Research Methods for improving Offshore Windfarms

Robin Kuipers (201854288)

Individual Essay, BF992 Research Methods

**Introduction**

In this essay, I will summarise two important methods within my area of research, optimisation and simulation. Before that, I will explain why I am talking about these methods and what my research is about. I will end with some closing thoughts on the methods and their combination.

**Research lay-out**

My research topic and methods are different than most other research that takes place at the Strathclyde Business School. It is part of the natural sciences, as opposed to most other research done in this faculty, which is social science.

The official title of my research is “Simulation and Optimisation of Offshore Renewable Energy Arrays for Minimal Life-Cycle Costs”, meaning the research aims to minimize costs of Offshore Renewable Energy Arrays, mostly windfarms in the North Sea. The Life-Cycle Costs can effectively be split in three phases; the installation, the maintenance and the decommission. The primary methods used for this in the literature, and which I plan to use, are simulation and optimisation; the goal is to mathematically model the schedule of an installation, maintenance and/or decommission project in such a way that solving the minimisation-equation(s) can still be done in a reasonable time, and give an efficient schedule.

It should also be noted I am further along with my research than most people taking this course, having started roughly 18 months ago. Due to this, I have already looked into which methods fit my research best, and I have written extensively about them in my first year report.

Because of the above reasons, I have opted to write about Optimisation and Simulation as my two methods. Neither is discussed in the course, but these are the two fundamental methods of my research (area) and they work very well together, which is why I want to talk about both.

**Optimisation**

Optimisation is an umbrella term for various techniques used to explore the quality of different configurations of a certain system. For the problem described above, the different configurations could be the different possible schedules used for an installation project. Which schedules are possible is restricted in the mathematical model underlying the optimisation; for example a vessel (ship performing the operations) cannot perform multiple tasks at the same time, and each task needs to be assigned exactly once. Within this space of valid schedules, optimisation methods can be used to try and find the best one (or in bigger problems, often simply a good one) based on given metrics, such as expected duration or costs of schedules.

As my research is focussed on improving schedules and scheduling techniques, optimisation is a very well fitting method, and is very broadly used in the literature. In the specific literature regarding my area of scheduling under uncertainty, (mixed)-integer programming and local search are the most common ways of optimising. There are other methods that are used more in different areas where optimisation is used, such as genetic algorithms or dynamic programming. I aim to keep these techniques in mind, as it may be worthwhile to try them out for my research, and there is no clear reason as to why those techniques would not work well for the problems my research looks at.

A big drawback of many optimisation techniques is that it can often be infeasible to solve a problem to optimality due to the amount of time that can take. Within my research, it is impossible to calculate the objectively best schedule due to the sheer number of possible schedules. This is why problems are often simplified, and/or heuristic approaches are taken. For example, integer programming is a technique that by its nature will give an optimal solution, and if given the installation scheduling problem in its full complexity, will simply never return a result. This can be mitigated by splitting the problem into smaller problems that on its own can be solved in reasonable time. Doing this can strongly reduce the amount of possible schedules to consider, which will speed up the process but also means the resulting solution is unlikely to be the best overall schedule.

Other optimisation techniques such as local search are inherently heuristic, which means they are based on estimates and guesses. Local search finds good solutions by taking an existing solution and attempting to improve it with small changes. Repeatedly doing this will improve the quality of the schedule, but it also means it can get stuck in local optima, a situation where the solution is not the optimal solution, but it is better than any solution that can be found only with small changes.

However, one could say these drawbacks of imprecision are a result of the problem considered, not the methods themselves, as there are no known methods to solve the problem within reasonable time. As there is a lot of literature on how to best adapt these methods to any specific problem, I have a lot of options to try if I encounter these problems of infeasibility within reasonable time.

**Simulation**

The other method I will be using, and which is used heavily in related literature, is Simulation. This can in itself be used to support decisions, or it can be combined with other methods like optimisation. In a simulation, the process of interest is simulated, picking a concrete value for everything that can be uncertain. For example, a task might be modelled as lasting anywhere between 30 and 60 minutes, all with equal probability. In each simulation a random value between 30 and 60 will be picked for it, and this will be done for every such uncertain value. This is repeated for each simulation, and if a large number of simulations is completed this way it will give us some idea about how the process would work in reality. When used for the projects I will be looking at, such as the installation projects, this can give a good idea about the quality of a given schedule, and test things like the average delay of a task. It might turn out that a schedule is unrealistic there needs to be more time between tasks to buffer delays. Findings like that are difficult to tell without simulation.

In the literature for logistics this is a widely used method. In (Barlow, et al., 2018) a standalone simulation model is used to determine effective start dates for the project by best avoiding operations in months with bad weather conditions. In (Kerkhove & Vanhoucke, 2019) a simulation model is used that works with their optimisation model such that any schedule produced by the optimisation model is evaluated in the simulation model. This type of interaction between simulation and optimisation is what I am planning to do in my models as well.

Simulation does also have limitations. Every aspect of a simulation model needs to be validated thoroughly, since a simulation model that does not accurately reflect reality will not produce results that will be helpful in reality. In many cases a balance will need to be found between having enough detail, but not so much that the runtime for a simulation becomes too much. For example, the biggest source of uncertainty in my research project will be the weather conditions. In reality the weather is unpredictable with certainty and even if the forecast for tomorrow predicts calm weather, we can never be entirely sure. In the simulation models I have seen for projects like this, there is always an assumption that the construction workers have perfect knowledge of the weather in the future, which is a simplification of reality to make the simulations less complex and intensive to compute. This balance between accuracy and time is central in designing a simulation model, from which processes to include (imperfect or perfect forecasts) to which models to rely on (a very detailed weather model or a more time-effective one) to which time steps to use (simulation processes 5 minutes at a time, or 1 hour) to how many simulations to run (which strongly affect accuracy but also time needed). However, as with optimisation, this method is very widely used, and there is a large body of literature available to help with these decisions, and to find this balance.

**Closing thoughts**

The two methods described here have similar weaknesses, namely that a balance needs to be found between precision and feasibility, but different purposes. Moreover, using them in combination can be beneficial. Optimisation can have difficulty in handling uncertainty, but by combining it with simulation this can be remedied. However their common weakness, that they can be very costly in time when detail is required, will have to be a constant consideration for anyone wishing to use both of these methods.

**Bibliography:**

Barlow, E. et al., 2018. A mixed-method optimisation and simulation framework for supporting logistical decisions during offshore wind farm installations. *European Journal of Operational Research,* 264(3), pp. 894-906.

Kerkhove, L.-P. & Vanhoucke, M., 2019. Optimised scheduling for weather sensitive offshore construction projects. *Omega,* Volume 66, pp. 58-78.