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HIN – Health Issue Network as Means to Improve Case–Based Learning in Health Sciences Education

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Abstract. HIN (Health Issue Network) is introduced as a peculiar approach to enhance Case-Based Learning (CBL) methodology for health sciences education, as well as innovative tool to query problem-oriented EHRs. In this paper HIN's Petri Nets-based formalism is described, and a first example of its twofold (*lower* and *upper*) representation level is proposed.

Keywords. health issues, CBL, EHR, Petri Nets, education

1. Introduction

There is a raising awareness that education and professional development are connected to the ability to practice competently within changed and ever-changing epidemiological, clinical and organizational contexts. To this purpose, case-based learning (CBL) is increasingly being recognized as a major educational method in healthcare [1] as it links theory to practice through the application of theoretical knowledge to real cases and encourages the use of methods of inquiry-based learning [2]. Case studies can help learners to develop critical thinking skills in assessing the available information and in identifying logic flaws or false assumptions [3]. CBL applications are mainly addressed to acute, hospital-based cases, which do not reflect the case-mix of the epidemiological transition, whose complexity is related to multiple, associated chronic conditions that can evolve in many possible ways in the long term. For these reasons, healthcare records of general practitioners (GPs) are a good source of complex and long-lasting clinical conditions. However, these records are not so detailed as the hospital ones and, generally, each GP follows their own methodology to describe the individual's care pathway. This causes difficulties to extract and organize the relevant information from the wide network of health problems stored in life-long longitudinal records. The present paper introduces the HIN approach (Health Issue

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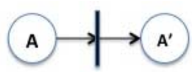
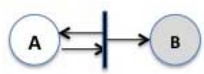
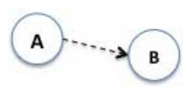
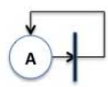
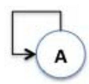
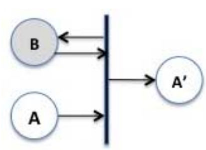
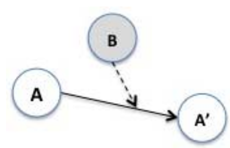
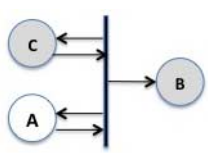
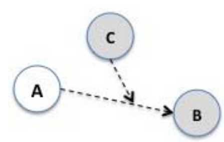
Network) as a way to represent how health issues (HIs) evolve over time, based on a sound formalism. HIN also stands as a logical paradigm towards the development of a semi-automatic system of data extraction and anonymisation from GPs' problem–oriented EHRs. A major goal is to provide clinical libraries of real cases to develop CBL exercises, applying the principles already introduced in [4], where the HIs are enriched by medical annotations and links to external sources of knowledge for educational purposes. The advantage is to base the teaching materials on real rough data instead of simply "seeing from the outside" how data management works within a EHR, or studying theoretical diagnostics-therapeutic paths. To address these goals, HIN uses a twofold representation level: a) The *lower* network of HIs, designed from a predefined didactic object, which acts as template to realize and perform specific queries to extract data from problem-oriented EHRs; b) The *upper* network of HIs obtained from real data, that can help students to manage the complexity based on the epidemiological transition. The paper is structured as follows: the description of the nature and the evolution dynamics of HIs, along with the formalism used for the production of cases for CBL, is reported in Section 2. Section 3 reports the application of HIN twofold representation level for a specific case study. Finally, discussion and conclusions are presented.

2. Materials and Methods

Petri Net (PN) formalism [5] is widely used in the literature since its formal semantics make it suitable for complex concurrent processes' description [6]. More specifically, PNs allow the study of many properties of healthcare systems that can be compared to complex systems [7], as well as the description of their underlying workflows. In our approach, PNs are used in HIN for modeling, analysis and design of the possible evolutions of a HI (i.e. a health problem, a disease, an illness or another kind of health condition). In our approach PNs are used for modeling, analysis and design of the HI evolutions. In particular, PNs' places are the HIs, while transitions (in form of bars) point out the evolution dynamics of a HI. Edges connect places and transitions. Additional information related to both places and transitions is reported in data sheets that specify some features of the network, such as the main data that should be captured by the GP, or the threshold values able to identify a HI evolution. Tokens contemporary present in the HIN places represent the health status of a generic subject. They migrate from one place to another, and each place can only contain one token at a time (PN safe net). However, when a complication occurs a new HI belonging to a different class of HIs is generated. This is e.g. the case of a patient with Type 2 Diabetes Mellitus who has a complication of nephropathy. In this case the token doubles: one is added to the destination HI (i.e. nephropathy), while the other remains in the source HI (i.e. Type 2 Diabetes Mellitus). To simplify the adoption of this methodology in an educational environment a lighter version of the PN-based formalism, named f-HIN (*friendly HIN*), is implemented based on the same mathematical properties as HIN for a generic subject. Nodes in f-HIN are used to indicate HIs, and edges to point out the evolutions. More specifically, edges are normally drawn with a whole line. A dashed line is instead used to denote a complication. Table 1 reports both HIN and f-HIN representations of the evolution dynamics also reporting some examples of evolution compositions. In the HIN+CBL mixed approach three different categories of cases are considered: (i) the *rough* clinical case is the result of the data extraction and anonymisation from a GP's EHR. A specific query is generated to find out all the subjects that are interested by nodes and transitions of f-HIN as figured out by the teacher. The query sets as conditions all the HIs that compose the firing sequence chosen by the teacher, and the time sequence through which the requested HIs occur. The rough case also features the clinical information related to all the HIs considered. The comparison (based on re-writing rules) between the HIN/f-HIN defined by teacher and the one related to the selected case allows verifying the quality of the latter and therefore to choose a rough case which is a candidate to generate the reference case; (ii) the *reference* case is a complete instance of a real case, obtained from the rough case (or by selecting the most viable one among those obtained, according to the teacher's criteria) then "cleaned up" and enriched with surrounding elements like vocal messages, links to protocols, etc., in order to accomplish the clinical didactic objective; (iii) the *didactic* case is a subset of the reference case as modulated from the teacher to generate a timely CBL exercise.

Table 1. HIN and f-HIN main evolution rules and related formalisms

Type of evolution	Description	HIN (*Petri Net–based formalism*)	f-HIN (*CBL–related formalism*)
		BASIC	
Worsening	The HI changes into a different and more serious one		
Examining in depth	The HI needs further tests for a better comprehension		
Improvement	The HI becomes less serious than before		
Complication	The HI complicates and generates a new issue that belongs to a different class of HIs		
Recurrence	The HI tends to occur again through time		
		COMPOSITE	
Worsening or Examining in depth, with Comorbidity (or Risk Factor)	The HI changes into a different and more serious one that belongs to the same class of HIs, or needs a further analysis, because of another concurrent HI		
Complication with Comorbidity (or Risk Factor)	The HI complicates and generates a new issue that belongs to a different class of HIs, because of another concurrent HI		

3. HIN Application Example

A simple example of the first step of the approach is related to a teacher who wants to generate an exercise about a generic patient with metabolic syndrome. The patient suffers from Obesity that complicates during time in this order: Hypertension, Type 2 Diabetes Mellitus (T2DM), and Low back pain (LBP, diagnostic hypothesis recognized as LBP without irradiation after a further examination).

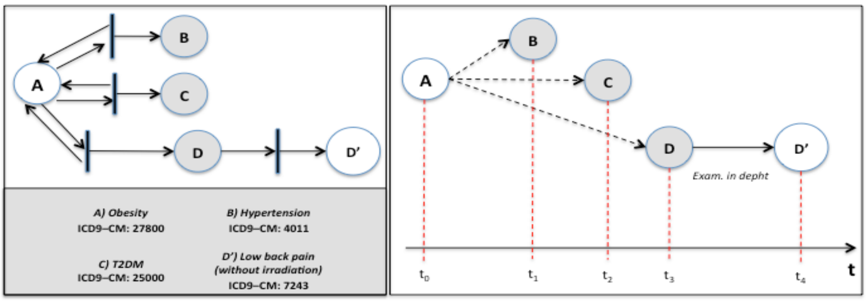


Figure 1. HIN (left) and f-HIN (right) for a generic patient with metabolic syndrome

The teacher figures out the related f-HIN composed by a set of HIs and related evolution dynamics. The resulting f-HIN and the equivalent HIN are depicted in Fig.1. For each HI the ICD9-CM code is also reported. For f-HIN the time axis is reported. The reachability set of HIs achievable by the "Obesity" as the starting HI indicates all the possible HIs sequences; thanks to the temporal order of the f-HIN the correct sequence is chosen, and the query can be generated with conditions composed by all the HIs and the time sequence through which the requested HIs occur. The SQL query is then generated (see Fig.2).

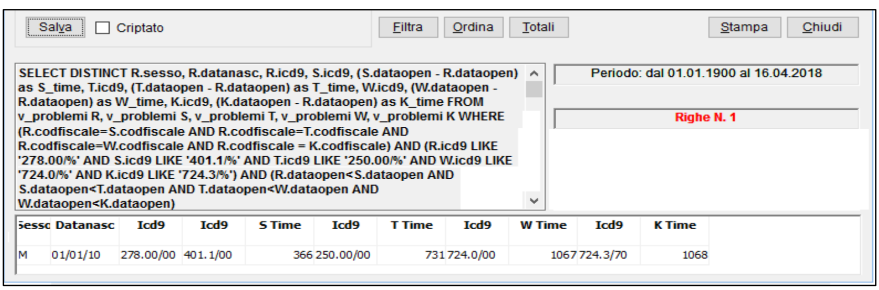


Figure 2. Execution of the query to extract "rough" cases concerning patients with metabolic syndrome

In our case the query was implemented using the Dedalus' *Millewin*® EHR (as the most used among GPs in Italy). The data extraction process considered the anonymisation of the patient files selected by means of the cancellation of all patients' personal data; it also considered the transformation of the real dates into timings calculated starting from a conventional "zero time" that marks the beginning of the clinical history of the patient [4]. The resulting patient file retrieved was checked in order to confirm its correspondence with the defined criteria. It is likely to expect that real cases can cause additional HIs to show up which, tough not included in the case modeled, can actually affect the patient's care path (e.g. in this case a complication of Diabetes, or the worsening of Hypertension). The additional retrieved HIs may also be comprised in the making of both the reference and the didactic cases, thus enriching the HIN spectrum and leading to both a higher educational value and an effective teacher/learner interaction in a CBL environment.

4. Discussion and Conclusions

Usually, GPs' EHRs are more synthetic than the hospital ones, since they are meant to record longitudinal, life-long clinical data of complex patients. For this reason they cannot record too many details and can also miss some of the HIs. Moreover, they have other problems, e.g.: (i) patients' health status and functional levels are not always explicitly reported; (ii) GP' clinical reasoning is usually not reported, so the logical process remains implicit; (iii) it is not easy to rebuilt the many fragments of a clinical process into an overall picture. These kinds of EHRs more often only contain lists of diagnostic tests, or drug prescription without making clear to the reader what was the interpretation of the data by the GP, the reasons that led them to start, suspend or change a treatment and the reasons why a lab or instrumental test was performed. For these reasons the PN-based HIN approach introduced in this paper acts as formal tool in order to facilitate the reconstruction of unexpressed links between HIs through a temporal representation of their evolution. HIN allows the educational designer to formally describe in an easy way the evolution of the problems and their subsequent connections. First, the combination of HI temporal order and PN properties in HIN allows identifying the clinical cases that meet the educational requirements. Then, the semantics associated with the type of HIs and their connections make it possible for learners to understand the reasoning of the physician and therefore the logical process developed. The link between the HI and the clinical information reported in the EHR (clinical data, drug, etc.) sets a parallelism between the sequence of HIs and the corresponding sequence of clinical activities that generate the data reported in the EHR. This leads eventually to figure out the actual care path defined by the GP. HIN helps realize and perform specific queries to extract "rough" cases: thus a major expected benefit is to make the richness of GPs' records easily available for educational purposes.

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