Planning medical oxygen supply distribution to treat hospitalized COVID-19 patients

Thiago Berton Ferreira
Graduate Program in Computer Science - School of Technology
Pontifical Catholic University of Rio Grande do Sul - PUCRS
Porto Alegre, Brazil
thiago.ferreira96@edu.pucrs.br

Abstract

The recent novel coronavirus disease (COVID-19) outbreak caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) currently poses a threat to public health. This highly contagious disease usually manifest respiratory disorder in infected patient and rapidly spread over the globe leading to a worldwide pandemic. In severe cases, the patients must be put on an oxygen supply or mechanical ventilator to push airflow into the patient's lungs and help them breathe. However, many hospitals in different nations, particularly in developing countries, faced issues with medical oxygen shortages due to the total depletion of the gas in health units and, in some cases, poor public healthcare administration. In this case, automated planning can be employed as an approach to reduce the chances of an oxygen crisis in health systems. This work will compromise with the use of automated planning techniques through PDDL+ language to estimate the daily oxygen needs within a hospital taking into account the COVID-19 infected patients' demand.

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first reported in Wuhan, China in December 2019 (Chen et al. 2020). SARS-CoV-2 is the virus responsible for the COVID-19, a contagious disease that can cause severe respiratory illness. Since then, the coronavirus disease 2019 has spread all over the globe becoming a worldwide health challenge. The COVID-19 pandemic and the social distancing measures have already resulted in a critical impact on socio-cultural, political, and economic aspects of our society (George, Lakhani, and Puranam 2020).

The COVID-19 has put intense pressure on health-related systems and increased the already existing demand for medical oxygen therapy. Many hospitals, especially in developing countries that already struggled before the pandemic to meet their daily oxygen needs, suffered from oxygen shortages (Jones 2020). As a result of this crisis, a desperate situation rapidly emerged within hospitals, patients, and patient family members due to the critical status of oxygen as a vital approach for treating COVID-19 infection cases (Usher 2021).

Due to pandemic proportions, several modeling approaches have been introduced to help simulate and counteract the effects of COVID-19 in the global population. COVID et al. 2020 developed a deterministic SEIR (susceptible, exposed, infectious, and recovered) compartmental framework to provide a state-level epidemiological analysis of the SARS-CoV-2 infection across the United States. Observations from the first recorded case in the U.S. (1 February 2020) to 21 September 2020 were used to estimate the effects of non-pharmaceutical intervention strategies such as social distancing and mask use. The study pointed out that the use of face masks by 95% of the population could be sufficient to minimize the worst effects of epidemic resurgences in many states. Oliveira et al. 2021 created a compartment model named SEIIHURD that, based on the data from the first wave of COVID-19 in Brazil, estimated the number of beds required to attend the population in the state of Bahia, Brazil. The model considered the transmission of the virus by asymptomatic/mild cases, hospitalization of severe cases, and mortality to evaluate the responsiveness of the state health services in terms of the number of beds. Although the current advances, it has not been developed models designed to plan and estimate the minimal oxygen thresholds required in hospitals to avoid the collapse of health systems due to crisis and shortage of medical oxygen therapy.

Planning is an area in Artificial Intelligence (AI) that concerns the course of actions needed to achieve a specific goal, optimizing the agent's performance (Ghallab, Nau, and Traverso 2004). More specifically, the classical planning seeks to identify a sequence of actions, also known as a plan, that drives the initial state of this particular problem to the goal state (Fox, Long, and Magazzeni 2017). An AI planning system, or planner, takes the problem formalisation as input and constructs complex plans of actions to reach the most optimal problem solution. The Planning Domain Definition Language (PDDL) is a standard encoding language for automated planning tasks and is widely adopted by planning systems (Borgo, Cashmore, and Magazzeni 2018). To better represent mixed discrete-continuous domains, an extension of PDDL named PDDL+ was created which incorporates fully-featured autonomous processes allowing a more precise tool for modeling (Batusov and Soutchanski 2019). This work proposes the use of automated planning techniques using PDDL+ to solve the paradigm of medical oxygen distribution to treat respiratory diseases.

Technical approach

The proposed study will be conducted through automated planning techniques using PDDL+ language and the Expressive Numeric Heuristic Search Planner (ENHSP) (Scala et al. 2016) planner to formalise the domain and problem. The main objective of this model will be to estimate, according to the number of patients and using a constant oxygen demand rate for each patient, the minimum medical oxygen supply required for those patients. Ideally, the model will help avoid oxygen shortage in the health facility and have high scalability to estimate the oxygen demand on a local and regional scale.

The planner will be tested with at least two problem domains, one considering a single hospital and another one considering more than one healthcare unit.

Project management

	Week 1	Week 2	Week 3	Week 4	Week 5
Planning techniques (PDDL+)	**X**				
Develop the planner		**X**			
Testing		**X**	**X**		
Evaluate results			**X**	**X**	
Write paper				**X**	**X**

Table 1: Project Schedule

Conclusion

In summary, the model will estimate the required medical oxygen supply levels within health units to meet the eventual needs to treat COVID-19 infected patients. Ideally, this approach will help reduce the occurrence of shortages of medical oxygen in hospitals and, thus, minimize the risks of collapses of health systems during the COVID-19 pandemic. The proposed model can ultimately contribute to the decrease in the death rate of the novel coronavirus disease.

References

Batusov, V., and Soutchanski, M. 2019. A logical semantics for pddl+. In *Proceedings of the International Conference on Automated Planning and Scheduling*, volume 29, 40–48.

Borgo, R.; Cashmore, M.; and Magazzeni, D. 2018. Towards providing explanations for ai planner decisions. *arXiv preprint arXiv:1810.06338*.

Chen, J.; Lu, H.; Melino, G.; Boccia, S.; Piacentini, M.; Ricciardi, W.; Wang, Y.; Shi, Y.; and Zhu, T. 2020. Covid-19 infection: the china and italy perspectives. *Cell death & disease* 11(6):1–17.

COVID, T. I.; Reiner, R.; Barber, R.; and Collins, J. 2020. Modeling covid-19 scenarios for the united states. *Nature medicine*.

Fox, M.; Long, D.; and Magazzeni, D. 2017. Explainable planning. *arXiv preprint arXiv:1709.10256*.

George, G.; Lakhani, K. R.; and Puranam, P. 2020. What has changed? the impact of covid pandemic on the technology and innovation management research agenda. *Journal of Management Studies* 57(8):1754–1758.

Ghallab, M.; Nau, D.; and Traverso, P. 2004. *Automated Planning: theory and practice*. Elsevier.

Jones, D. S. 2020. History in a crisis—lessons for covid-19. *New England Journal of Medicine* 382(18):1681–1683.

Oliveira, J. F.; Jorge, D. C.; Veiga, R. V.; Rodrigues, M. S.; Torquato, M. F.; da Silva, N. B.; Fiaccone, R. L.; Cardim, L. L.; Pereira, F. A.; de Castro, C. P.; et al. 2021. Mathematical modeling of covid-19 in 14.8 million individuals in bahia, brazil. *Nature communications* 12(1):1–13.

Scala, E.; Haslum, P.; Thiébaux, S.; and Ramirez, M. 2016. Interval-based relaxation for general numeric planning. In *Proceedings of the Twenty-second European Conference on Artificial Intelligence*, 655–663.

Usher, A. D. 2021. Medical oxygen crisis: a belated covid-19 response. *The Lancet* 397(10277):868–869.