3 Projects 2019-2020

Below you find a list of projects to chose from. Do not be impressed by the variation in length of the descriptions. It is not because a description is longer and contains a few formulas, that the project is de facto more difficult (sometimes even the opposite is true). Each project might require some information gathering, (realistic) assumption making and modeling choices on your behalf. Each student gets a project within a specific domain to be analyzed, implemented and optimized. Regular contact with teaching staff is required to monitor progress.

The following guidelines are applicable:

- Each project is an individual assignment
- Different project per person in each language regime
- Several obligatory meetings to evaluate progress:
  - Nov 6: presentation of the project + student choice
  - Nov 12/13: first meeting on the understanding of the project an the angle of approach
  - Nov 26: second meeting on the advancement
  - Dec 10: final meeting. Serve to discuss preliminary results en identify potential problems
  - Jan X: presentation (30-60')
- Course staff will be available during the normal contact hours (Tue 1020-1540, Wed 0855-1120).

3.1 Networks

3.1.1 Communication network robustness (and failure)

The internet is inherently resilient, if one pathway is broken or unavailable, traffic gets rerouted trough other servers. Consider the components of the backbone of the internet and their failure rates (Mean Time Between Failure - MTBF). Study the robustness of the network making use of techniques from operations research combined with the more event driven approach from the failures.

Think about:

- Path finding on the network (reachable <> latency).

- Looking at this problem for a 'macro' view (i.e. flow of data on a network) vs a 'micro view' (i.e. tracking individual data packets)
- Try to find failure/critical modes (=> clear link with network layout and centrality measures for each node)
- Reliability recommendations (the probability of the network being 'broken' should be limited)
- Specific examples for which you know the outcome (e.g. single point of failure for a star layout, maximum resilience for a complete graph layout)
- usability in a military context (target priority)

3.1.2 Infection spreading

You study the spreading of a disease such as influenza within a population (e.g. school, work, family etc.). The model will be used to obtain an estimate on the amount of people that are infected and for how long they are you. Several factors should be taken into account:

- evolution of the state of a person (infection time/rate, mortality rate, healing times, vaccination)
- exposure time to an infected person
- resistance of the users (autoimmune response)
- network lay-out (who's interaction with whom)
- spreading rate

3.1.3 Rumor spreading

You study the role of 'important' persons in rumor propagation in a social network e.g. in the military academy. The propagation of a rumor can be modeled in different ways:

1. A node v's decision to become active can be based on an arbitrary monotone function of the set of neighbors of v that are already active. Thus, associated with v is a monotone threshold function f_v that maps subsets of v's neighbor set to real numbers in $[0, 1]$, subject to the condition that $f_v(\varnothing) = 0$. Each node v initially chooses θ_v uniformly at random from the interval $[0, 1]$. Now, however, v becomes active in step t if$f_v(S) \geq \theta_v$, where S is the set of neighbors of v that are active in step $t - 1$.
2. Maki-Thompson(MK) model (direct contact between nodes)
3. Consensus models

4. ...

Think about

- Amount of initial spreaders
- “Importance” of spreaders
- network layout (connected, Barabasi-Albert, Watts–Strogatz model)
- ‘potential’ of a rumor
- you should consider the actual contagion process,

3.1.4 Token ring networks

The data transmission process goes as follows:

Empty information frames are continuously circulated on the ring. When a computer has a message to send, it seizes the token. The computer will then be able to send the frame. The frame is then examined by each successive workstation. The workstation that identifies itself to be the destination for the message copies it from the frame and changes the token back to 0. When the frame gets back to the originator, it sees that the token has been changed to 0 and that the message has been copied and received. It removes the message from the frame. The frame continues to circulate as an "empty" frame, ready to be taken by a workstation when it has a message to send.

- Implement a token ring network
- You should think about:
  - maximum throughput
  - different strategies to deal with the packages (e.g. a high volume workstation might block the network at all times):
    - exhaustive service, where a node continues to receive service until the buffer is empty.
    - gated service, where the node serves all traffic that was present at the instant that the server arrived and started serving, but subsequent arrivals during this service time must wait until the next server visit.
    - limited service, where a maximum fixed number of jobs can be served in each visit by the server
  - work with priorities

3.2 Logistics

3.2.1 Shared mobility solutions

Consider a ride share system something like Blablacar, i.e. when you are planning to make a trip, you announce it up front (‘lead time’) and propose some places in your vehicle that can be shared with people having the same destination. This can increase the travel time (and total cost) by a small amount, but given the fact that you can share the cost, it is more interesting for both parties. A trip has three specific time values: announcement time, earliest departure time and latest arrival time. Make an initial simulation starting on a small scale (e.g. from Brussels to Paris, no distinction between burrows) and increasingly add possibilities such as intermediate stops etc. The objective is to minimize the amount of system wide kilometers driven (and at the same time reduce traffic congestion and individual costs).

Think about:

- rush hour vs calmer periods
- availability (ratio demand/offer) + success rates
- decision deadline (for attribution + attribution strategies)
- making demand/offer scale with population density
- flexibility of the driver

3.2.2 Product delivery

You work for a logistics company that collects processed food from several production facilities. These facilities run 24/7 and everything needs to be collected in a central depot. The production facilities produce in batches of products in different sizes. You're goal is to optimize the transportation tactics in order to minimize the cost. You should think about:

- waiting times on site vs going back each time
- traveling between production locations
- reliability
- impact of the time of day on traffic and travel times.

3.2.3 Supply chain optimization

You work in a logistics battalion and are consulted to make the resupply chain more efficient. Currently the planning is currently carried out according to manual methods. You see some margin for improvement. Combine classic techniques with the stochastic nature of traffic in order to come up with more efficient planning. You will be confronted with the curse of dimensionality of for increasing number of stops, so avoid large-scale testing ($>$ hundreds of stops). Using heuristics can be useful, but this is less straightforward when including the stochastic nature of the travel times. Travel times could be modeled using a lognormal distribution.

Think about:

- different strategies to plan the supply trip
- how to include the stochastic nature of the traffic
- how to suggest an optimized trip
- working with a small scale example before switching to a real-life application.
- comparing an optimization (by simulation) approach with a linear programming approach (computation cost, quality of the result. . .). Can you link this to the scalability of the problem?

3.2.4 Traffic light timing and sequencing for optimal flow control of traffic

The arrival of 5G technology promises a potential overhaul of traffic and transportation systems as we know them. Traffic lights can adapt dynamically around traffic flow, adjusting lights to minimize unnecessary delays. On the highway, convoys of connected vehicles can form "mini-clouds," communicating with each other to warn vehicles behind of fluctuations in the road and to maintain a steady distance between each other. This sets the stage for a series of transportation advances that could transform the road of the future into a very different – and safer – place. Your task is to model traffic, traffic lights and their possible interaction. Study the difference between a 'dumb', semi-intelligent and an intelligent system.

Think about:

- how to measure traffic (flow/density)
- how to quantify a good system (e.g. a system that leaves the mean road green all the time might be great from a certain point of view, but you do not want to be the person waiting for eternity in the perpendicular road)
- possible interactions (road-vehicle, vehicle-vehicle, . . .) and their outcomes.

3.2.5 Ice cream production

The recent heatwaves and unpredictable summer have lead to stock-outs with an ice cream producer. The corporation currently has a 12-month production plan that takes into account seasonal variation, but is has proven several times to be inefficient. This is where you come in. Your simulation might that takes into account the product's shelf life, warehousing capacity (and its associated cost), production layout (each production line has a running cost), breakdowns in the manufacturing process, variable human resource availability. The obvious goals are to minimize costs, avoid stock-outs and optimize production. You should use a year long period to run the analysis.

Think about:

- how to quantify everything
- somewhat realistic data

- searching the limits of the plant. The plant can be considered as a a series of machines creating a linear flow, including buffers between each machine.
- dealing with sudden peaks in demand (e.g. heat wave)
- different strategies

3.2.6 Airport transit

A local airport with a limited number of terminals want to optimize it's passenger flow. You are consulted to make this happen using simulation. For the project consider a small Belgian or international airport. You should think about:

- landing and take-off times between planes + type of plane and their capacity
- 'choke points' (e.g. gates, security posts, customs, luggage drop-off/retrieval...) and their staffing
- corridor capacity and movement speed in function of the density
- occasional breakdowns

3.2.7 Emergency evacuation

When a new venue for large public events is being designed, building regulations impose a specific amount of exits depending on the expected attendance. You want to optimize the building layout on order to maximize evacuation efficiency. instead of looking at the problem as a flow problem, each user is modeled individually according to the following principle:

- people try to move to the nearest exit
- People move at different speeds (in function of the density)
- if the way is blocked, people can look for another exit.

You should think about:

- How to quantify everything
- how include incidents
- exit capacity

3.3 Military

3.3.1 On the job training

With an ever increasing personnel shortage, some training courses are no longer systematically organized. To cover this, one might resort to on the job training, i.e. unexperienced personnel gets appointed a coach who is supposed to teach them how to do the job by explaining it to the new candidate. The big question is how to schedule this training whilst maintaining the required output level. Consider the following (non-exhaustive) list of possible interactions:

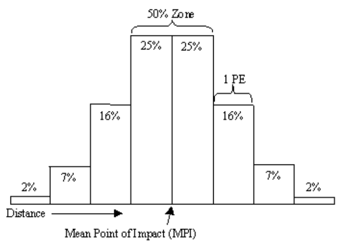
- trainer output decreases with trainee needs
- a trainee's output decreases with the trainee's needs
- the initial trainee's need's follows some distribution (e.g. uniform/normal/...)
- the trainee's need decreases with the amount of training already received (maybe also considering the initial potential)

You should model all these interactions and come up with a plan that respects the required output and at the same time maximizes the amount of finished trainees in a given timeframe.

3.3.2 Artillery guidelines

- Basic: artillery usage is subject to errors. One can distinguish two kinds of errors:
  - accuracy (closeness of the mean outcome to where it should be), which is in its turn composed of the target acquisition error and/or coördinates of the target on the one hand and the methods to orient the gun on the other (firing data).
  - consistency (the spread around the mean point of impact) depends a lot on the variation of the round's muzzle velocity (which can be traced back to ammunition handling and storage etc.), but also on the gun's age (wear)

  The distance between the MPI and the target is expressed in Probable Errors (PE).



- Different parameters can be included:
  - Range Probable Error: e.g. an FT 155-AM-2, the value of range probable error for charge 5 green bag (GB) at a range of 6,000 meters is 15 meters.
  - Time-To-Burst Probable Error: e.g. a 155-mm howitzer firing charge 5GB at a range of 6,000 meters, has a probable error in time to burst of 0.11 second (terminal velocity ±300m/s

  - Height-Of-Burst Probable Error: With the projectile fuzed to burst in the air, the height-of-burst probable error (PEHB) (Figure 3-13) is the vertical component of 1 time-to-burst probable error. The height-of-burst probable error reflects the combined effects of dispersion caused by variations in the functioning of the time fuze and dispersion caused by the conditions described in paragraph 3-5(a). The values listed (in meters) follow the same pattern of distribution as for those discussed for range dispersion.
  - Range-to-burst probable error (PERB) (Figure 3-13) is the horizontal component of 1 time-to-burst probable error. When this value is added to or subtracted from the expected range to burst, it will produce an interval along the line of fire that should contain 50 percent of the rounds fired. These values are listed in Table G of the firing tables.

You are asked to use simulation in order to provide updated field manuals for an artillery barrage.

Think about:

- Different strategies with respect to effectiveness (each gun firing with the same data from different locations vs. all guns firing at the same point)
  - Reloading times and target movement
  - Impact of a forward observer that can rectify in case of a bad first shot.

3.3.3 Passive early warning system

Modern fighter planes make use of stealth technology to reduce their radar cross section in order to be invisible on active radar. The planes are however equipped with a large array of sensors and radars themselves that they might use for collision detection during low level approaches. You come up with the following idea: you will us a large array of passive sensors listening on multiple frequencies to detect inbound aircraft. The sensors use frequency hopping because you do not know exactly what frequencies are being used by your adversaries). Given: a specific adversary using a unidirectional antenna (for the radiation pattern) on a given frequency with an associated realistic pulse width and pulse repetition period flying an inbound trajectory. Determine: an optimal detection system that allows you to detect the incoming plane.

Think about:

- Multiple sensors communication amongst them (with transmission delays etc.)
- keeping track of everything that is being detected
- Frequency band the sensors are using, as well as their hopping rate, hopping strategy, geographical layout
- ...

3.3.4 Air force tactics (wargaming)

The survivability of weapon systems and platforms and the protection of them against new, lethal, and asymmetric threat innovations are critical in today's defense environment. One of the tools can be used to assess survivability is simulation to model conventional land and air warfare at the campaign level. In order to convince the higher ups in the chain of the usefulness, you decide to build a demo tool with limited capabilities.

Think about:

- The range of potential outcomes of a military campaign to provide provide decision-makers with quantitatively based results.
- Incorporate scenarios, force structure, terrain, and weapon systems (+ effectiveness data).
- Detection probabilities, evasive measures, decoys…
- Monte Carlo type simulation and statistical inference.

3.3.5 Air force maintenance strategies

All airplanes undergo regular planned maintenance to limit unforeseen downtime due to a technical malfunction. You are asked to optimize the time between these inspection in order to minimize downtime and maintenance cost, using historical data. Typically aircraft maintenance is divide into several levels: line inspection, A-level, C-level and D-level. Try to apply this for a lifetime analysis of a C-130.

Usually, as a machine ages, the probability of its failure increases. When a machine fails, a repair becomes necessary. On the other hand, a machine can be maintained before it fails. If one waits too long, one pays for expensive repairs, while maintenance too early in the machine's life can cause maintenance costs to be excessive.

Think about:

- different types of failure (internal/external factors, operational theatre etc.).
- failures avoided detected by predictive maintenance.
- measuring both planned and unplanned downtime.
- …