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It's time for a change to better utilize resources in healthcare

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Abstract. To manage the rapid increase of hospital patients, there is an immediate need to improve efficiency of resource utilisation in healthcare. Adopting and applying traditional Operational Research techniques such as optimization is probably the most potent instrument to do this. However, to create a significant impact we need to dissolve the traditional problem partitions – formed by the limitation in processing power, outdated methods, and manual practice. Over the years, a substantial increase in processing power with significant improved methods has taken place. Still, the old partitions remain. We argue that it is high time to move to a more efficient partition that supports a better resource utilisation.

Keywords: optimization; problem decomposition; health care; computational power

Introduction

In developed countries, population ageing along with the skewed demographic development, result in a rapid increase of hospital patients: This combined with the public's rising expectations of quality treatment and the government desire to reduce the health expenditure adds an increasing strain on the health system. More efficient use of resources is needed. However, planning and scheduling processes in health care is very complex and are often highly coupled across, as well as along, organizational levels while sharing limited resources along the clinical pathways and involve different time horizons. The health professionals' manual approach involves simplification and dividing the problems into more manageable portions. Although much smaller than the original problem, the complexity of even these sub-problems does not lend itself well to efficient manual planning. Operational Research (OR) techniques such as optimization excel at these types of problem (they have for decades been successfully applied to complex resource allocation problems in industry). For the last decades OR researchers have studied different planning and scheduling problems in healthcare or more accurately sub-problems have been targeted; restricted mainly by the manual practice and the limitation of algorithms and computer power. Over the years, the optimization methods' capabilities, the PC's processing power along with its memory size have increased substantially. Also, data availability has increased. Still, the old problem partitioning remains and now restrain optimization algorithms to find good solutions. It's time for a partition change (the need for partition change is not uniquely aiming at the healthcare domain.)—we need to dissolve the outdated partition and investigate appropriate dynamic ones that potentially could provide better resource utilization and subsequently reduce the strain in healthcare.

The paper is organized as follows: Section 2 provides the background information and supporting evidence. In section 3 we argue the need for change and give examples of course of action. We summarize the situation and our arguments in section 4.

Background

Unsustainable Development: In developed countries, population ageing with the skewed demographic development results in a rapid increase of hospital patients. At the same time, the public's expectation of quality treatment is rising (due to technological advances) along with the government's desire to cut health expenditures. All this induces a growing strain on the health care system. Currently every sixth pupil in Norway starts working in the health care sector. It is estimated that to handle the increased amount of patients with the current system, in 2025, every fourth pupil and in 2035, every third pupil, must work in the health care sector [Bovim, 2010]. If this trend continues, in 2115 every pupil will need to start work in healthcare—in the years after, not even that would be enough (see figure). In Flanders, Belgium, currently, 11.5 % of the active workers (294.000 people) are working in the health care sector. The number was 5, 6 % in 1980. In 2014, it will be 13% [Flemish Agency for Care and Health, 2011]. Clearly, increasing the healthcare sector by hiring is not the solution.

Complexity & OR tools: Furthermore, planning and scheduling processes in the health care sector are very complex (e.g. surgery planning, personnel scheduling, room allocation, medical image equipment scheduling). The processes are often highly coupled across, as well as along, organizational levels (operational, tactical and strategic planning) while sharing limited resources along the clinical pathway (also known as care pathways, critical pathways, etc) over different time horizons. This complexity does not lend itself well to efficient manual planning. However, the health care sector to a very large extent lacks Operational Research (OR) support tools to assist them (to benefit from the suggested changes of this paper the healthcare organisation must em-brace OR techniques to a much greater extent.).

For decades, such tools have been successfully applied to complex resource allocation problems in the industry. In one sense, health care is a business like any other, trying to utilize resources (equipment, staff, etc.) efficiently at strategic, tactical, and operational level while involving multiple decision-makers with conflicting goals.

Fig. 1. the proportion of Norwegian pupils that needs to work in Norwegian healthcare to manage the increase of patients.

Partitions: Researchers have studied different planning and scheduling problems in health care for decades. Initially, small, clean cut problems were formulated and with the increase in algorithmic and computer processing power, larger and more complex problem instances have been solved. But still, the lion's share of optimization problems solved today is isolated problems that do not consider the shared resources across the organisation. To compensate for this limitation, assumptions are made; e.g. all the necessary resources are available for the problem at hand and/or enough resources and capacity is available upstream and downstream. Such assumptions are necessary oversimplifications due to the way the problems are historically segregated. Researchers often criticize that the people in need of optimization tools decompose their problem into smaller parts to allow them to manually handle them and thereby disregard the larger picture and miss chance for optimality. In one way, we now do the same: The problem partition was set up with the rationale that this is what the algorithm and computer could handle at that time. However, time has passed and algorithmic improvement and computer power have drastically improved. When working with the old partitions, we disregard the larger picture and miss chance for optimality.

Data access and distribution: Most hospitals are working hard to digitize patients' medical records (e.g. patient journals), which makes medical data increasingly more accessible for authorized personnel. On this task many hospitals are succeeding and becoming on par with the industry. However, planning data has not got the same attention as medical data and is today mostly managed within the boundaries of each partition—kind of locked up within partitions. In this situation, merging problems into larger ones poses an additional challenge to researchers on how to ensure data accessibility of updated data whenever decisions need to be taken. From technology point of view, centralize planning data is possible and sharing planning data across partitions, or just removing these partitions will make optimization-based decision support across partitions possible. Here, hospitals need to work toward centralized planning data.

Improved Methods & Greater Processing Power: The optimization algorithms are judged by methods quality versus their response time performance. The ability of optimization algorithms has increased dramatically during the last decades [Hoffmann, 2000]; mainly due to the improved methods and the increased processing powers of personal computers. A Linear Programming example: Bixby (2002) argued that algorithmic and software improvements have played as large a part as processing power (the increase in memory is also beneficial for the algorithms.), when it comes to solving larger linear programs faster. During the period 1987 to 2000, Bixby estimated a speedup increase of six orders of magnitude in solving power, where processing power and memory contributed by three orders of magnitude and the remaining three orders of magnitude is due to improved algorithm: "A model that might have taken a year to solve ten years ago, can now solve in less than 30 seconds.".

Recent developments in hybrid, parallel and heterogeneous computing open up for solutions to the performance challenges those optimization algorithms will encounter when moving towards integration of planning processes. An important trend is hybrid optimization methods where combining exact and approximating methods extract strengths of both approaches while avoiding their weaknesses. In addition the application of artificial intelligence approaches opens up some perspectives. Data mining and other machine learning methods are very powerful approaches that can help speeding up modelling, parameterization and data exchange among separate problems. Planners who are forced to share resources may also benefit from distributed approaches dealing with their individual objectives without the requirement of one global model.

Moore's law [Moore, 1975] predicts that processing power will double (more exactly, the number of transistors on integrated circuits doubles approximately every two years, which roughly double the processing power. This prediction has roughly been true until 2013) approximately every year and its prediction has held true for several decades. In recent years the chip manufacturers could not maintain this yearly improvement anymore by just increasing the processors' clock frequency. They needed to change the architecture and started to produce multi-core processors which allowed them to continue doubling the processor power. In addition, driven by computer game race for ever more impressive graphics, more powerful programmable Graphics Processing Units (GPUs) are produced. Also, we now have Accelerated

Processing Units (APUs), which are based on heterogeneous system architecture and combine different types of processors (e.g. CPU, GPU) on a single chip and thereby avoid the prior bottleneck, the interconnect bus between the chips.

Most PC based optimisation algorithms use sequential optimization methods, which was not an issue while we had an exponential increase of processor clock frequency. However, the modern PC architecture is parallel and heterogeneous—its multiple cores, programmable GPUs, and APUs open up for parallel computing and heterogeneous computing. Hybrid optimization methods, as mentioned above, lend themselves well to parallelization (still more research is needed).

Time for a change

To manage the rapid increase of hospital patients, there is an immediate need to improve resource utilisation in healthcare. Today many healthcare decisions are not supported by numbers, data, or statistics due to a lack of OR technology for efficiency increase of daily hospital activities. Without such technology there will be no data that could assess decisions post factum. Today it is manually solved by simplification and by dividing problems into sub-problems, with the shortcoming of losing out on efficient solutions: Decisions taken at one part of a system, e.g. patient admission in hospitals, may be the right ones to take in an isolated environment. Nevertheless, their impact on subsequent activities, e.g. operation theatre scheduling, workload of nurses in the wards, etc. is not considered at all. The complexity of healthcare resource allocation problems does not lend itself well to efficient manual solving. Adopting and applying traditional OR techniques such as optimization might be the most promising way forward. OR researchers have been studying resource allocation problems in health care for over forty years. More precisely, partly due to the complexity, sub-problems have been selected; often restricted by the manual practice and/or the capability of algorithms and computer power at that time. These sub-problems (a.k.a. partitions) are illustrated in the left pyramid of Figure 2. Hulshof et al., (2012) present a detailed taxonomy of these types of problems on a strategic, tactical and operational level (their paper contributes by providing a taxonomy and specification of planning and control decisions in resource capacity planning and control). Their paper paints the useful picture of resource allocation problems and their interrelations.

To significantly improve the resource utilization we need to harness the substantial increase in processing power (GPUs, APUs and multicore computers) and methods improved that have taken place over the years. This increase should allow algorithms to target larger and more integrated allocation problems (more global problems) and we could expect new and better solutions to be found. So we need to investigate how to best merge, extend, and connect problems that share resources (see Figure 1, right pyramid) and/or influence each other over time (e.g. long term manpower planning vs. short term task scheduling).

This paper goal is to argue for a partition change and highlight that it's high time for researcher to investigate and update these partitions. The left pyramid in figure 2 exemplify some plausible new partitions that could be worth investigating: 1). On a strategic level: Should and could service mix and case mix be tackled as one and could Regional coverage be included as well? 2) Tactical level: Could admission scheduling be merged with patient-to-bed assignment along with discharge planning? Is the time right to partly merge Surgery scheduling and nurse rostering? Maybe a more tangible merger: shift design and nurse rostering are closely coupled together but treated separately. 3) Operational level: Could we merge staff rescheduling and nurse-to-patient assignment? Could the current computer and algorithmic solving capacity handle a these merged problems?

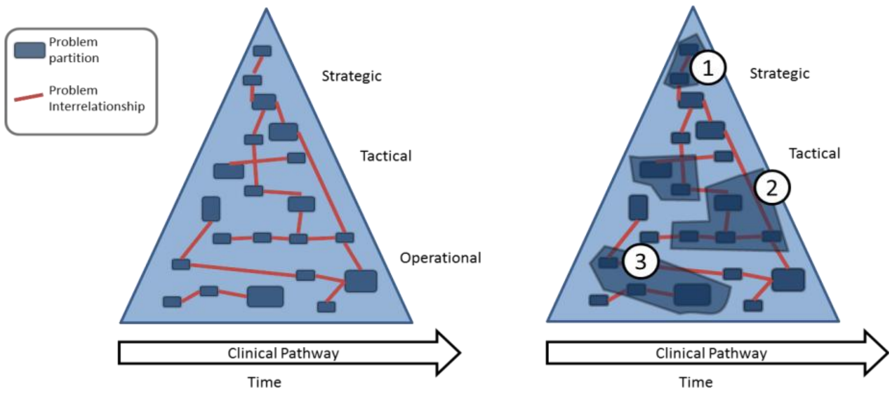

Fig. 2. Old problem partitions and preferred problem partitions.

The benefit of change is the introduction of new more globally efficient solutions. In general, this should open up for better resource allocation solutions, as well as for a swifter and more even flow of patients through their clinical pathway. Devaraj et al [2013] statistically showed (based on 567 U.S. hospitals) that focusing on IT investments create not only an even and swifter flow of patients and financial performance (efficiency), but it improved treatment quality as well. Currently, roughly speaking, each partition works with its own planning data and with assumptions about the world outside the partition. These assumptions are mostly based on previous experience, and on agreements. In contrast, we envisage a future in centralized planning data and sharing (detailed) planning decisions across partitions leads to improved coordination and better patient flow. In addition, it should free up some health care workers to concentrate more on care duties than on management or operational decisions, which in turn should improve quality of care.

However, it is not an easy quick task without challenges: A large effort is required to model all the details of the operational problems in health care and to couple them in such a way that a composed approach offers benefits. Also, a challenge is how to get access to up–to-date data whenever decisions need to be taken. Unchanged is the modelling challenge: Health care planners and decision makers may base decisions partly on information that has not made it to the model. It takes many discussions before computational models correspond sufficiently well to the situation perceived by experienced manual planners.

Conclusion

There is an immediate need to improve efficiency of resource utilisation in healthcare. Adopting and applying OR techniques such as optimization is a very promising but to create a significant impact we need to dissolve the traditional problem partitions – created due to the limitation in processing power, algorithmic development, and the natural manual practice. Over the years, there has been a drastic increase of solving capacity that should be capable of solving larger and more integrated allocation problems—extending the problem releases new and better solutions (i.e. improve overall resource utilisation in healthcare). So we need to create a new participation that better matches the current solving capacity. Note that a prerequisite for deriving the benefits discussed is that OR techniques are adopted by healthcare organisations to a greater extent.

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