PLANNING IN HOME HEALTH CARE STRUCTURES USING REINFORCEMENT LEARNING

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ABSTRACT

In many countries, hospitalization costs for both patients and governments have known a significant increase. Recent studies linked these costs mainly to people getting chronic diseases, and patients expressing preferences for their comfort. Home Health Care (HHC) became a potential answer to these issues by providing health care in a friendly environment and reducing costs while respecting important constraints. Using Reinforcement Learning, we propose developing a novel framework to solve the patient - caregiver matching problem, leading to real-world social impact by increasing the general well-being of patients and making significant progress towards integrating HHC in health care systems.

1 PROBLEM

According to the World Health Organization, 1 in 5 people in the world will be aged 60 and older by the year 2050, outnumbering children younger than 5 years. As people age, they are more exposed to chronic diseases: according to a study in 2012, 88% of seniors above 65 years in the U.S. have at least one chronic condition and 25% have 4 or more conditions (Landers et al., 2016), leading to an increase of hospitalization costs for both patients and governments. In addition, seniors prefer receiving health care in their homes. Thus, Home Health Care (HHC) became a potential answer to these issues in many countries (Du et al., 2017) by providing health care in a friendly environment and reducing costs (Chappell & Hollander, 2011). Nevertheless, for this service to be efficient, HHC systems should allocate their resources in a way that satisfies critical constraints including, but not restricted to: temporal constraints, allocating competent caregivers with regard to patients' profiles, respecting the patient's preferences such as the identity of the caregiver and increasing the probability of continuous care (one caregiver per patient). Our problem is different from a *traditional* resources allocation problem since the degree of constraints satisfaction is *decisive* to the quality of the service.

2 PROPOSAL

We propose developing a novel framework based on reinforcement learning and the attention mechanism to improve the results of previous works targeting the planning component in Home Health Care alongside with the domain constraints mentioned before.

To the best of our knowledge, most of the previous work tackled a subset of possible constraints in small instances without taking into consideration different aspects of a real-world problem. Also, temporal and assignment constraints gained much attention neglecting important real-world aspects such as patients' preferences and dislikes, and synchronization constraints (Di Mascolo et al., 2017). We aim at providing a general framework that will extend existing techniques with more admissible constraints alongside with alleviating size limitations.Recent papers showed how Reinforcement Learning can be a compelling choice to learn a constrained policy (Achiam et al., 2017). It provides a flexible approach when combined with neural networks in dealing with this kind of problems while making guarantees about constraints satisfaction, along-side with the dynamic aspect and its robustness to stochasticity we face in concrete situations. The Vehicle Routing Problem is still an essential component in the proposed work to solve the routing part. However, we consider the results from previous work (Bello et al., 2016, Kool et al., 2018, Nazari et al., 2018) to address it from a neural perspective.

3 IMPACT

Previous work puts the main focus on reducing costs. Our method focuses on maximizing the satisfaction of patients' needs which will lead to an effective real-world social impact:

- In the short-term: we will maximize the allocation of resources and address the needs of a maximum number of patients.
- In the medium-term: first, we will try to ensure a continuous care, which consists on assigning the same medical staff to a given patient. Second, we will allocate medical staff with the required qualifications for the patient's specific health issues and dependence level. Finally, we will try to meet the patients' preferences, such as the identity of medical staff, which will maximize their general well-being.
- In the long-term: by allocating competent medical staff to patients and ensuring a continuous care, we will reduce the probability of *unplanned hospital admissions* that comes with heavy consequences on all stakeholders (Ellenbecker et al., 2008).

4 EVALUATION

We will evaluate our method based on different *key performance indicators (KPIs)* that measure the satisfaction of patients as the number of patients that receive home care when needed, the number of caregivers for the same patient, the correspondence level between medical staff qualifications and the patient's needs, health care costs and the frequency of unplanned hospital admissions.

First, we will use existing data to validate our mathematical solution. Second, a possible small-scale real-world environment would be a Local Community Service Center (CLSC) in Québec, Canada (as already done by Elbenani et al., 2011). This environment might fail to reflect the efficiency of our solution, since resources might be limited as well as the needs of patients. However, a larger-scale deployment will provide a more realistic environment and a larger feasible domain of solutions.

We are currently discussing the possibility of a collaboration with a public health-care organization in Québec. The organization has developed some expertise when it comes to measuring the satisfaction of patients and would help us define more useful and relevant KPIs.

5 RISKS

In this specific problem, the targeted population is vulnerable and sensitive to the decisions that we make. Obvious risks include inadequate health issue assessment, failure to provide well-trained medical staff and delay in receiving more adequate treatment in the hospital. However, we are aware that these constraints are critical to avoid risks, this is why we put the satisfaction of constraints in the heart of our method.

The resulting system that we propose could be abused if a caregiver benefits from the fact that they are the only one as a staff member who deals with a given patient and mistreats them in any possible way. Nevertheless, we intend to solve this issue by asking patients to give a continuous feedback about the service.

6 DATA

It is important to mention that previous studies have used generated data in their experiments and do not consider any real use cases for their work. However, we are not following the same path. First, we will be using a public dataset we found online through the Kaggle platform (Hack&Health) to address a simplified version of the problem. Then, we intend to collaborate with a Local Health Care Provider who made similar datasets available for previous works (Elbenani et al., 2011). As mentioned before, a possible collaboration with a public health-care organization is being discussed and the potential collaborators are open to the possibility of giving us access to anonymous data in the context of this work.

The dataset retrived from Kaggle contains a wide range of features to treat and formulate our problem. A set of visit records of Home Care Services over two years is given. It was collected from a Home Medical Services Company in the metropolitan area of Barcelona, Spain. This dataset contains 40000 rows (visits) and 15 columns, in which we can find information about the patient (age, location) and his medical status (Pathology, Number of home assistance) and also about the visit (date, time of delay, the visit status).

The dataset was first published for a Kaggle challenge to predict the level of sanitary actions in geographical areas based on environmental agents and its effect on "Fragile" people.

7 LABELS

After establishing a set of constraints that are sufficient to model a real use case, we will need to collect features in order to cover these constraints. Here we present some potential ones: the qualification of medical staff that should match the needs of patients, thus we need basic information on medical records of patients in order to be able to distinguish different conditions. Another interesting constraint is to identify common temporal patterns among patients for instance, conditions with the need of regular visits within the same time slot. This kind of constraints supposes that the needs of patients have already been categorized as punctual visits or regular visits. Also, we will be in need of some feedback mechanism to measure the patient's satisfaction that can be a weekly or monthly evaluation form that patients are asked to fill-in.

8 SOCIAL SYSTEM

Our team is composed of three graduate students with solid knowledge and rich experience in machine learning, optimization and supply chain management and two professors, one with an excellent problem solving skills in machine learning and optimization, the other is a health science professional.

Being in permanent contact with the health science professional can guide us through modeling and defining sophisticated constraints related to our problem and help us gain a better understanding of how home health care works thus showing us what needs to be prioritized.

9 TECHNICAL SYSTEM

From a technical point of view, the planning of Home Health Care can be seen as a resource allocation problem that can be modeled as a variant of the Vehicle Routing Problem (VRP). This latter have already been addressed using the combination of Reinforcement Learning with the attention mechanism. However, our problem requires taking into account specific *crucial* constraints, which was not tackled in previous works. We imagine our novel framework to be able to answer the specific structure of the health care problem. We will train our model using the data mentioned above then deploy it as a mobile system, allowing patients to interface with their health care providers instantly with no delays. Caregivers will have access as well to their planned visits in real time.

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