Graph Theoretical Resolution of a State-agent-environment Model

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https://doi.org/10.62343/csit.2024.2

Abstract — **This paper investigates a simple state-agent-environment model of Artificial Intelligence theory. The general framework of AI in this part provides search and planning and is based on the development of modelling mathematical formalisms with a consequent validation-check, and pathfinding stages. The application problem and the use case considered in this paper belongs to the domain of personalized medicine. The problem is known as the dynamic treatment regime (DTR), and we demonstrate that in addition to traditional AI techniques for such problems, a simpler graph theoretical development can be incorporated that solves the validation and pathfinding problems with less efforts and complexities. The results obtained are achieved by using graph connectivity checking algorithms, algorithms of pathfinding in rooted trees, and checking additional graph components to be a one dicycle cactus graph; and provide a means of consecutive restructuring the whole graph for the connectivity property that preserves the validated DTR policy.**

Keywords — **Pattern recognition, dynamic treatment regime, target class, graph theory, artificial intelligence**.

State-action-environment (SAE) based models are significant part of the artificial intelligence (AI) [1]. Although the strategies required to solve such problems are well investigated, the model itself is diverse in its nature, being considered either fragmentary, fleetingly, or too abstract to tackle in a systematic and flexible applicable analysis. The most commonly used AI techniques in this area are smart search strategies, constraint solving approaches, and planning strategies and algorithms. Early SAE formalisms and languages such as satisfiability modulo theories (SMT), and PDDL (Planning Domain Definition Language), as well as many later tools that serve these models, allow users to describe algorithms and use a type of exhaustive search and planning strategy, usually breadth first search, to check if that model can solve the defined problem. In formal basis, SMT is a generalization of Boolean satisfiability problem (SAT) to more complex formulas involving not only Boolean, but also real numbers, integers, and/or various data structures such as lists, arrays, bit vectors, and strings.

SAE models are very common. They are specific in game and control theory, optimization and various model validation problems. This part of artificial intelligence considers problems related to the hardness of selection of options and overcoming various intractability of tasks. But it is possible that the task under consideration is not typically difficult, in which case, there is no need to use full AI tools. Theoretical analysis is possible and suffices. Below we look at one problem of this type and show how to model it using graph theory and how to solve it using combinatorial algorithms of acceptable complexity.

Adaptive treatment strategies are emerging as a new paradigm for the treatment and long term management of disorders such as alcoholism, smoking cessation, depression and hypertension [2]. In adaptive treatment strategies, the treatment type is repeatedly adjusted according to the individual's medical conditions. Adaptive treatment strategies are frequently called dynamic treatment regimes. DTR is composed of a sequence of decision rules, one per treatment admission. Currently, scientists try to use hard combination of *clinical experiences, behavioral, psychosocial and biological theories and randomized experimental studies* designed to formulate the decision rules composing adaptive treatment strategies. A general goal of the DTR domain is to obtain optimized adaptive treatment strategies for sets of diseases, that is, to produce a treatment strategies that yield the best mean value of the outcome. In this paper, we consider a completely different objective that is a new research topic in the DTR domain. We continue from the point where the DTR strategy (policy) is already adopted, and the issue is in applying logical analyses, to generate *validation analyses* and *recommended improvement* of the policy when needed.

DTR graph theoretical validation. A SAE model can allow a solution (path) to be discovered, but it can also fail to do so even if the problem has a solution. The reasons why the model may fail are various, starting from an insufficiently detailed representation for a state, not including all required validations and transitions, even up to not considering particular search strategies which may not be able to find a solution even if it exists. We propose validating a DTR model by checking whether three claims (implemented as logical formulas) can be proven as valid:

- Final state validation (FSV): a valid final state exists, which satisfies the conditions for reachability from an arbitrary initial state.
- Path to the final state (PFS): if FSV is true, a path between the initial state and final state is constructed using valid transitions described in the model.
- Analysis and correcting defects (ACD): if FSV is false, generate recommendations in the form of necessary transitions for a true FSV.

Considering the DTR problem in terms of SAE, our work provides results that rely on and expand the following:

Proposition [3]: Transition Graph G of a deterministic SAE for DTR consists of one tree, rooted at the goal vertex v_0, and may have several other connectivity components structured as one cycle directed cactus graphs.

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