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Business development with computational optimization

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Foreword

This paper provides an overview of computational optimization and how it can benefit your business or non-profit organization. The paper is based on over tens of years of industry-leading knowledge from Weoptit's experts. The author of this paper is Tuomas Lahtinen (DSc), who has been with Weoptit since spring 2018. At Weoptit he has developed optimization solutions, is involved in the design of intelligent solutions for business development, and leads high-impact optimization projects. He has graduated from Aalto University with a doctoral dissertation on problem solving processes utilizing modeling and optimization.

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Weoptit Oy

Weoptit Oy is a Finnish consulting and software company founded in 2013 and owned by Visma Consulting Oy. Our world-class data and advanced analytics solutions are based on tens of years of experience in developing optimization models and algorithms. Our experts have multiple world records in widely known benchmark instances of different optimization problems and extensive experience in developing high-quality optimization-based solutions for challenging problems. Our clients include some of the world's largest companies as well as several Finnish listed companies.

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Computational optimization – the technology of better

In business, and more widely in purposeful organizations, we seek tangible improvements such as increases in productivity, cost cutting, higher efficiency, higher speed, the elimination of waste, or the calibration of resource levels or other parameters. Optimization commonly refers to the systematic advancement of these objectives. In practice, this may involve the development of processes and practices, more accurate planning, infrastructure improvements, the deployment of new systems, increases in the degree of automation, and generally better informed and smarter decision making.

Computational optimization steps into the scene especially in complicated planning and decision-making problems. These problems often include many interconnected decisions, rules, constraints, uncertainties, and objectives. In such cases, it can be very profitable to utilize the advanced computational capabilities of modern computers and IT-solutions.

Computational optimization, which is also called artificial intelligence, prescriptive analytics, advanced analytics, and operations research, is a key technology of the 21st century (Gartner). This branch of technology originated from the planning of military operations during the world wars.

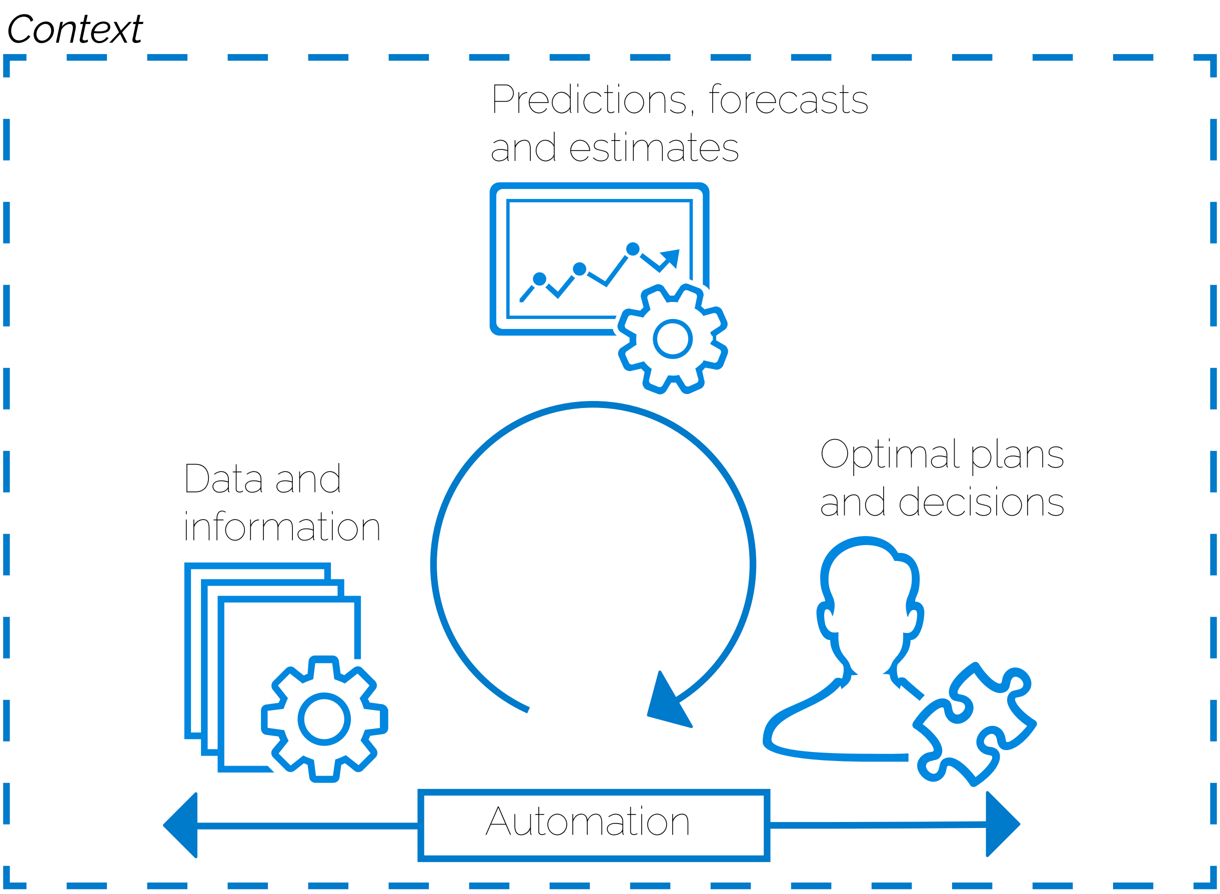
At that time, physicists and mathematicians were recruited to support the planning of large-scale operations with human lives at stake.

Today, the optimization technology is more powerful than ever as computational capabilities and the availability of data have skyrocketed. Moreover, computational optimization typically lies in the core of most artificial intelligence solutions.

Navigators, web-based route planning guides, and recommendation machines are familiar applications of computational optimization. Optimization has long been an important source of competitive advantage for the largest and most successful companies such as Amazon and Google. Since 2014, the football league NFL has scheduled matches using computational optimization. This has drastically changed the challenging problem of developing a viable match schedule to a point where it is now possible to search for the best schedule (Gurobi).

Recently, emerging players such as Wolt, the Finnish food delivery platform company, have begun taking over markets with the aid of advanced optimization. After securing a 130 million dollar funding in Summer 2019, Wolt's CEO Miki Kuusi said *"When we go to a big city, this [quickly reaching positive cashflow] is a lot easier because we get so much more volume and our optimization is so much more efficient."* (Bloomberg).

In the big picture, computational optimization and its cousins machine learning and statistics can be used to improve and automate the three core tasks of management: situational awareness, forecasting plus prediction, and decision making. In many companies, computational optimization is the missing element to get the full potential out of data. Modern optimization technologies facilitate planning for the future in the best possible way based on data, information, predictions and estimates.



Computational optimization in a nutshell

Finding solutions to complex planning and optimization problems is a recurring high-effort task for many organizations. The number of possible solutions can be enormous and finding even one of them can be demanding. Without computational optimization, the problem solver relies on his or her experience and simple rules. Typically, he or she is aided by Excel or some other software tool that does not utilize advanced optimization technologies. In such cases, taking computational optimization into use typically improves the results and decreases the problem solving burden significantly. Optimization algorithms have been developed over decades, and with the aid of modern computational and IT capabilities they are extremely powerful.

In practice, with optimization technology the user's task is to define the problem and ensure that the input data is correct. After this, the computer will perform appropriate computations and return a high-quality solution to the problem.

Computational optimization = A search for the best solution carried out by a computer in a clearly defined (and often complex) problem.

Optimization model = A mathematical representation of the problem. The model consists of decision variables, constraints, and an objective function. Data and expert estimates are required to calibrate the model parameters.

- Decision variables represent the possible choices and variables to be controlled. They resemble the pieces in the game of chess.
- Constraints define the possible values that the decision variables can attain. In chess, the rules and the limits of the board dictate the possible moves for the pieces.
- The objective function defines what is a desirable solution and what the optimization tries to achieve. In chess, the objective function for a move can be the maximization of the probability of winning.

Optimization algorithm = Instructions for the computer on how to search for the best solution to the optimization problem. The algorithm is typically the key determinant of the performance of the computational optimization.

Examples of optimization model components and data sources:

Decision variables	Objective function	Constraints	Data sources
Work shift starting times	Minimize overtime compensations, maximize ergonimics	Sufficient rest times between shifts, labor agreements	HR-database, laws and regulations, experience of managers
Routes of transport vehicles	Route lengths, route completion times	Meeting the agreed delivery times, compatibilities of vehicle types with the routes	Road map, vehicle database, customer contract database
Production quantities on given time steps	Expenses	Satisfying the product demand, production related capacities	Demand predictions, technical descriptions of production lines

The solution quality and the computation time in computational optimization are determined by the algorithm, the implementation of the optimization program, programming language, as well as the attributes of the computer used to solve the problem. Typically, the solution quality improves as more time is spent on looking for the best solution. It is important to realize that the performance of so-called "optimizations" can vary a lot – it matters what is under the hood.

The benefits of computational optimization can emerge from multiple sources. Cost cutting is perhaps the most widely understood source of benefit, but there are many other possible reasons to utilize optimization as described in the **following table.**

Benefits of computational optimization:

Benefit type	Description
Expense reductions	More accurate planning enables cost-cutting and time-savings via reduction of overlaps, idle time, excess inventories, or other “waste”.
Improvements in production	Production quantity and quality improve when resources are allocated to the most profitable type of work.
Staff well-being and ergonomics	Staff preferences and well-being factors can be considered more comprehensively and successfully than before.
Less time spent on crafting plans	Optimization enables automating high effort tasks. Time expenditure using optimization can be a fraction of the time required with traditional methods.
Utilization of up-to-date information	When planning takes less time, it can be moved closer to the time when the plan is to be implemented.
Plan updating made easy	Plans can be effortlessly updated in case of deviations or surprises.
Scenario analysis	Alternative plans or solutions can be created using different assumptions or objectives.
Bottleneck identification	The optimization can be run with different assumptions concerning process element capacities. This will show the bottleneck elements.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Optimization project

The deployment of computational optimization-based solutions can bring in much greater benefits than traditional IT solutions. However, one must be prepared for certain uncertainties that do not exist in traditional IT projects. Fortunately, the challenges can be tackled by approaching the optimization project wisely.

- Firstly, both the data availability and its quality must be ensured.
- Secondly, example calculations must be performed with real data to ensure that sufficiently large improvements can be gained via better optimization.
- Thirdly, the optimization algorithm must be tested with full-scale data to guarantee a sufficiently low computation time.
- Finally, the adoption of optimization-based solutions requires significant change management efforts when the solutions are tightly coupled with business processes and decision making.

The goal of the optimization project can be, e.g. a Software-as-a-Service or On-Premise software, or alternatively a one-shot computation. The following phases are included in a typical optimization project.

1. Exploration

The objective is to form an optimization business case. This can relate to, e.g., a recurring planning or a decision-making problem, or alternatively to significant one-shot decision such as an investment.

Pay attention to clarifying the sources and the scope of benefits sought for. Be aware of the risk of harmful sub-optimization. The availability of critical data should be ensured.

Next step can be taken, if the potential benefits from optimization are significant and critical data is available.

Example

The case is the automatization and optimization of rostering on a monthly level. Realistically, the benefits could be five percentage point cuts in overtime compensations, and the reduction of time spent on planning to one fifth of the current situation. The data for the project can be obtained from HR-database. Demand for work is predicted based on customer data, and the managers' expertise on wellbeing factors are considered. In addition, the relevant laws and regulations are taken into account.

2. Definition

The objective is to define what is included in the optimization, and to develop a project plan with workload estimates.

Pay attention to specifying the data sources and evaluate the quality of the data. Identify uncertainties related to technical implementation. Consider effects to the business processes.

Next step can be taken if the expected benefits clearly exceed the costs.

Example

The roster optimization can be done one planning period at a time given that the constraints imposed by the previous roster are considered. The optimization approach is validated using example data. The deployment of the optimization solution will change the tasks of the managers. Their manual roster creation burden will decrease, and more effort needs to be spent on ensuring that correct data is entered into the optimization. The cost of a Proof-Of-Concept project is much lower than the potential benefits.

3. Implementation

The objective is to form a high-quality solution.

Pay attention to validating the performance of the computational optimization. Deviations from the plan often occur and need to be resolved. The implementation phase typically starts with a Proof-Of-Concept project, after which a production version is built. In one-shot calculations, an extensive report is prepared after the Proof-Of-Concept. Technical choices ought to be made bearing in mind possible extensions and additional development.

Next step can be taken if the solution behaves as desired and its benefits have been validated.

Example

The solution is validated in a Proof-Of-Concept project, after which the development of an IT-system is started. The system is built as a Software-as-a-Service solution. Integrations to other business systems are built. Agile development methods are followed. User experience designers are involved in the team, and there is dialogue with the end-users to ensure usability.

4. Deployment

The objective is to deploy the optimization results or the optimization-based IT-solution to operative use.

Pay attention to the change management and the usability of the solution. The risk of using incorrect input data in optimizations should be minimized.

Next step can be taken when the solution is in use and creating concrete benefits for the customer.

Example

Necessary changes to the solution are made based on use-tests. The change management has been planned well in advance. Stakeholders have been informed about the new solution and its impacts. Users have been taught to use the new solution. The solution is deployed step-by-step to mitigate risks. The data input is controlled with error checks. An approval protocol is built related to the input data that have the greatest impact on the optimization results. All the input and output data are stored in a database so that the results and related historical trends can be analyzed later.

5. Maintenance

The objective is to ensure sustainable benefits and to correct possible issues.

Pay attention to changes in the input data, in the systems integrated to the solution, in the assumptions, and in the business environment that is optimized. The quality of optimization results ought to be reviewed periodically. Development and extension ideas should be collected and stored in order to improve the solution over time. In addition, a sufficient level of security and system reliability has to be ensured.

Use of the solution may need to be terminated if the situation has changed such that the solution no longer functions as intended or does not create benefits anymore. Better solutions may have come up which justifies the move to a new system.

Example

Maintenance and support is provided to the customer. The provider is informed in advance about possible changes in the systems integrated in the optimization solution. A monitoring view is built for the admin users so they can track the performance of the optimization solution. User feedback and development ideas are logged.

Applications

Computational optimization can be applied in many domains. The following table gives examples of application areas that Weoptit is familiar with. More information about our references can be found a **www.weoptit.com**.

Application	Description
Waste management	Optimal routes for garbage pick-up trucks save time and money as well as reduce emissions. The solution must consider, e.g., agreed time windows for emptying of waste bins and the compatibility of the trucks for the waste types picked up.
Courier services	Courier services require optimization for real-time allocation of tasks to couriers, and for the optimization of the courier routes. The computation time must be very short to enable real-time optimizations. The solution must consider, e.g., time windows and different types of transportation vehicles.
Facility placement	The optimal placement of facilities such as inventories or distribution centers creates enduring competitive advantage for a company. The solution must consider, e.g., fleet, demand, delivery distances, service levels, and inventory levels.
Inventory levels	Order quantities and inventory capacities, for example, can be optimized based on demand forecasts. The overall system linked to the inventory needs to be considered.
Scheduling	The scheduling of process phases or tasks is a recurring problem in production environments. Computational optimization helps tackle challenging cases with many interdependencies across the different phases or tasks. Finding a good schedule is important also in education related timetabling, and in creating schedules for professional leagues, for example.
Rostering	A roster can be generated with computational optimization considering resource demand of specified tasks, the resources available, laws and regulations, staff preferences, well-being, and costs. The outcome is right types of resources in the right place at the right time.
Production	The production plan can be optimized to achieve cost-effective production. The desired output levels can be based on, e.g., demand forecasts. The optimization model also enables the analysis of process bottlenecks.
Disruption management	The modeling of disruption effects (including the ripple effect) in networks enables the prioritization of disruption mitigation actions.

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