Scientific Data Visualization

Vizualizarea Stiintifica a Datelor

Vizualizarea datelor stiintifice

Modelare, Simulare, Vizualizare

Ziua	Ora	Sala	Sapt.	Tip
Miercuri	16~18	L339	S1	Seminar
	18~20	C335	*	Curs

http://www.cs.ubbcluj.ro/~per/Web_Page/Cursuri.htm

- http://www.cs.ubbcluj.ro/~per/Scs_Per/Sdv/Sdv.html

Universitatea Babeş-Bolyai, Cluj-Napoca

Facultatea de Matematică şi Informatică

Home	Cursuri	Proiecte	Cv	Calendar	Lucrari Lic. Dis. GrI	Contact

Cursuri 2016-2017

Semestrul I	Per	Act.	Dur.	
	03.10 – 23.12	Act. Did.	12 Săpt.*	Grafică pe Calculator
	* 30.11.2016	Sfântul Andrei	Liber	Decision Support Systems
	* 01.12.2016	Ziua Naţională	Liber	Info-Didactic: Tehnologia informaţiei (pentru perfecţionarea profesorilor)
	26.12 – 08.01	Vacanţă	2 Săpt.	Util.Soft.Spec. (EFS~SPM, IFR)
				Proiect Colectiv
	09.01 – 22.01	Act. Did.	2 Săpt.	Fundamentele Programării
	23.01 – 12.02	Sesiune	3 Săpt.	Fundamentele Programării (Sem., Lab.)
	13.02 – 19.02	Vacanţă	1 Săpt.	Proiect Individual
	20.02 – 26.02	Restanţe	1 Săpt.	Progr. Calc.

Semestrul II	Sapt.	S	NeTer.	
	27.02 ~ 16.04	S_1-S_7	Act. Did.	
	17.04 ~ 23.04	V_1	Vacanta	
	24.04 ~ 11.06	S_8-S_{14}	Act. Did.	Prelucrarea Imaginilor (Cr Re Im)
	12.06 ~ 2.07	E_1-E_3	Ses. Ex.	
	03.07 ~ 9.07	V_2	Vacanta	Scientific Data Visualization Mos
	10.07 ~ 16.07	R	Restanta	
	Sapt.	S	Term.	Verificarea si validarea sistemelor soft
	27.02 ~ 16.04	S_1-S_7	Act. Did.	Util.Soft.Spec. (Kineto, IFR)
	17.04 ~ 23.04	V_1	Vacanta	Proiect Colectiv
	24.04 ~ 28.05	S_8-S_{12}	Act. Did.	Visualization and Validation in Simulation
	29.05 ~ 11.06	E_1-E_2	Ses. Ex.	Structuri de Date şi Algoritmi
	20.06 ~ 2.07	P_1-P_2	Prog. Ld	Proiect Individual
	03.07 ~ 9.07	Ld_1	Ex. Ld	Oop
	1.05 & 5.06		Liber	

2

Specializarea:

Calcul de înalta performanta şi analiza volumelor mari de date

○ *Semestrul* II

Discipline oferite pentru curs opțional 1	
Disciplina	Cadru didactic
Vizualizarea datelor stiintifice	*Lect. dr. Vasile Prejmerean*

General data

3.1 Hours per week	3	Of which: 3.2 course	2	3.3 seminar/laboratory	1
3.4 Total hours in the curriculum	42	Of which: 3.5 course	28	3.6 seminar/laboratory	14
Time allotment:					hours
Learning using manual, course support, bibliography, course notes					36
Additional documentation (in libraries, on electronic platforms, field documentation)					36
Preparation for seminars/labs, homework, papers, portfolios and essays					36
Tutorship					18
Evaluations					18
Other activities: **Project**					14

3.7 Total individual study hours	158
3.8 Total hours per semester	200
3.9 Number of ECTS credits	7

Course objectives

To assimilate visualization and simulation techniques and the simulation as a method of studying the real phenomenon. To gain skills related to problem solving through simulation. To teach the students the concepts used in the field of modeling and simulation and to acquire the methods for validation of simulation.

After promotion the students should be able to use simulation as a method of solving real problems. They will know to verify their programs and to validate the simulation results.

Course contents

1. Simulation.

2. The Steps of a Simulation Study.

3. Verifying and validating a simulation model.

4. Techniques for validation.

5. Inspection. Testing.

6. Sensitivity analysis.

7. Calibration.

8. Input analysis.

9. Output analysis: output data analysis for simulations.

10. Statistical techniques needed for validation - data analysis and visualization

11. Visualization and simulation techniques

12. Interactive simulation and visualization

Bibliography

1. ARSHAM H., Systems Simulation: The Shortest Path from Learning to Applications, http://www.ubmail.ubalt.edu/~harsham/simulation/sim.htm

2. BALCI, O., Validation, Verification, and Testing Techniques throught the Life Cycle of a Simulation Study, Annals of Operations Research, 1994, no.12, pp.1-49

3. BLAGA P., Statistica prin MATLAB, Presa Universitara Clujeana, 2002.

4. DODESCU Gh., Simularea sistemelor, Ed.Militara, Bucuresti.

5. M.Frenţiu, Verificarea corectitudinii programelor, Ed.Univ."Petru-Maior", Tg.-Mureş, 2001, 116 pp., ISBN 973-8084-32-6

6. Averill M. Law and W. David Kelton, Simulation Modeling and Analysis, McGraw Hill, Third Edition (2000).

7. Kleijnen J.P.C., Theory and methodology of Verification and validation of simulation models, European Journal of Operational Research, 82(1995), 145-162.

8. STATE, L., J.POPESCU, Modele probabiliste in Inteligenta Artificiala, Litog. Univ. Bucuresti, 1979.

9. VADUVA I., Modele de simulare cu calculatorul, Ed. Tehnica, Bucuresti 1977.

…

Additional references

O1. Jack P.C. Kleijnen, Five-stage procedure for the evaluation of simulation models through statistical techniques, Proceedings of the 1996 Winter Simulation Conference, p.248-254.

O2. Kleijnen J.P.C., Sensitivity analysis and optimization, Proceed. of the 1995 Winter Simulation Conference, p.133-140, 19959.

O3. Kleijnen J.P.C., Validation of models: statistical techniques and data availability, Proceed. of the 1999 Winter Simulation Conference, 1999.

O4. RACEANU, E., Limbaje de simulare, Ed.Militara, Bucuresti, 1981

O5. SANDERSON D.P., R.SHARMA, R.ROZIN, and S.TREU, The Hierarchical Simulation Language HSL: A Versatile Tool for Process-Oriented Simulation, ACM Trans.on Modeling and Computer Simulation, Vol.1, no.2, 1991, pp.113-153.

O6. T.I. Oren, Concepts and Criteria to Asses Acceptability of Simulation Study : a frame of reference, Comm.ACM, vol.24(1981), no.4, 180-184.

O7. Papers on Software Metrics from the Journals:

a. IEEE Software.

b. IEEE Transactions on Software Engineering.

c. Transactions on Modeling and Simulation, ACM.

d. Software -- Practice and Experience, Wiley.

Assessment

A mark S is given for the activities at the seminars during the term. Then, a written examination must be given (mark W). The final grade is :

$$F = (W + S) / 2$$ rounded according to the presences at the activities during the term.

Presence to the seminars is needed. The mark A reflects the activity of the student during the term and cannot be improved at exams.

$$S \rightarrow (Paper, \; Aplication \sim Project \; (Progr.+Doc.)) = 2* (P*15\% + A*35\%)$$

$$F = (Ref.*15\% + Apl._{*}35\% + W*50\%)$$

10. Evaluation			
Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)
10.4 Course	- know the basic elements and concepts of the Scientific Data Visualization;	Written exam	50%
10.5 Seminar / Project	- complexity, importance and degree of timeliness of the synthesis made	Paper presentation	15%
	- apply the course concepts - problem solving	Project presentation	35%
10.6 Minimum performance standards			
➤ At least grade 5 at written exam, paper presentations and project realised.			

Characteristics of Simulation

Models *represent* reality, **simulation** *imitates* it.

Simulation is a technique for *conducting experiments*.

Simulation is a *descriptive method* – there is no automatic search for an optimal solution.

A simulation model *describes or predicts the characteristics* of a given system under different conditions.

The simulation process usually repeats an experiment many times to obtain an estimate (and a variance) of the overall effect of certain action.

Simulation is used when the problem is too complex to be treated using numerical optimization techniques.

Advantages of **Simulation**

Simulation is used in MSS for:

- The theory is fairly straightforward.

- A great amount of *time compression* can be attained.

- **Simulation is descriptive** – allows the manager to pose *what-if* questions → *trial-and-error* approach to problem solving and can do so faster, at less expense, more accurately, and with less risk.

- The model is built from the manager's perspective.

- The simulation model is built for one particular problem and typically cannot solve any other problem – every component in the model corresponds to part of the real system.

Disadvantages of Simulation

Disadvantages of simulation are:

- **The optimal solution cannot be guaranteed**, but relatively good ones are generally found.

- **Simulation model construction** can be a slow and costly process, although never modeling system are easier to use than ever.

- **Solutions and inferences** from a simulation study are usually not transferable to other problems because the model incorporates unique problem factors.

- **Simulation is** sometimes so **easy to explain** to managers that analytic methods are often overlooked.

- **Simulation software** sometimes requires special skills because of the complexity of the formal solution method.

The Methodology of Simulation

Simulation involves setting up a model of a real system and conducting repetitive experiments on it.

The methodology consists of the following steps:

1. *Define the problem.* We examine and classify the real-world problem – we specify why a simulation approach is appropriate. .

2. *Construct the simulation model.* This step involves determination of the variables and their relationships, as well as data gathering.

3. *Test and validate the model.* The simulation model must represent the system being studied.

4. *Design the simulation experiments.* When the model has been proven valid, an experiment is designed – how long to run the simulation (accuracy and cost?).

5. *Conduct the experiments:* involves issues ranging from random-number generation to result presentation.

6. *Evaluate the results.* The results must be interpreted – sensitivity analysis.

7. *Implement the results.* The chances of success are better because the manager is usually more involved with the simulation process then other models.

The Process of **Simulation**

Real-world problem

Construct the simulation model	**Define the problem**

Test and validate the model	**Design the simulation experiments**	**Conduct the experiments**	**Evaluate the results**	**Implement the results**
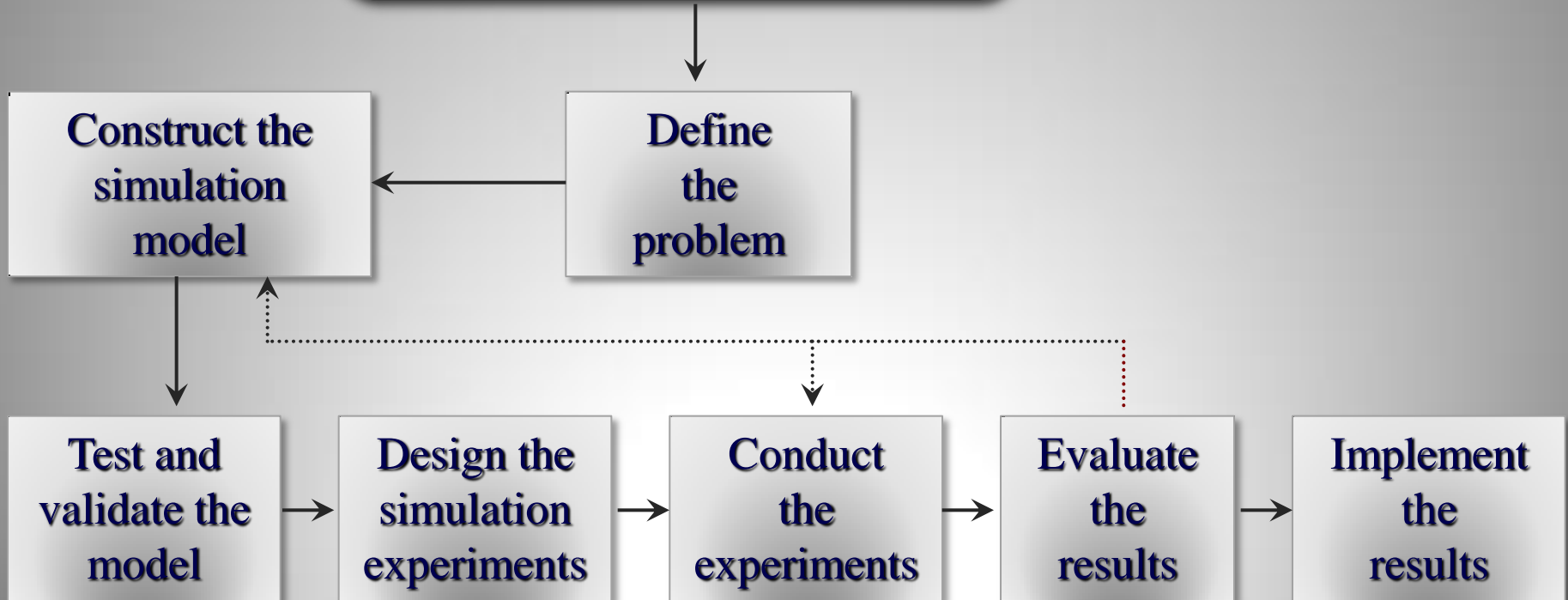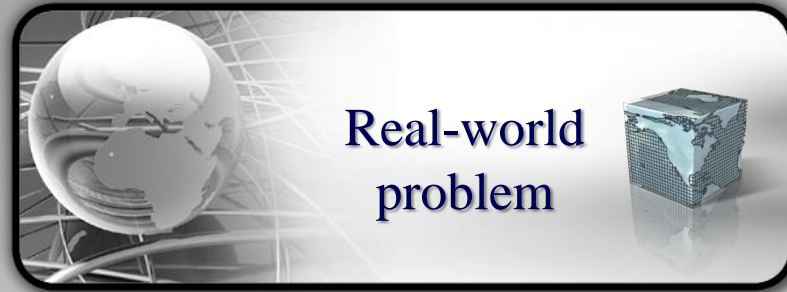
Simulation Types

The types of **Simulation** are:

1. *Probabilistic Simulation.* The independent variables are probabilistic:
   - *Discrete distributions* – a situation with a limited number of events (variables) that can take on only a finite number of values.
   - *Continuous distributions* – unlimited number of possible events that follow density functions, such as the *normal distribution*.
2. *Time-Dependent Simulation* – is important to know the precise time of arrival.
3. *Time-Independent Simulation* - is not important to know exactly when the event occurred.
4. *Object-oriented Simulation.* SIMPROCESS: object-oriented process modeling tool that lets the user create a simulation model by using screen-based objects. UML could be used in practice for modeling complex, real-time systems.
5. *Visual Simulation.* The graphical display of computerized results, which may include animation, is one of the most successful developments in computer-human interaction and problem solving.

Visual Interactive **Simulation**

We examine methods that show a decision maker a representation of the decision-making situation in action as it runs through scenarios of the decision maker's choices of alternatives.

"These powerful methods overcome some of the inadequacies of conventional methods and help build trust in the solution attained because they can be visualized directly."

Conventional Simulation Inadequacies

Simulation is a descriptive and mathematics-based method for gaining insight into complex decision-making situations. Simulation does not usually allow decision makers to see how a solution to a complex problem evolves over time, nor can decision makers interact with the simulation.

Simulation generally reports statistical results at the end of experiments. If the simulation results do not match the intuition or judgment of the decision maker, a *confidence gap* in the results can occur.

… Visual Interactive **Simulation**

Visual Interactive Simulation **(VIS)** also know as *Visual Interactive Modeling* **(VIM)** and **Visual Interactive Problem Solving**, is a simulation method that lets decision makers see what the model is doing and how it interacts with the decisions made, as they are made.

The user can employ his knowledge to determine and try different decision strategies while interacting with the model. Decision maker also contribute to model validation, and support and trust their results.

VIS uses animated computer graphics display to present the impact of different decisions. It differs from regular graphics in that the user can adjust the decision-making process and see the results of the intervention. A visual model is a graphic used as an integral part of decision making or problem solving. VIS displays the effects of different decisions in graphic form on a computer screen. The simulation system identified the most important input factors that significantly affected performance.

… Visual Interactive **Simulation**

Visual Interactive Models

Visual Interactive Simulation can represent static or dynamic systems:
- *Static models* display a visual image of the result of one decision alternative at a time.
- *Dynamic models* display systems that evolve over time, and the evolution is represented by animation.

The latest visual simulation technology has been coupled with the concept of virtual reality, where an artificial world is created for a number of purposes, from training to entertainment to viewing data in an artificial landscape.

The *VIM* approach can also be used in conjunction with artificial intelligence. Integration of the two techniques adds several capabilities that range from the ability to build systems graphically to learning about the dynamics of the system.

Steps in developing a simulation

- Modelling (*)
- Simulation (No. Random → Stat.)
- Verification / Validation (simulation)
- Calibration
- Sensitivity Analysis
- Visualization
- …

Modelling

Simulation

Visualization

Verification Validation

Calibration

Sensitivity Analysis
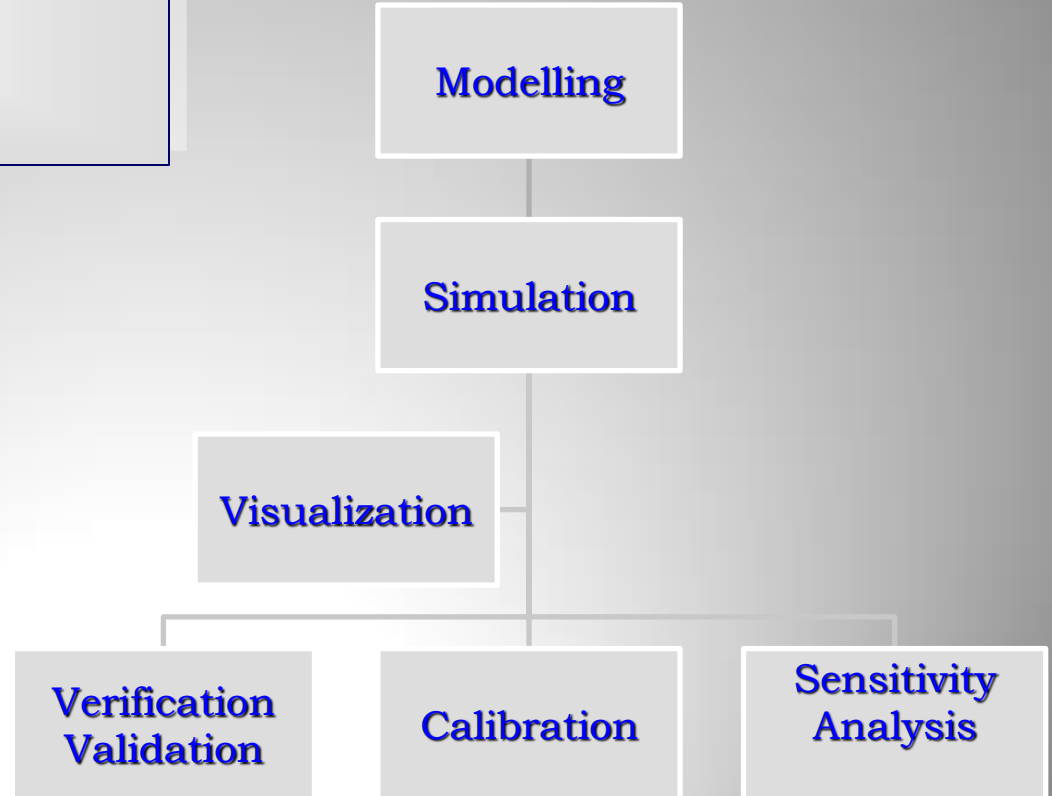
Models

Model = approximate representation of a real phenomenon to study its properties. Take into account only factors (considered important) that influence the desired result.

- Models can be (classification):

  - physical, mathematical

  - deterministic, stochastic

  - discrete, continuous

  - static, dynamic system

- A project can be used as a model to study the real property.

Simulation ...

- **Simulation** =

  - imitation (reproduction, miming) their processes and phenomena through mathematical

  - modeling Technique computer experiments involving the use of mathematical models describing the behavior of a real system

  - generating artificial history and analysis of a system to shoot the story called conclusions about the system

… Simulation …

- **Simulation can be used to study**
  - new systems projects,
  - systems existing real or imagined (ice age).

- **When to use simulation?**
  - system is too complex to be studied analytically;
  - system has no analytical solution,
  - we want to study the effect of changes on an existing system
  - to observe the behavior of an analytical system,
  - to observe the behavior of a system to improve the system, driving (driving a car , flight, fight …)
  - to convince us about the correctness of the analytical solutions

- **When not used simulation?**

  when there is a simple analytical solution,

  it is possible to direct experience,

  the simulation cost exceeds earnings,

  the data are not necessary,

  when there is no time (you do not have enough time).

Advantages of simulation

- You can study real systems exist, or spent a long time ago, or to be built,

- can check certain assumptions without affecting real phenomenon,

- real systems can be studied over a long stretch, compress time,

- helps to make decisions, changing parameters and choosing the best solution,

- can study systems have analytical solution, or systems that analytical solution is very complicated or difficult to obtain.

- Before you purchase some equipment can simulate their operation and decide whether is profitable purchase.

- Certain assumptions can be checked without the use of materials, not made of real systems, so they save resources,

- you can analyze the importance of variables in the model, or dependent variables.

How to simulate?

- Write a simulation program where all the rules of writing a program! But further work is needed:

    - verification of the model ;

    - preliminary data collection and statistical analysis ;

    - analysis of simulation results.

  So, using statistical methods of data processing...

Steps in simulation (of a phenomenon):

1) Formulation of the problem
2) Analysis of problem
3) Collecting and processing data and parameter estimation:
4) Building the simulation model:
5) evaluation model, analysis of all elements involved, the study variables
6) building simulation program (including viewing)
7) Verification and validation of simulation program
8) Validation of simulation!
9) The analysis of simulation
10) Redefine
11) Presenting the results of simulation
12) Documentation

... Steps in simulation (of a phenomenon):

1) Formulation of the problem :

- What's the problem?

- What do we know?

- What are we to know?

. questions that must be answered,

. hypotheses to be tested,

. effects to be estimated.

2) Problem analysis:

– data entry (input data),

– results (output data),

– method of solving (any form).

3) Collecting and processing data and parameter estimation:
- – may suggest hypotheses,
- – can improve the model
- – used to estimate parameters,
- – used to validate the model.

4) Building the simulation model:
- – specifying variables,
- – specifying functional relations,
  - » setting simulation experiments,
- – establishing the criteria for validation.

5) Evaluation model, analysis of all elements involved, the study variables:
- – model contains all the essential variables?
- – distributions are known variables?
- – is quite accurate estimation?
- – functional relations are correct?

6) Building simulation program:
- simulation time/clock (a: fixed increments, b: the events in event);
- simulation algorithm;
- selecting language;
- writing program

7) Verification and validation of simulation program.

8) Validation of simulation.

9) Analysis of simulation results:
- collection,
- processing,
- statistical calculations,
- interpretation of results.

10) Redefine:
- update (after changes);
- change to see the effect and to obtain other results;
- maintenance,
- adaptation to another user,
- another alternative.

11) Presentation of simulation results:
- interpretation (through visualization specialist)
- decisions

12) Documentation.

13) ... .

Homework (Examples)

- Railway Station & Transportation → $T_{imp}M_{ediu}A_{st.}$, $N_rM_{ed}C_{al}$ (st)

- Warehouse & Customer → C_{ost} (1 an)

- Traffic

- Epidemic

- ...

Examples in *Labor*

Resources and Links

We recommend the following resources and links:

- The INFORMS Web site : informs.org.
- OR/MS Today : orms-today.com.
- COIN-OR : coin-or.org.
- COIN-OR : coin-or.org.
- NEOS Server for Optimization : neos.mcs.anl.gov/neos/index.html.
- H.Arsham's Modeling & Simulation Resources page: home.ubalt.edu/ntsbarsh/Business-stat/RefSim.htm.
- Decision Science Resources page : home.ubalt.edu/ntsbarsh/Business-stat/Refop.htm.
- Jay Aronson's DSS Sofware Web page: terry.uga.edu/people/jaronson/dss/DSS-Software.htm.
- Decision Analysis Society : faculty.fuqua.duke.edu/daweb/dasw6.htm.
- Interactive Linear Programming group: faqs.org/faqs/linear-programming-faq/.

- The Society for Modeling & Simulation International ~ JDMS: The Journal of Defense Modeling & Simulation ~ http://www.scs.org/jdms
- Ali M. Niknejad, Analysis, Simulation, and Applications of Passive Devices on Conductive Substrates
- Prof. Stephen G. Powell, Applications of Simulation ~ stephen.g.powell@dartmouth.edu, Tuck 210
- EXPLORING MONTE CARLO SIMULATION APPLICATIONS FOR PROJECT MANAGEMENT, Young Hoon Kawak and Lisa Ingall, Department of Decision Sciences, School of Business, The George Washington University , Washington , DC , USA, IBM Systems Technology Group , Silver Spring , MD
- Application of simulation techniques for accident management training in nuclear power plants, IAEA-TECDOC-1352, International Atomic Energy Agency, May 2003.

http://upm.ro/intranet/ecalin/cd_educational/cd/book/book.html

Capitolul 1- Introducere
    O privire generala
    Scopul cartii
    Ideea principala
    Structura cartii
Capitolul 2 - Problematica vizualizarii
    Problematica generala
    Cadrul stiintific
    Problema specifica
Capitolul 3 - Vizualizarea stiintifica
    Asupra terminologiei
    Probleme actuale in vizualizarea stiintifica
    Modelul de referinta in procesul de vizualizare stiintifica
    Conditiile fundamentale ale vizualizarii stiintifice
    Modele pentru date
    Exprimarea unor conditii suplimentare pentru functia de vizualizare
    Nivelul vizualizare logica
    Nivelul vizualizare fizica
    Cu privire la ordonarea obiectelor geometrice virtualel
    Relaxarea conditiilor procesului de vizualizare
    Concluzi

Capitolul 7 - Construirea sistemelor de vizualizare cu VTK

    VTK - O prezentare generala

    Modelul grafic VTK

    Obiecte VTK

    Vizualizari cu VTK

Capitolul 8 - Aplicatii

    Reconstructia 3D a reliefului

    Vizualizarea zacamintelor pe baza datelor de foraj

    Vizualizarea datelor experimentale sincrona si comparativa

Anexa A - Resurse privind vizualizarea stiintifica

Anexa B - Sisteme pentru vizualizare

Anexa C - Resurse VTK

Anexa D - Tcl/Tk

Glosar

http://upm.ro/intranet/ecalin/cd_educational/cd/book/book.html