson (2004)

Experimentation

- Interactive experimentation (exploratory simulation)
  - Involves watching the simulation and making changes to the model to see the effects
    - Develop an understanding of the model
    - Identify key problem areas
    - Identify potential solutions

- Batch experimentation (parameter variation)
  - Setting experimental factors and leaving the models to run for a pre-defined run length and number of replications
  - Display is normally switched off to improve run speed

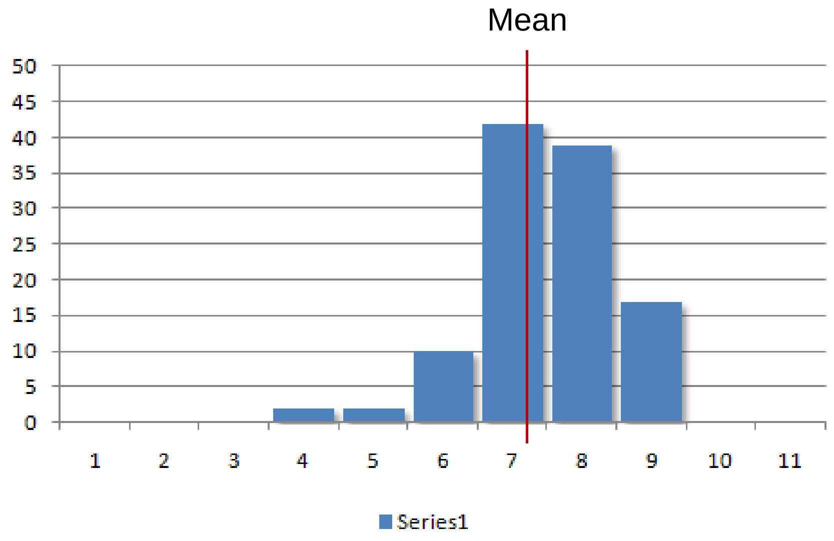
Experimentation

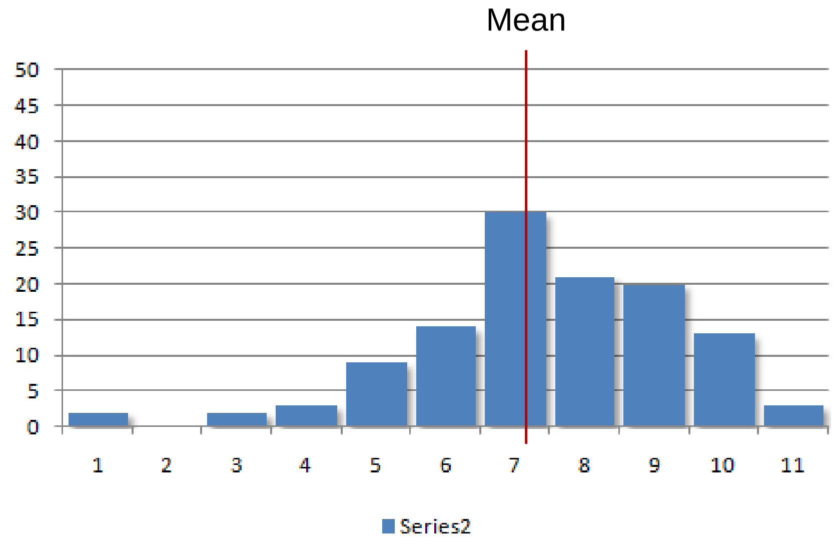
- Comparing alternatives (manual optimisation)
  - There is a limited number of scenarios to be compared
  - Scenarios emerge as the simulation study progresses
- Search experimentation (automated optimisation)
  - There are no predefined scenarios
  - One or more experimental factors are varied until a target or optimum level is reached

Output Analysis (for Stochastic Simulation)

Output Analysis – Single Scenario

- For each response two measures are generally of interest
  - Mean
  - Variability





Output Analysis – Single Scenario

- Point estimate: Mean
  - A point estimate is a single value given as the estimate of a population parameter that is of interest, for example the mean of some quantity
- Interval estimate: Variability
  - Because simulation experiments provide only a sample of output data it is important that a confidence interval for each mean is reported
  - The confidence interval provides information about the range within which the population mean is expected to lie

Output Analysis - Comparing Alternatives

- Is the difference in a results significant?
  - Not simply a case of comparing mean values of key responses
  - Example:
    - Key response: daily throughput
      - Scenario A: Mean = 1050 units per day
      - Scenario B: Mean = 1080 units per day
    - Is scenario B the better alternative?
    - We need to consider two more factors:
      - Standard deviation of each mean daily throughput
      - Number of replications (or batches)
    - A small number of replications and a lot of variation in the results gives little confidence that the difference is significant!

Output Analysis - Comparing Alternatives

- A paired-t confidence interval helps to identify the statistical significance of a difference in the result of two scenarios.

(http://eu.wiley.com//legacy/wileychi/robinson/supp/CompareTwo.xls)

$$CI = \overline{D} \pm t_{n-1,\alpha/2} \frac{S_D}{\sqrt{n}}$$

$$\overline{D} = \frac{\sum_{j=1}^{n} (X_{1j} - X_{2j})}{n}$$

$$S_D = \sqrt{\frac{\sum_{j=1}^{n} (X_{1j} - X_{2j} - \overline{D})^2}{n-1}}$$

where:

$\overline{D}$ = mean difference between scenario 1 (X_1) and scenario 2 (X_2)
X_{1j} = result from scenario 1 and replication j
X_{2j} = result from scenario 2 and replication j
S_D = standard deviation of the differences
n = number of replications performed (same for both scenarios)
$t_{n-1,\alpha/2}$ = value from Student's t-distribution with $n-1$ degree of freedom and a significance level of $\alpha/2$

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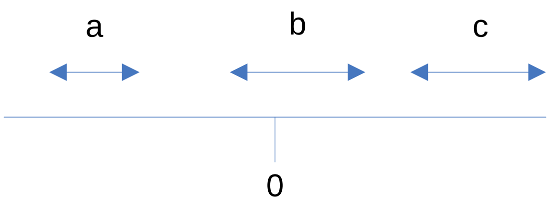
Output Analysis - Comparing Alternatives

- The resulting confidence interval can lead to three outcomes:
  - Outcome a: It can be concluded **with the specified level of confidence** (usually 95%) that the result of scenario 1 is **less than (<)** the result for scenario 2
  - Outcome b: It can be concluded **with the specified level of confidence** (usually 95%) that the result of scenario 1 is **not significantly different** from the result of scenario 2
  - Outcome c: It can be concluded **with the specified level of confidence** (usually 95%) that the result of scenario 1 is **greater than (>)** the result for scenario 2



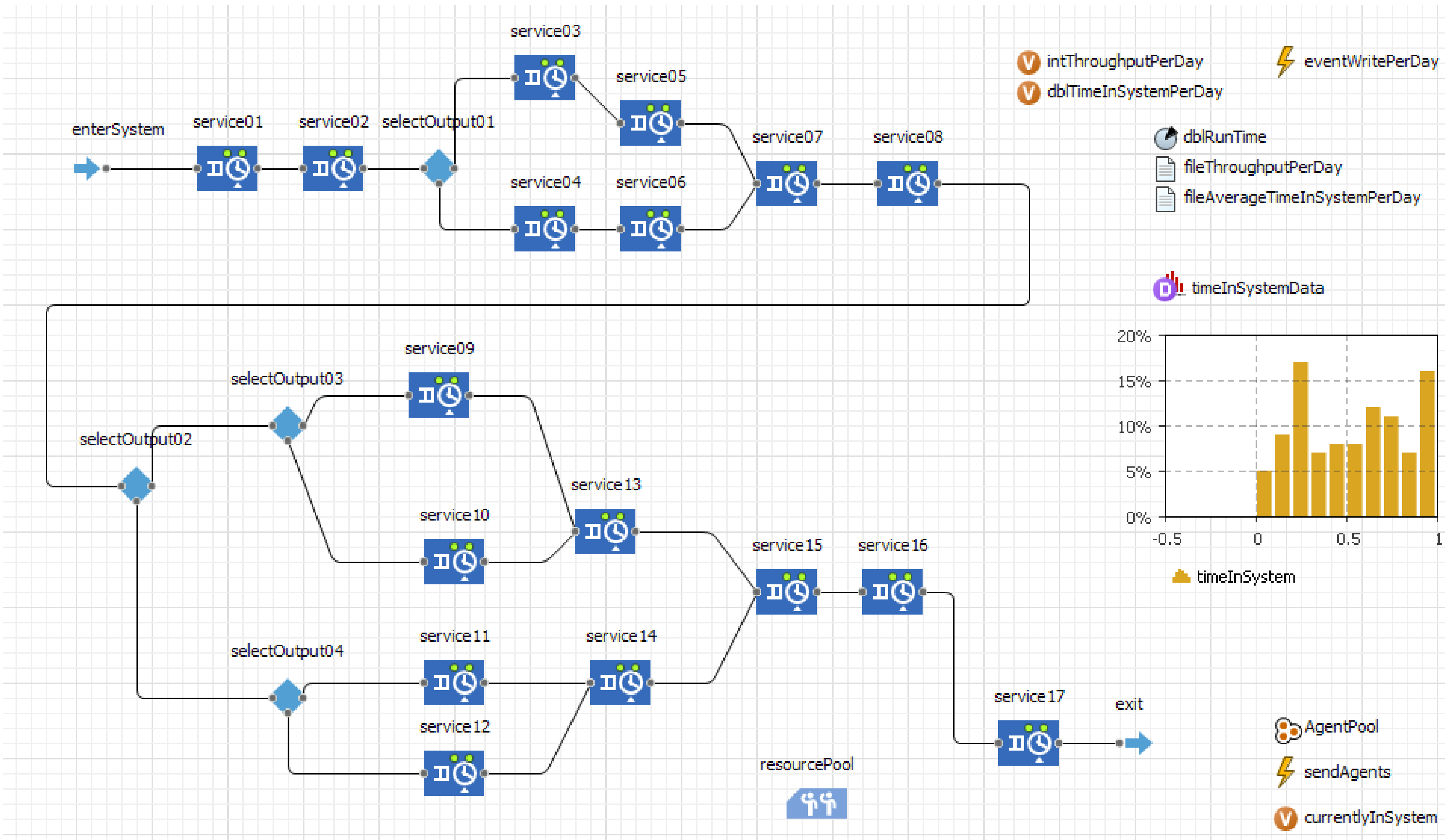
Potential outcomes from a paired-t confidence interval

Output Analysis - Comparing Alternatives

- What is the difference between:
  - Statistical significance of a difference in the result
  - Practical significance of a difference in the result

- Statistical significance:
  - Is the difference in the result real?

- Practical significance:
  - Is the difference sufficiently large to affect the decision?



enterSystem
service01
service02
selectOutput01
service03
service04
service05
service06
service07
service08
intThroughputPerDay
dblTimeInSystemPerDay
eventWritePerDay
dblRunTime
fileThroughputPerDay
fileAverageTimeInSystemPerDay
timeInSystemData
selectOutput02
selectOutput03
service09
service10
service13
selectOutput04
service11
service12
service14
service15
service16
service17
exit
resourcePool
20%
15%
10%
5%
0%
-0.5
0
0.5
1
timeInSystem
AgentPool
sendAgents
currentlyInSystem

Output Analysis - Comparing Alternatives

- Experimental set up:
  - Warm-up period: 6 days
  - Number of replications: 6
  - Run length: 10x warm-up period = 60 days

Output Analysis - Comparing Alternatives

- Throughput per day

Comparison of Two Scenarios								
						Sign. level	5.0%	
	randomTrue(0.5)	randomTrue(0.7)				Confidence interval		
Replication	Scenario 1 result	Scenario 2 result	Difference	Cum. mean difference	SD of cum. mean difference	Lower interval	Upper interval	Conclusion
1	246.02	239.88	6.14	6.14	n/a	n/a	n/a	n/a
2	243.51	241.64	1.87	4.01	3.019	-23.12	31.13	No difference
3	244.79	244.68	0.11	2.71	3.101	-5.00	10.41	No difference
4	243.99	244.59	-0.60	1.88	3.024	-2.93	6.69	No difference
5	245.65	244.24	1.41	1.79	2.627	-1.48	5.05	No difference
6	243.66	243.2	0.46	1.57	2.411	-0.97	4.10	No difference

- Average time in system per day

Comparison of Two Scenarios								
						Sign. level	5.0%	
	randomTrue(0.5)	randomTrue(0.7)				Confidence interval		
Replication	Scenario 1 result	Scenario 2 result	Difference	Cum. mean difference	SD of cum. mean difference	Lower interval	Upper interval	Conclusion
1	100.66	97.36	3.30	3.30	n/a	n/a	n/a	n/a
2	97.68	97.35	0.33	1.81	2.102	-17.07	20.70	No difference
3	99.38	98.40	0.98	1.54	1.562	-2.35	5.42	No difference
4	98.89	98.37	0.52	1.28	1.374	-0.91	3.47	No difference
5	99.41	100.30	-0.89	0.85	1.535	-1.06	2.75	No difference
6	97.81	97.39	0.42	0.78	1.384	-0.68	2.23	No difference

Output Analysis - Comparing Many Scenarios

- Use paired-t confidence interval + Bonferroni inequality
  - If we want to make ***c*** confidence interval statements, the confidence interval should be formed with a significance level of **α/c**
  - If we want to compare each scenario to the current set-up (base scenario) then **c=s-1** where **s** is the number of scenarios
    - Example: Comparing 4 scenarios to the base scenario
      - c = 5-1 = 4
      - If overall confidence required = 95% (α = 5%) then the individual significance levels α = 5/4 = 1.25%
  - If we want to compare each scenario to each scenario then **c = s(s-1)/2**
    - Example: Comparing 5 scenarios
      - c = 5*(4/2) = 10
      - If overall confidence required = 95% (α = 5%) then the individual significance levels α = 5/10 = 0.5%

Output Analysis - Comparing Many Scenarios

- The examples in tables:

Comparing Scenario 2-5 to Base Scenario 1: Overall confidence 95%			
	98.75% confidence intervals for differences		
Comparison	Lower interval	Upper interval	Conclusion
Scenario 1 to 2	...	...	Scen. 1 > Scen. 2
Scenario 1 to 3	...	...	No difference
Scenario 1 to 4	...	...	...
Scenario 1 to 5	...	...	...

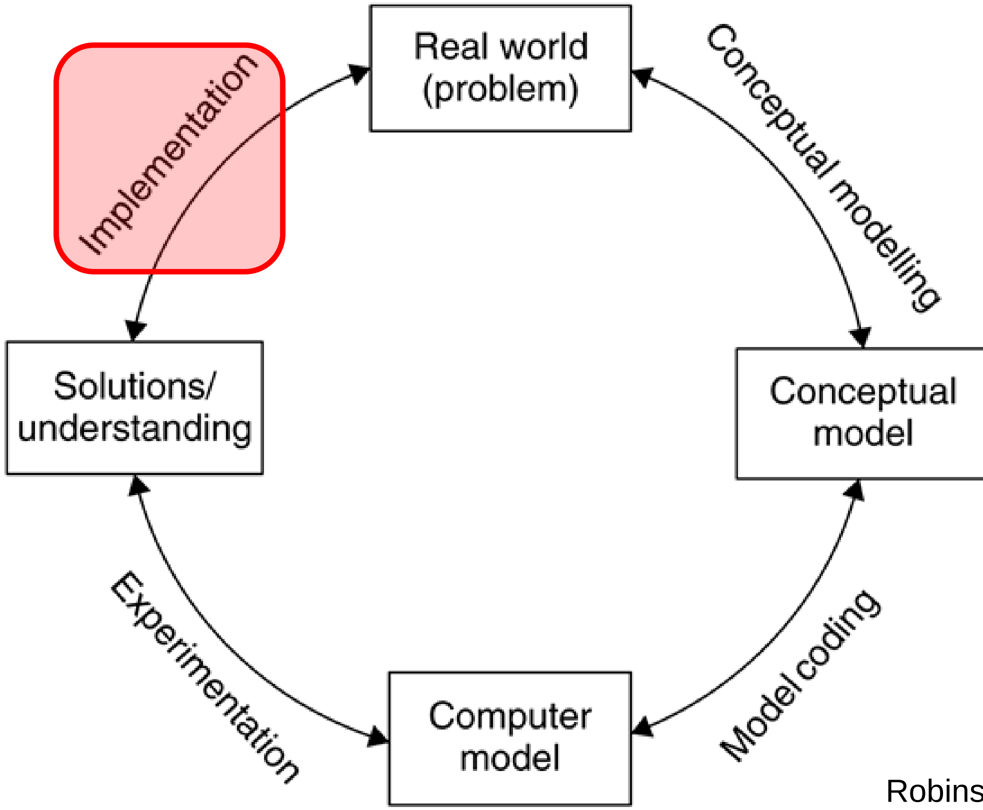
Comparing between all scenarios: Overall confidence 95%				
Calculations	99.5% confidence intervals for differences			
Scenario	2	3	4	5
1	lower int., upper int.	lower int., upper int.	lower int., upper int.	lower int., upper int.
2		lower int., upper int.	lower int., upper int.	lower int., upper int.
3			lower int., upper int.	lower int., upper int.
4				lower int., upper int.
Comparing between all scenarios: Overall confidence 95%				
Conclusions	99.5% confidence intervals for differences			
Scenario	2	3	4	5
1	Scen. 1 > Scen. 2	No difference	...	...
2		...	...	...
3			...	...
4				...

Output Analysis - Comparing Many Scenarios

- Conclusion:
  - Use of Bonferroni inequality is quite effective as long as the number of scenarios stays small
  - As the amount of scenarios increases the number of confidence intervals can quickly become unmanageable (in particular for full comparisons)

Implementation of Study Outcomes

- Simulation study cycle



Robinson (2004)

Implementation of Study Outcomes

- Different ways of Implementation?
  - Implementing the findings from the simulation study
  - Implementing the model
  - Implementing as learning

Implementation does not just happen after the simulation study is completed!

Implementation of Study Outcomes

- Implementing the findings
  - Findings are derived from:
    - Process of enquiry
    - Experimentation results
  - To implement the findings effectively a final report needs to be provided and an implementation process needs to be put in place
    - Communication of results:
      - Written report (needs to contain conclusions and recommendations)
      - Presentation (for immediate feedback and clarification of issues)
  - Client decides which recommendations should be implemented
    - Decision = f(organisational culture, finance available, ...)
    - Simulation study is usually only a small part of a wider project
  - Implementation process should be monitored (and model updated)

Implementation of Study Outcomes

- Implementing the model (hand-over to client)
  - Model might be handed over to the client for their use
    - If client wants to perform his/her own experiments
    - If simulation is designed to help making recurring decisions
    - If client wants to improve understanding of and confidence in the results
    - If client wants to use it for staff training
  - Requires adequate user documentation and training
  - Support and maintenance contract should be put in place

Implementation of Study Outcomes

- Implementing as learning
  - Improved understanding gained from developing and using the model
  - No formal implementation process
    - The learning is normally intangible rather than explicit
  - Leads to a change in management attitudes, believes and behaviours
  - It is important to keep the client involved throughout the modelling process

Implementation of Study Outcomes

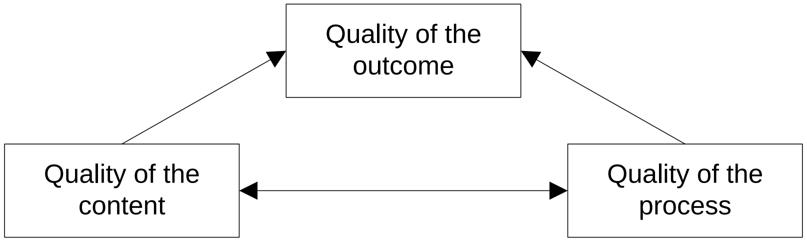
- Choose a Group Activity "first choice"
  - How would you implement it?

Simulation Project Analysis

- Defining simulation project success?
  - Balci (1985): A simulation study can be considered successful if the results are credible and are accepted and used by the decision maker
  - Robinson and Pidd (1998): The simulation study achieves its objectives and/or shows a benefit; the results of the study are accepted; the results of the study are implemented; the implementation proves that the results of the study are correct (solution validation)
- Solution validation?
  - Determining that the results obtained from the model of the proposed solution are sufficiently accurate for the purpose at hand. This is **similar** to **black-box validation** in that it entails a comparison with the real world. It is **different** in that it only compares the final model of the proposed solution to the implemented solution.

Simulation Project Analysis

- Contributors to simulation project success:
  - Achieving clients expectations!
    - Who are the real stakeholders?
    - What do they need?
    - How do they define success?



  - Simulation Quality Trilogy (Robinson 2002)
    - Quality of the Content: The extent to which the technical work within the modelling process conforms to the requirements of the study.
    - Quality of the Process: The extent to which the process of the delivery of the work conforms to the clients' expectations.
    - Quality of the Outcome: The extent to which the simulation study is useful within the wider context for which it is intended.

Simulation Project Analysis

- Measuring simulation project success:
  - Post project review: Discuss what went well, what could have been done better and what could be improved next time (assessing content and process quality)
  - Independent verification and validation (assessing content quality)
  - Questionnaire: Measuring clients expectations against modellers performance

Simulation Project Analysis

- What can go wrong (www.simio.biz)?
  - Tackling the wrong problem
    - Simulating to justify/prove what's already decided
    - Biting off more than can be analysed effectively
    - Simulating "because you can"
  - The right problem … the wrong time
    - Too early: Lack of required information, change in scope or goals
    - Too late: Cannot make recommended changes
  - Data woes
    - Having too much data
    - Having too little data
    - Having the right amount of data – but not understanding them

Simulation Project Analysis

- What can go wrong (cont.)?
  - Letting the window of opportunity close
    - Getting lost in details
    - Waiting too long to start analysis
    - Having too much fun with animation
    - Leaving the debugging for when the model's complete

Do not forget that a simulation project is **dynamic** and that all steps involved in a simulation study are **iterative**!

Simulation Project Analysis

- Do a post project review of the Group Activity
  - What went well?
  - What could have been done better?
  - What went completely wrong?
  - What could be improved next time?

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Simulation Project Analysis

Proceedings of the 2012 Winter Simulation Conference
C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A. M. Uhrmacher, eds.

SEVEN PITFALLS IN MODELING AND SIMULATION RESEARCH

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ABSTRACT

Modeling and simulation is applied in many disciplines. While its multidisciplinarity is part of its fascination, its ubiquity also holds some dangers. Being not aware about these dangers might imply that resources are wasted, (PhD-) projects fail, and the overall progress of modeling and simulation is needlessly slowed down. Seven of these pitfalls are identified and tentative recommendations are made on how these pitfalls can be avoided.

- http://www.informs-sim.org/wsc12papers/includes/files/inv277.pdf

Simulation Project Analysis

- http://jasss.soc.surrey.ac.uk/15/2/5.html

Useful to know … when to put a ";"

Library Reference Guides >

Object parameters: static, dynamic and code

Parameters of all AnyLogic library objects (Process Modeling Library, Pedestrian Library, Rail Library and Road Traffic Library) are of three types:

- *Static*. Evaluated once, but may be changed during the model execution. In the field of a static parameter you can define its value (that can be casted to the type of the parameter).
- *Dynamic*. Evaluated each time it is needed, e.g. each time the delay time, the speed or other property of an agent needs to be obtained.
- *Code*. Dynamically executed code piece, evaluated each time a certain event occurs at the object: the agent enters/exits it, conveyor stops, etc. Here you should put a semicolon at the end of each line of code.

Examples

Parameter type	Object	Parameter	Valid value
Static	**Queue**	***Capacity***	`15`
	Delay	***Agent location***	`pathDelay`
Dynamic	**SelectOutput**	***Condition***	`agent.type==1`
	PedServices	***Delay time***	`2.5 + uniform( 2, agent.complexity * 60 )`
Code	**Sink**	***On enter***	`dataset.add( time() - agent.timestamp );` `serviced++;`

	TrainSource	***Car setup***	`if( carindex == 0 ) {`
			`    car.setShape( locomotive );`
			`}`
			`else {`
			`    car.setShape( boxCar );`
			`}`

Questions / Comments

References

- Robinson (2004). Simulation: The practice of model development and use. John Wiley & Sons: Chichester, UK