Machine Learning as Key Technology of AI: Automated Workforce Planning

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1 Introduction

In recent decades, the digital revolution has increasingly penetrated our lives. As a result, digital information and data are omnipresent. This change brings with it the opportunity to make sensible use of the ever-increasing volumes of data. In the healthcare sector in particular, there is substantial potential in the realization of responsible technological progress. The promising fields of application for innovative technologies are contrasted by increasingly complex staffing requirements, a shortage of skilled workers and a predominantly inadequate IT infrastructure. Thus, health care institutions and leaders are increasingly facing essential challenges in this dynamically economic world. Since the focus of health care systems is on service delivery, staffing cost is one of the largest factors. For instance, it is useful to answer the question of what optimal staff deployment planning can look like in order to efficiently compensate for bottlenecks.

As an interdisciplinary science, AI can be a solution to this question. AI consists of several sub-disciplines, which are useful for different tasks. The core of AI is always the imitation of intelligent behavior, which, as experience shows, is accompanied by increases in efficiency. This technological singularity usually begins in the sub-discipline of machine learning.

Therefore, this chapter will first outline the basics of machines capable of learning and then, identify the elementary prerequisites of the technology. This will be followed by requirements and challenges for automated workforce management, which include the areas of resources, society, and legislation as well as data and interfaces. We then discuss possible components and advantages of an automated
solution. Finally, a roadmap will be presented to support the implementation of machine learning in practice.

2 Machine Learning

One of the most important areas of AI is the development of machine learning methodologies. But what does learning mean and how can we distinguish the learning ability of computers and humans? Learning describes the acquisition of skills and knowledge. It is an individual process, sometimes based on experience only. For example, while most people usually find it difficult to learn a foreign language, computers are able to store and apply the relevant data very quickly. The only limiting criteria are computing power or storage capacity. During bionics, attempts are made to model the principles in the field of brain research on computers. Artificial neural networks are being developed which are intended to simulate human neural connections in an abstract way (Ertel 2016).

2.1 Data Mining

Progressive digitalization and automation result in large amounts of data. While a few years ago, experts described data as the gold of the twenty-first century and highlighted its enormous potential, there is still a long way to go. This is often explained to the complexity of high-dimensional input data, which results in limitations of manual statistical data analysis. Therefore, generating usable knowledge from large databases must have a positive cost–benefit ratio. Machine learning methods can derive structures or forecasts from high-dimensional input data (Richter 2019). With this assistance, knowledge can be extracted from data and used sensibly. It should be noted that the learning ability and success of algorithms depend in particular on the quality and quantity of existing data.

2.2 Learning Methods

Machine learning, the development of powerful algorithms, can be differentiated into different teaching methods. Decisive for the choice of method is whether predefined target values are already known and a teacher should be consulted or similarities be recognized independently.

In the case of Supervised Learning, both input and output data must be marked by a teacher. Thus the algorithm knows the pre-structured data and is trained accordingly. The goal is to find possible connections or patterns between known input and output values. Therefore, the AI uses methods of linear regression, linear discriminant analysis, and the decision tree method (Kreutzer and Sirrenberg 2019). Imaginable Scenario is a machine that is trained with extensive medical knowledge to recognize the symptoms of appendicitis. The task of the AI system can be to
diagnose whether the patient is suffering from appendicitis or not (Das and Neelima 2020).

If undefined target values are present and similarities and patterns are to be recognized independently from the existing input data, the learning form **Unsupervised Learning** is used. Due to the complexity and quantity of data, the goal of the algorithm is to independently gain new insights and identify data groups with similar characteristics. The performance of the algorithm improves with increasing data volume (Kreutzer and Sirrenberg 2019). Linked to the above scenario, unspecified patient data, symptoms, and diseases are transmitted to the machine. In the course of the learning process, the algorithm independently establishes relationships. For example, it assigns typical symptoms to appendicitis and provides a basis for deciding whether the patient might suffer from this disease.

**Reinforcement Learning** can lead to an acceleration of the learning success (Huss 2019). The method is strongly oriented on the human learning process, which can be described as learning through experience. Tom Mitchell already made the following statement in 1997:

> Machine Learning is the study of computer algorithms that allow computer programs to automatically improve through experience.

With Reinforcement Learning, neither training data nor optimal solution are available. The AI iteratively runs through a trial-and-error process in order to independently try possible solutions. For good decisions required for the goal being achieved, the AI receives a “reward,” for bad decisions a “punishment.” The algorithm optimizes the solution strategy again independently. The goal of the algorithm is to learn an optimal strategy, which results from its experiences made (Ertel 2016). The classical field of application of reinforcement learning is robotics. Since tasks of robots are usually complex and no training tasks are available, it is necessary to learn from experience. As an example, the company Adlatus works in the development of self-sufficient service robots for automated room disinfection of hospital staff and patients from COVID-19. The integrated advanced navigation concept is based on an algorithm-based measurement to optimally detect obstacles in the room. With the combination of sensor data and image processing the functionality of deep learning algorithms is also used.

### 2.3 Deep Learning and Neural Networks

As early as 1943, McCulloch and Pitts laid the foundation for Deep Learning. They developed a mathematical model of a neuron, which was presented as the basic switching element for brains. Since then, humans have faced the task of modeling neural networks in order to solve regression and classification problems by artificially emulating neurons. These are high-dimensional problems that are accompanied by high-dimensional input layers. This results in AI systems for which computations are very time-consuming and involve well-trained developers who can take on the demanding task (Kruse et al. 2015).
Deep Learning is also known as expert system. For a positive learning success, a sufficient amount of training data is needed for the simulation. As the machine becomes safer and faster with increasing experience (used data memory), it develops into an expert system. Since the brain structure of a human being adapts to environmental influences, science today no longer aims to reproduce the human brain. Rather, the new goal is to create a human-like adaptive capacity (Goyal et al. 2020).

Computing power of such AI systems can already beat humans in chess or in the game “Go,” which has 361 board positions and a total of $2.08 \times 10^{170}$ valid game positions. Why should not AI have the intelligence to take over the optimal staff planning of a hospital?

3 Requirements for the Use of AI Systems

Although the requirements for automated staff scheduling in hospitals are very similar, certain conditions should be met before considering implementation of an AI system. According to Topohl, three requirements are relevant in this regard. First, the course must be set to obtain elementary information about each individual patient involved. This includes patient data, as well as data of hospital staff, both are subject to special protection. Furthermore, an understanding of the positive influences of AI in the health care system must be created. AI systems will not only find their way into pattern recognition to support diagnosis but a variety of other fields of application can be experienced and improved by new technologies. Lastly the relationship between patients and physicians must be mentioned. The time factor is increasingly becoming a scarce commodity. Greater demands are being placed on doctors, while the calculation of operations is increasingly based on time. Only when the potential of AI has also been recognized by the hospital staff and a basis of trust has been created it will be possible to use smart solutions as an effective working aid (Topohl 2019).

4 Challenging Aspects

Before intelligent support can lead to a reduction in workload, the requirements and challenges of AI-based workforce planning must be analyzed. In order to ensure a combination of workflow management, duty scheduling, resource planning, and time recording, high quality data availability must be ensured. Only then can planning and forecasting be carried out according to requirements. In addition to the classifiable requirements of resources, society and legislation as well as data and interfaces, general requirements must be mentioned (Fig. 1). On the one hand, planning-related conflicts should be avoided. On the other hand, a clear and flexible solution should be created (Bent et al. 2016). The overriding goal is to minimize the organizational effort in order to relieve skilled workers and increase their job satisfaction with a user-friendly solution. In contrast to this, there are business
management conditions as well as short-, medium-, and long-term goals of the health care institution.

4.1 Resources

Key function and at the same time the main challenge relates to the required resources. Due to the shortage of skilled workers, staffing resources are particularly at risk. Especially health care facilities tend to be chronically short-staffed with qualified employees. The emergence of scientific research and results leads to the additional difficulty for specialists to stay up to date. A modified capacity building in medical education is becoming increasingly necessary (Klein et al. 2018). It is essential to impart basic knowledge in the areas of machine learning and information technology (Budde et al. 2019). This is one of the only ways to create the basis for human acceptance to use algorithms in the future, to support decision processes, and to consider AI as a modern working partner.

The fulfillment of requirements that administrators have for AI-based staff planning is also essential. These include user-friendly operation and the expression of service requests. In addition, existing service structures and staffing strengths and competencies must be included.
4.2 Society and Legislation

Besides the challenge of extrapolating past scenarios to future periods, country-specific legislation also shapes the respective framework, such as compliance with working-time laws. Furthermore, AI systems are almost always accompanied by ethical questions, especially in the medical environment. Not least because of the influence of politics and society, a superior strategy for the use of AI is needed. This includes, for example, adjustments of funding conditions. These have a significant influence on the innovation process of a country. National digitization strategies also have positive effects at the sector level (Frederking et al. 2019). In healthcare institutions, the integration of the use of AI into strategy development and implementation is equally effective.

4.3 Data and Interfaces

The performance of an AI heavily depends on data quality. Moreover, greater success can be achieved when data from many different sources is available and networked at the same time. Here the connection between Big Data and AI becomes clear. If one thinks about linking data from other research fields, the benefit can increase exponentially. However, medical data is now particularly sensitive. In some countries, data protection issues are therefore increasingly arising, which must first be resolved and integrated into the considerations (Budde et al. 2019). Only then can further requirements be analyzed. Furthermore, IT infrastructures are usually very heterogeneous. It would be helpful to homogenize the environment in order to establish a uniform basis for AI systems. This results in the necessity of developing standards and norms, which are laid down in guidelines. An example is the use of HL7 standards (Frederking et al. 2019).

In order to be able to automatically determine process times in the near future or to forecast the end dates of tasks, functional interfaces to budget planning and working time documentation are recommended. Integrations and smooth information transfer help to save planning time and reduce error rates. Due to the complexity it is important that IT departments of health care facilities receive sufficient support.

5 Automated Workforce Planning System

The following describes the components of an automated workforce planning and the advantages of such a solution can work. Moreover the conception of a directional implementation plan will be presented.
5.1 Components

The goal is the automated creation of a staffing deployment plan taking into account all relevant parameters and requirements. AI is able to take over this task by applying a combination of already described procedures and further approaches. This is already possible today. Here, the components of real-time staff planning, user-friendliness, and security can be highlighted (Fig. 2).

Intelligent workforce planning is done in real time. The medical environment is subject to constant change. Risks and disruptive factors characterize the daily work routine. This requires not only short-, medium-, and long-term staff planning, but also a short-term update of the occupancy in hospitals. An AI system is able to carry out spontaneous service changes, taking into account the lower staff limits and adherence to quality of care. In addition, it is possible to forecast difficulties on the basis of past data and to configure plans differently as a preventive measure. The plans can then be tracked by staff in real time, anytime, and anywhere. The integration of additional software, for example, accounting solutions, leads to further useful adjustments throughout the system and thus to a reduction in workload.

Intelligent workforce planning is user-friendly. The retrieval of information in real time can be carried out by staff with desktop computers as well as mobile devices. User-friendly dashboards with the optional creation of a report or an invoice can be integrated. The staff can express vacation requests via the digital infrastructure, which shortens official channels and makes approvals/rejections faster. Despite an intuitive user interface, it makes sense to integrate training environments.

Intelligent workforce planning is safe. Since data storage is subject to country-specific regulations, individual precautions must be taken. Regardless of this, data must be backed-up continuously. With intelligent solutions, regular updates should also be carried out.

Fig. 2 Components of automated workforce planning. Source: Author
5.2 Advantages

Since human beings should always be in the center of attention and gain advantages when supported by AI, the opportunities are viewed from the perspective of the clinic staff. Basically, automated staff planning can lead to knowing the right person with the necessary qualifications at the right time and in the right place. In the best-case scenario, taking into account individual wishes of each person. Simplified, positive effects on clinic management, clinic staff, and planners are considered.

The exhaustion of the potential of the AI leads to the fact that in the future, clinic managers will find an optimal utilization control. Dominant regulations of the legislation are fully complied with. Interfaces to staff management open up the possibility of effective career management. The predominant gain for the clinic management is economic efficiency, combined with increased employee satisfaction.

Clinic staff have online access to relevant schedules and can easily enter service requests. In addition, they are immediately notified of any changes. Easy access to contacts is ensured in order to be able to consult with colleagues faster. A decisive advantage for the staff is the absence of overload due to incorrect planning.

Planners are almost completely relieved. They only check the fully automated plan for remaining errors. Manual entries are still possible at any time. Furthermore, it is possible to give only authorized users access to specific tools. Since planners are mainly performed by senior physicians, automated staff planning can be very attractive.

5.3 Roadmap for Implementation

Due to social conditions, AI solutions still face a certain skepticism. On the one hand, this is accompanied by the necessity to conduct a comprehensive requirements analysis. On the other hand, the stakeholder analysis is of great importance. In addition, AI projects require a sufficiently pronounced project management competence. Social, organizational, and methodological competence are thus bundled within one responsibility.

The procedure for initiating and implementing AI projects should include four phases: Analysis, Design, Test, Monitoring (Fig. 3). These are all subject to different requirements that must be taken into account.

In the Analysis phase, the first delimitation and collection of relevant parameters takes place. By implementing an environment analysis, both the social environment (stakeholders) and the factual environment (risks, processes and regulations) can be identified. This is followed by analysis and documentation of project requirements. In this context, it is important to formulate criteria that are as specific as possible in order to ensure traceability. In order to integrate synergy effects but also different perspectives, a workshop should be initiated for the delimitation, in which relevant
parties of the project participate. The aim of this phase is to provide a first rough outline of project contents.

The goal of the subsequent **Design phase** is to gain a detailed view of requirements. Interviews with potential users will be conducted and the affinity to technology will be determined (Schiller et al. 2019). Subsequently, further information is compiled in a detailed conception. Accordingly, the validation of the first technical concept is carried out and a prototype is developed.

In the **Testing phase** the participation of potential users should lead to optimizations. The prototype will be tested and optimized for usability and functionality.

The final phase combines constructive feedback on the prototype and the development of the alpha version. In the **Monitoring phase**, the influence of important stakeholders provides a further opportunity to adapt the technical implementation to existing conditions.

### 6 Conclusion

Machines are able to work 24/7. They do not need vacations, do not suffer from overload, and do not complain. To date, the end point of technological progress has not yet been reached and may in fact never be reached. We are only at the beginning of the digital transformation and the exhaustion of possibilities. New perspectives and tools regularly open up. But the use of AI is always tied to the fulfillment of certain conditions. Technology is not always the best solution to a
problem. Those willing to innovate should therefore always first weigh the cost-benefit ratio and evaluate possible risks. Nevertheless, the hurdles are getting smaller and any technological progress is becoming increasingly important. AI systems hold an enormous potential. Our demand for support is growing, while machines can satisfy it. Ultimately, the overarching goal of all AI-based projects should be for the benefit of patients and physicians, and in fact for the whole of humanity.

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