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How AI could help physicians during their medical consultations: An analysis of physicians' decision process to develop efficient decision support systems for medical consultations

Antoine RICHARD^{1,2}, Brice MAYAG¹, Yves MEINARD¹, François TALBOT²,
Alexis TSOUKIAS¹

¹ LAMSADE UMR 7243, Université Paris-Dauphine, France

² Hospices Civils de Lyon, France

Résumé : Physicians of the Hospitals of Lyon (HCL) use a Health Information System (HIS) during their medical consultations that gives them access to several functionalities. With the aim to develop Clinical Decision Support Systems (CDSSs) as new functionalities of the HIS, we analyse what kind of tools could be the most useful to help physicians during their day-to-day medical consultations. This paper presents the methods we used to collect data to analyse physicians' decision process during medical consultations. We also present two models of these decision processes and a discussion about the nature of tools that physicians really need during a medical consultation.

Mots-clés : Clinical Decision Support Systems, Health Information System, Decision Process Analysis

1 Introduction

Physicians at the Hospitals of Lyon (HCL) use a Health Information System (HIS) during their medical consultations. This HIS allows them to access to several functionalities such as : access to information concerning patients, possibility to write down drug prescriptions, enter information about a patient, etc. In order to develop Clinical Decision Support Systems (CDSSs) as new functionalities of this HIS, we want to determine what kind of tools could be the most useful to help physicians during their daily medical consultations. Indeed, following (Heeks, 2006), we admit that a gap between the design of our systems and the reality of physicians' practices can produce the reject of our systems by physicians. To avoid that risk, we have had the opportunity to discuss with physicians of the HCL about their practices, observe some medical consultations and have access to the HCL database.

The paper is organized as follows. In section 2, we review previous analyses of physicians' decision process during medical consultations. In section 3, we explain th several medical consultations, and we explain how we analyse data collected by the HIS during medical consultations by using process mining. In section 4, we present results of process mining and we propose two models to describe physicians' decision process during medical consultations. The first model is a rule-based model that describes the decision process that physicians follow during a specific medical consultation. The second one is a more general model that describes the decision process followed by physicians during medical consultations in general. In section 5, we discuss the revelance of our proposed models and what they show on the physicians' decision process during medical consultations. We then conclude this paper in section 6, by presenting our future work.

2 Related Works

Even through numerous studies have analysed reasoning of physicians during diagnoses, there are only a limited number of papers analyzing the decision process of physicians during

medical consultations. According, as an example, to (Rojas *et al.*, 2016), process mining in healthcare context is mostly used to analyse the evolution of patients' treatments or to analyse workflows in hospitals. Medical consultations, in those types of analysis, are often considerate to be a part of a larger clinical process, and not as a decision process itself.

An early analysis was made by (Leaper *et al.*, 1973). They observe 1 307 diagnoses made by 28 physicians, on patients suffering from abdominal pain. One major result of this study is the fact that physicians, for a same patient and a same diagnostic, do not follow the same decision path. They conclude that an absolute decision process of a diagnosis does not exist, and that a diagnostic support system must be adapted to the personal diagnostic process of each physician.

Earlier still, (Taylor *et al.*, 1971) proposed a comparison between physicians' diagnostic process and a computer diagnostic process, and how their diagnosis could diverge. This study was made on 6 physicians who were asked to solve 20 cases of non-toxic goitre. It was not a direct analysis of the diagnostic decision process, but they show in this paper that physicians follow a cyclical decision process.

A recent analysis was proposed by (Rebuge *et al.*, 2013). They used process mining to analyse data collected by the HIS of the Hospital of São João. This study shows the various uses that can be made of the HIS. Unfortunately, an HIS can't log everything that happens during a medical act, and the results are focused on how the HIS is used, not on the decision process of the physician.

3 Methods

In this section, we present how we have collected data for our analysis of the decision process of physicians during medical consultations. We start by some observations of medical consultations, following the protocol described in section 3.1. We then analyse data corresponding to a large set of medical consultations using process mining, as described in section 3.2.

3.1 Observations

Our aim during these observations was not only to understand how physicians interact with patients during a consultation, but also to understand how s/he interacts with the HIS. To that end, we have used indicators such as : the number of information obtained by interacting with the patient (by question or measurement), the number of information obtained by using the HIS, the duration of the medical consultation and the time passed to use the HIS.

For this study we observed eight medical consultations of a specialist in endocrinology. For each medical consultation, a single observer was positioned behind the physician to have a clear view on how s/he used the HIS. The observer took notes each time the physician got an information, registering the type of information and how the physician got it (via HIS or not). The observer also took notes when the physician decided of a prescription (drug prescription, medical laboratory analysis, etc.).

Due to the small number of medical consultations observed, we cannot present meaningful statistics in this paper. However, the HCL logs the activity of physicians in their database. Analysing these logs, as described in section 3.2, allows us to better understand the decision process of physicians during medical consultations.

3.2 Process Mining

The HIS used by physicians collects a lot of data on patients and physicians' activities. These data allow us to better understand how physicians use the HIS. Observations of medical consultations (Cf. section 3.1) allow us to better understand the relevance of data collected by the HIS, and then, help us during the cleaning step of the data analysis. To analyse the data collected by the HIS, we used the HeuristicMiner algorithm, developed by (Weijters *et al.*,

2006). HeuristicMiner is useful to extract an event graph from real data with noise, by using heuristic such as frequency of an event or dependency between several events.

4 Results

We present, in section 4.1, results of process mining. We then propose two models of the physicians' decision process during medical consultations. The first one, developed in section 4.2, is a local rule-based model of the decision process followed by a physician during a specific medical consultation. The second one, developed in section 4.3, is a more general model of the decision process followed by physicians during medical consultation in general.

4.1 Exported process

Figure 1 shows, as an example, the event graph extracted using HeuristicMiner from data collected by the HIS corresponding to 57 medical consultations made by the same physician during a month of work. Each node is associated with its frequency and each edge is associated with the degree of dependency between two events.

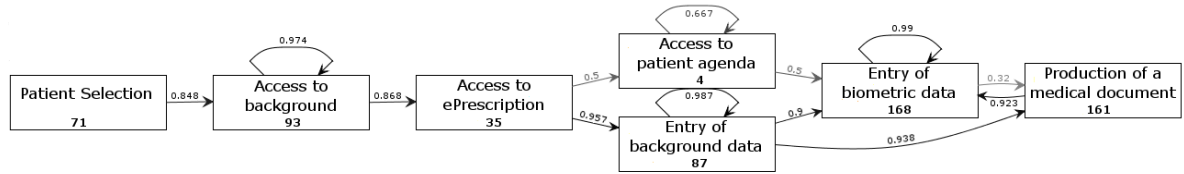


FIGURE 1 – Event graph obtained with HeuristicMiner by analysing 619 events, shared between 57 event logs

We can see in figure 1 that the physician starts by selecting the patient directory, getting access to her/his medical background and getting access to the application *ePrescription* (the physician uses this application to write her/his drug prescriptions). Then, the physician generally enters some background information about the patient into the system or, sometimes, s/he gets access to the patient's agenda. Then, the physician enters several biometric information about the patient and finishes her/his consultations by producing several medical documents (generally corresponding to drug prescriptions or analysis prescriptions). We can also see that, after producing medical documents, the physician could enter again biometric information about the patient. This could be considered to be a preview of the cyclical decision process that we develop in section 4.3.

4.2 Local rule-based model

A medical consultation could be seen as a set of moments $\mathcal{T} = \{t_0, t_1, \dots, t_n\}$, where t_i is a moment of the medical consultation when the physician makes a decision $d(t_i)$, and n is the number of decisions taken by the physician. The physician could make two types of decision : request an information (by asking a specific question to the patient, by consulting the HIS or by doing some measurements on the patient) or determine a prescription (drug, medical laboratory analysis, etc.). In fact, a physician could determine a prescription during the diagnostic process and write it only at the end of the consultation (as shown in figure 1). In general, the physician has an access to a set \mathcal{C} of information about the patient, such as height, blood pressure or glycated haemoglobin. $\mathcal{C}_{t_i} \subset \mathcal{C}$ is defined as the set of information about the patient, known by the physician at a moment t_i of the consultation process. An element $c_j(t_i)$ is defined as the content of a piece of information $c_j \in \mathcal{C}$, known by the physician at t_i (ex. $Weight(t_5) = 66.5kg$).

Table 1 shows an example of a decision process followed by a physician, summarized from one of our observations. Each row of table 1 corresponds to a moment t_i (the left column) of

\mathcal{T}	Gender	Age	Weight	Height	BMI	HChol	HDL	LDL	TG	\mathcal{D}
t_0	♂	55	∅	∅	∅	true	∅	∅	∅	Look at HDL
t_1	♂	55	∅	∅	∅	true	1.1	∅	∅	Look at LDL
t_2	♂	55	∅	∅	∅	true	1.1	5.53	∅	Look at TG
t_3	♂	55	∅	∅	∅	true	1.1	5.53	1.98	Prescribe Ezetrol
t_4	♂	55	∅	∅	∅	true	1.1	5.53	1.98	Look at Weight
t_5	♂	55	66.5	∅	∅	true	1.1	5.53	1.98	Look at Height
t_6	♂	55	66.5	165	24.43	true	1.1	5.53	1.98	End of Consultation

TABLE 1 – Example of a summarized physician's decision process during a medical consultation, for a patient with hypercholesterolemia

the process and to the decision $d(t_i)$ made by the physician at this moment (the right column). The other columns correspond to a subset of \mathcal{C} . We can see in table 1 that the physician, for each moment t_i , bases her/his decision $d(t_i)$ on the set \mathcal{C}_{t_i} . We assume that a physician must follow a set of rules \mathcal{R} to make a decision $d(t_i)$ at t_i , based on the set of information \mathcal{C}_{t_i} , as described in equation 1 (with v and w standing the values of $c_j(t_i)$ and $d(t_i)$).

$$\bigwedge_{c_j \in \mathcal{C}_{t_i}} (c_j(t_i) = v) \Rightarrow (d(t_i) = w) \quad (1)$$

According to (Leaper *et al.*, 1973), for the same patient and the same diagnosis, each physician follows her/his own idiosyncratic path. Then, we may assume that each physician has her/his own personal set of rules \mathcal{R} , her/his own decision process constructed from experience. However, we can suppose that, even if they do not follow the same path, physicians walk through the same steps, but not in the same order.

4.3 General model

In previous section, we saw that, in practice, physicians base their decisions on an idiosyncratic set of decision rules. This statement is confirmed by (Leaper *et al.*, 1973) : *"the diagnostic process - viewed as a monolithic structure - does not exist. Each clinician has his own pathway to diagnosis"*. However, if we do not take into account the medical specialty of the physician, the type of questions asked, the type of prescriptions made and the pathology of the patient, it seems that a general model of a diagnostic decision process, followed by physicians, exists.

As introduced by (Taylor *et al.*, 1971), physicians generally follow a cyclical decision process. We propose in this paper a general model of this cyclical decision process that physicians seem to follow. Figure 2 shows the general model of the decision process followed by physicians during medical consultations in general. Here, we will make the distinction between medical diagnoses, about the pathology of the patient, and the prescriptions that the physician gives to the patient (drug prescription, medical laboratory analysis, etc.).

The decision process of medical consultation can be described as follows. According to the current set of information known about the patient : (1) Establish a set of possible medical diagnoses, if the set is empty go to (6), else go to (2). (2) Establish a set of certain medical diagnoses, if the set is empty go to (3), else go to (5). (3) Determine which information could be relevant to establish a diagnostic. (4) Try to obtain information, by asking the patient or making a measurement, add it to set of known information, then go back to (1) (if information

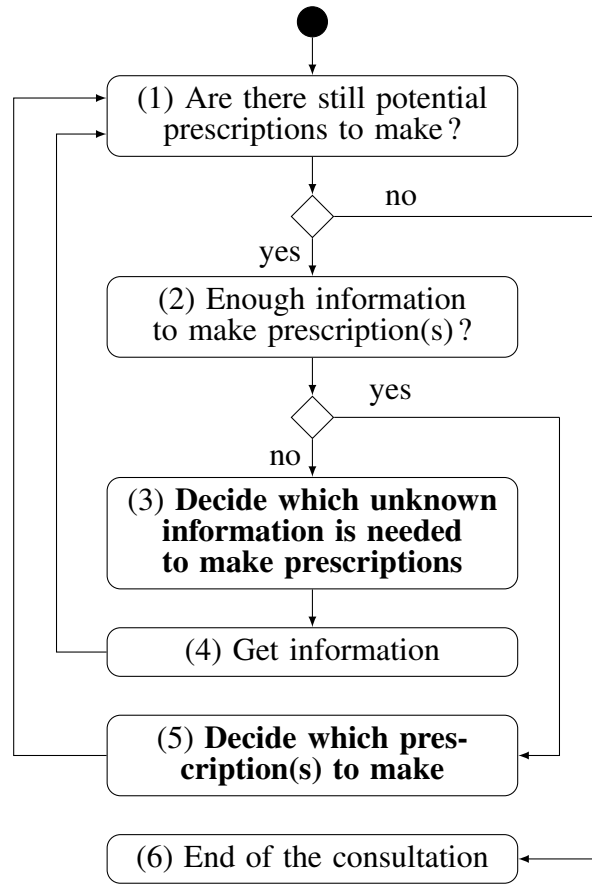


FIGURE 2 – General model of the decision process of physicians during medical consultations. A graphical representation in the form of a UML activity diagram

are still unknown, the physician can prescribe a medical laboratory analysis). (5) Determine which prescriptions to make according to the set of certain medical diagnoses, then go to (1). (6) The physician writes down determinate prescriptions and ends the consultation.

5 Discussion

Clinical Decision Support Systems (CDSSs) are healthcare tools that could help decision in various areas, in a whole hospital. (Osheroff *et al.*, 2012) define a CDSS as a system that must : *"provide the right information, to the right person, in the right intervention format, through the right channel, at the right time in workflow to improve health and healthcare decisions and outcomes"*. Unfortunately, as introduced in section 2, medical consultations and diagnostics are often seen as but a part of a larger clinical process, where patients just come with symptoms and physicians give drug prescriptions. Consequently, CDSSs used during medical consultations are often Alert Systems or Diagnostic Decision Support Systems made for a specific domain. (For an overview of DDSSs, see (Miller, 2016)).

However, as we have seen in section 4, a medical consultation is akin to a decision process. It is an investigation process, where the physician searches information about her/his patient to decide which prescription(s) s/he must make. The physician more often decides which piece of information s/he needs to reach quickly a diagnostic, and then formulates a prescription. We can also say that the decision of a prescription is secondary in comparison with the decision of which piece of information is needed. This gap between physicians' practices and CDSSs put at their disposal may explain the "[...] disturbingly high percen-

tage (i.e., 54-91%) of real-time clinical decision support suggestions are being over-ridden, or ignored, by clinicians" observed by (Sittig *et al.*, 2006), who made a literature review on acceptance of CDSSs by physicians.

Consequently, we assume that *if providing suggestions of prescriptions could be useful in certain circumstances, providing to the physician a selection of information about the patient at the beginning and during a medical consultation could be more helpful for day-to-day practices*. Currently, HISs used by physicians have generally a plethora of information about patients in their databases, and physicians have an access to all the information about the patient, generally at the same time when they open a patient directory. Those information must be summarized and adapted for each medical consultation.

6 Conclusion & Future Work

To conclude, we surmise that developing summarizers of electronic health records (EHR), such as those presented by (Pivovarov & Elhadad, 2015), combined with learning systems and adaptive algorithms, could provide a good daily assistance to physicians during their medical consultations. We also assume that, if we manage to develop AI tools to help physicians, these tools must be as transparent and understandable as possible. Indeed, physicians need to know how the system works to accept it. Also, physicians need to know how to help the system to help them, to reach a cooperative work between physicians and machines, *"to improve health and healthcare decisions and outcomes"*.

In the future, we aim at developing an EHR Summarizer that could be able to learn which information is needed by physicians, and able to adapt its results to information known about the patient at the beginning of a medical consultation (ex. symptoms, background, etc.).

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