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Monte-Carlo simulations using Maastricht University Simulation Tool

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Sharing Success

Monte Carlo methods in finance

- [Wiki: Monte Carlo methods in finance](#)
 - Monte Carlo methods are used in finance to value and analyze (complex) instruments, portfolios and investments by simulating the various sources of uncertainty affecting their value, and then determining their average value over the range of resultant outcomes.
 - The advantage of Monte Carlo methods over other techniques increases as the dimensions (sources of uncertainty) of the problem increase.
 - Essentially, the Monte Carlo method solves a problem by directly simulating the underlying (physical) process and then calculating the (average) result of the process.



A project selection example (an exercise from [Ragsdale])

TRC Technologies has \$2 million to invest in new R&D projects.

The following table summarizes

- the initial cost,
- probability of success, and
- revenue potential for each of the projects.

TRC's management wants to determine what set of projects should be selected.



Case Data



Project	Initial Cost (\$1000s)	Probability of success	Revenue Potential (\$1000s)	
			Mean	StDev
1	250	90%	750	15
2	650	70%	1500	50
3	250	60%	600	10
4	500	40%	1800	75
5	700	80%	1200	100
6	30	60%	180	5
7	350	70%	900	60
8	70	90%	250	20

Classic ROI approach

- Compute expected returns
- Compute ROI ratios
- Order the projects wrt decreasing ROI
- Select first ***k*** projects with investments summing up to 2000
- Done



Is this a good solution?



Project	Initial Cost (\$1000s)	Probability of success	Mean	ROI
1	250	90%	750	1,7
2	650	70%	1500	1,08
3	250	60%	600	1,16
4	500	40%	1800	2,24
5	700	80%	1200	0,54
6	30	60%	180	4,40
7	350	70%	900	1,31
8	70	90%	250	2,21

ROI vs Optimal Solution (-13,79%)



Project	ROI selection	Optimal Selection
1	1	1
2	0	1
3	1	1
4	1	1
5	0	0
6	1	0
7	1	1
8	1	0
Budget utilization	1450	2000
Return	2582	2995

Wooooops: ROI is suboptimal

- See file [Simulation.xls](#)
- This is, so-called, KNAPSACK problem
- NP-hard but admits FPTAS
- Small instances are solvable
- Possible mistake of ROI: 100%.
Take three projects (return, investment): (18, 19); (10, 10); (10, 10) and total budget=19
- Possible mistake of "greedy": 100%.
Take three projects (return, investment): (11, 10); (10, 10); (10, 10) and total budget=20



Where is simulation?

- What is the chance of getting revenue more than **X** , less than **Y** ?
- More generally, how the revenue is distributed?

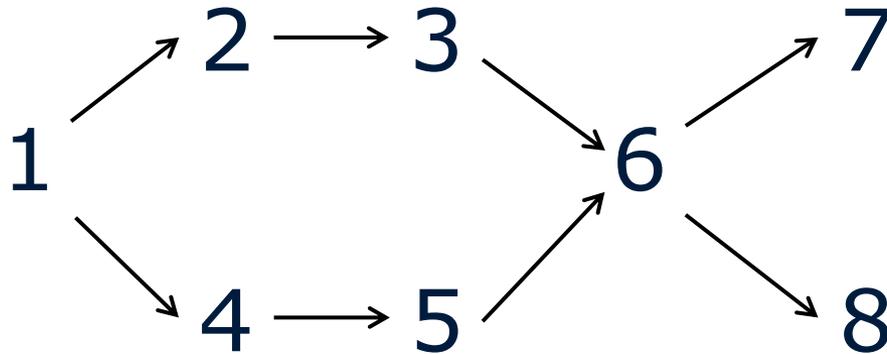
Here we need the Monte-Carlo...

See [Simulation.xls](#) -> "First Simulation"



Can we do something more sophisticated?

- What if we have enough money but the projects are dependent? E.g., we have a project network...



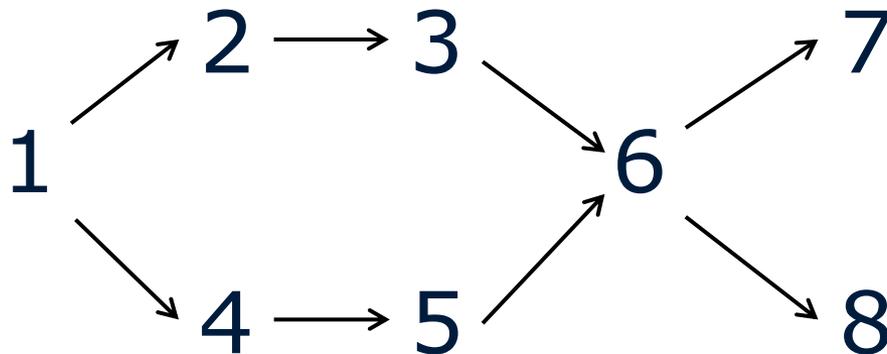
Relationships between the projects



- Let every project take some time normally distributed (or uniformly, or beta-, or triangularly distributed).
- If A precedes B in the network, B cannot start before A is completed.
- Given a project deadline, the return is penalized (discounted) if the project is late.

New (more complex) task

	1	2	3	4	5	6	7	8
Duration	10	14	13	16	7	12	17	24
StDev	1	2	1	3	0	2	4	5
Due	12	23	39	23	39	51	70	70
Discount per time unit of delay	8%	12%	10%	5%	7%	5%	3%	12%



Classic PERT approach

- Compute the expected completion time of a project summing the expected completion time of the latest predecessor and expected duration.
- Compute the delays by subtracting the due date from expected completion
- Compute the total discount penalizing every project individually with the given rate.



The total discount is \$360,000 Is this correct?



	1	2	3	4	5	6	7	8
Duration	10	14	13	16	7	12	17	24
Due	12	23	39	23	39	51	70	70
Discount per time unit of delay	8%	12%	10%	5%	7%	5%	3%	12%
Delay	0	0	0	3	0	0	0	3
Revenue	750	1500	600	1800	1200	180	900	250
Discount	0	0	0	270	0	0	0	90

PERT vs Expected delays/discount (error > 100%)



Project	PERT delay	Expected delay
1	0	0,01
2	0	1,55
3	0	0,31
4	3	3,29
5	0	0,04
6	0	0,53
7	0	0,63
8	3	4,42
Total discount	360	752

Even more sophisticated?



- Decision trees
- All kinds of conditional probabilities
- All common distributions
- Non-linear (very generic) discounts

Ok, but where is research? Where is the science???



- Reminders from Wiki:
 - Monte Carlo methods are used in finance to value and analyze (complex) instruments, portfolios and investments by simulating the various sources of uncertainty affecting their value, and then determining their average value over the range of resultant outcomes.
=> Applied Research Tool for instruments
 - Essentially, the Monte Carlo method solves a problem by directly simulating the underlying (physical) process and then calculating the (average) result of the process.
=> Practical Tool for portfolio & investment return optimization

Methodology design (ongoing research)

- Consider social or bank or payment or project or any other network
- Assume Alice develops a “**method**” analyzing a large sophisticated network satisfying some properties
- Alice wants to test her method on a large representative sample of nets
- Where to get this sample from?...



Simulated networks

- Sizes: millions of nodes
- Properties:
 - Bounded degree (current analysis of Facebook & LinkedIn)
 - Clustering coefficients (current analysis of Facebook & LinkedIn)
 - Small world (my student's project)



Project 1: Simulated small world networks of bounded degree

- Let n be the number of nodes
- Let k be the average length of a shortest path (small world)
- Let ℓ be the average degree of a node

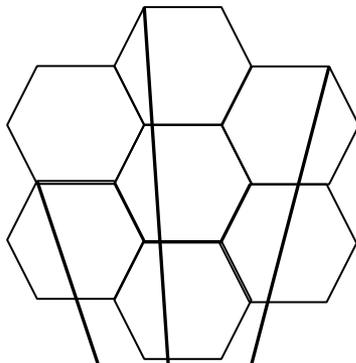
Any idea how to create such a network?



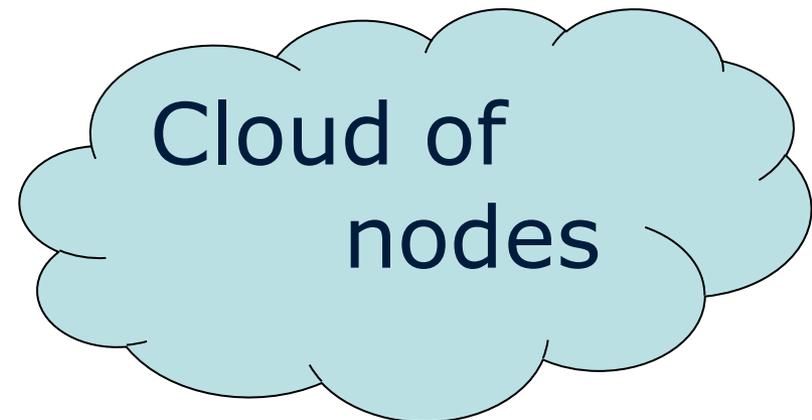
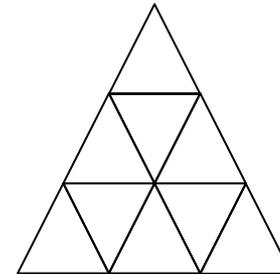
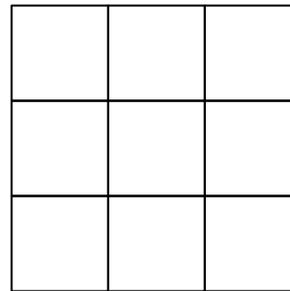
Walls, grids and triangular tessellations



Small world control



A node



Sentiment (or expert opinion) based rankings

- Applicable to universities, journals, products, banks... Say, Bob considers a set of intangible investment projects
- In a blog Bob counts the number of expert tweets where a comparable pair of projects appears
- Given a symmetric matrix of mutual appearances of pairs of projects, Bob is trying to find a permutation (ranking) of projects that minimizes the total weight-distance over all pairs



Project 2: Minimum linear arrangement



---	2	8	5
	---	3	6
		---	5

Sequence/Ranking	Weight-distance
1 2 3 4	$2 \times 1 + 8 \times 2 + 5 \times 3 + 3 \times 1 + 6 \times 2 + 5 \times 1 = 53$
3 4 1 2	$5 \times 1 + 8 \times 2 + 3 \times 3 + 5 \times 1 + 6 \times 2 + 2 \times 1 = 49$

- In real-life weight-log-distance measure!
- Simulate the blogs and test the ranking using Monte-Carlo!

Simulating ANOVA output

- Given a data set on features of bank clients, Cyril wants to construct a linear regression for credit risks against all other features
- Cyril does it in Excel and obtains a classic ANOVA output (adjusted R^2 , F value, intercept, coefficients, p-values etc)
- Now, for experiments Cyril wants to generate **at random** many new samples or one huge sample such that the output of ANOVA test will be similar to the one he has at hands

This project was given to one Master and to one PhD student & failed twice...
=> very challenging



Wrapping up

- We have seen the use of simulations
- We have seen that there are sharp limits of this use
- We have seen several possible directions for simulation design and applications





Thanks!