Protocol based intervention plan analyzer

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***Abstract*— The rapid spreading of the evidence and protocol based medicine decrease the complexity and also standardize the healing process. Patients are able to view the whole healing process through intervention plans and they can prepare themselves in advance to the coming interventions. On the other hand, practitioners can follow the clinical pathway of the patients, and can receive objective feedbacks from various sources about the impact of the services. Resource planning (with time, cost and other important parameters) and resource pre-allocation became feasible tasks in the healthcare sector. The evolution of consensus protocols developed by medical professionals and practitioners requires accurate measurement of the difference between plans and real world scenarios. To support these comparisons we have developed the Intervention Process Analyzer and Explorer (INPANEX) software solution. INPANEX enables practitioners and healthcare managers to review in an objective way the effectiveness of interventions targeted at health care professionals and aimed at improving the process of care and patient outcomes.**

Keywords*— *process analyzer, health care intervention plan, resource plan.

I. Introduction

A growing demand can be seen in the healthcare sector for value added, premium category medicals services, which involves continuous medical monitoring and care [1].

Another aspect within Europe is the increasing tendency of patient tourism and the ever growing number of medical services for foreigners at premium service providers [2].

Interventions at a premium medical service provider has always well defined parameters (e.g.: cost, duration, etc.) and the whole intervention plan of the patients can be easily represented by timed graph structures. Intervention plan is part of the clinical pathway and in larger scale it is an important part of the patient’s life path.

The intervention plans are basically build up from consensus protocol(s) in a personalized form. If we could compare the intervention plans with the occurred interventions we could objectively assess the difference and analyze its impact, the effectiveness of the protocol, and the real usage scenarios of the protocol. We have created an Intervention Process Analyzer and Explorer (shortly: INPANEX) software solution to cover the mentioned aspects.

The current article gives a short description about the created solution and the paper is structured as follows. In the first section we give an overview about our term definitions, in the next section we detail the pre-defined requirements of the solution and the identified data sources. Then, we give an overview about the intervention plan analysis (about the analysis levels, and the used methods), then we provide a short description about the internal architecture of the solution, and finally summarize our results.

A. Used term definitions

We have explored the literature [3], [6], [7] and defined / adapted some terms for our usage scenarios:

- Protocol: generic set of interventions (events and activities), and rules of a certain healthcare domain for a well defined group of patients, which was developed as a consensus agreement by a team of experts. It can have a constant evolution over time (can have version, can be expired after a well defined period of time), it is based on the best practices of the healthcare professionals (and also on patient expectations) and the recorded patient statistics. It contains a set of events and activities with time and spatial constraints. Its internal structure can be represented as formal process description or a graph (protocol graph), which can contain iterations, conditional alternative paths.
- Intervention plan: Belongs to a single patient and contains events, activities, medical services with time, location, and resource parameters in a personalized manner. It can contain multiple protocols and also can contain complex control patterns (such as iterations, conditions, etc.)
- Intervention plan graph: Visualization of the intervention plan as a directed graph.
- Clinical pathway: Contains a set of events and activities with time and spatial constraints described in minimum one (personalized) intervention plan.
- Realized interventions: Multisource dataset, which belong to a single patient, and contains event, activity and medical service logs, with time, location and patient data and various resource parameters. It is a clear reflection what was historically occurred with the patient during its clinical pathway.

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II. INTERVENTION PLAN ANALYSIS; AIM, AND REQUIREMENTS

Premium medical service providers are only viable, if they are able to run their "business" with high efficiency. The market filters out all the medical service providers, which are not able to assess their potential and the quality of their services.

These data can be only collected with accountable, objective measurements, and continuous high resolution service monitoring. On the patient side new requirements appeared such as pre-evaluation and interactive monitoring of health services and intervention modeling/virtualized service models with high accuracy.

Our development, the Intervention Process Analyzer and Explorer (INPANEX) provides effective solution to do comparative analysis between the intervention plans and the occurred interventions, assess the difference and provide large scale statistics about the frequently used intervention scenarios. The solution can be combined with external healthcare databases and data mining applications to reveal more aspects of healthcare services, and their effectiveness on patient health. The analysis process can run in an offline mode, totally independent from any interventions, without any intervention plan status restrictions (intervention plan should not be in a finished or closed status).

III. INPANEX DATA SOURCES

Our software solution collects information from various data sources, and stores these data in a semi structured data repository for further processing (Fig. 1).

The collected main data sets are the following:

- Patient data
  - Patient base data
  - Patient survey data (satisfaction survey, etc.)
  - Anamnesis data
- Healthcare service data
- Historical logs received from the medical service provider or any healthcare systems
- Protocol data
- Intervention plan data
- Realized intervention data (from the healthcare system)

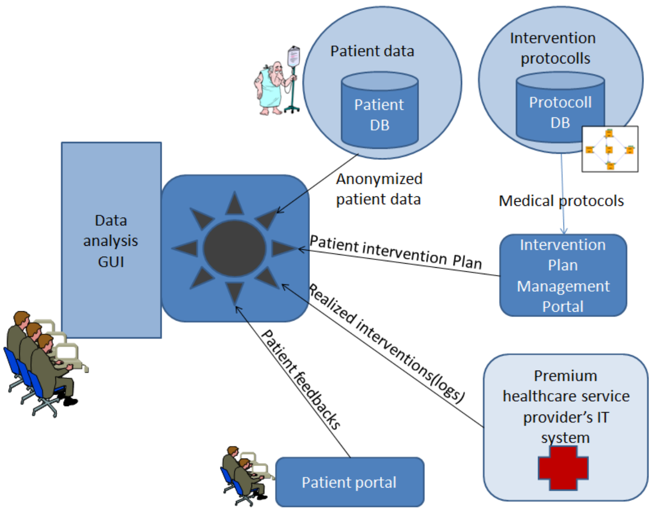

Fig. 1. INPANEX system overview

IV. BUILDING UP INTERVENTION PLANS

On the intervention plan editor GUI (Fig. 2) the intervention plan can be described as (an arbitrary complex) workflow, where the small circles are representing start/stop events, X represents alternative pathways with conditions, large boxes with labels and small icons are representing pre-defined intervention processes, and arcs define the direction of the path.

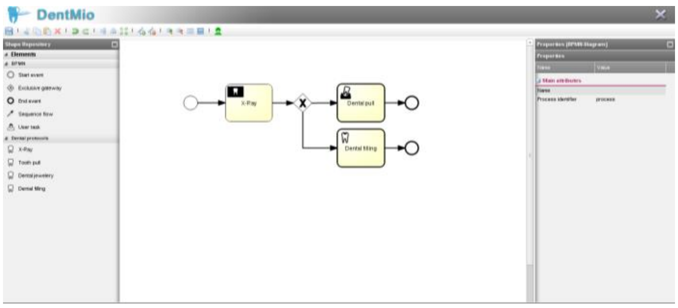

Fig. 2. Intervention plan editor and visualizer GUI

V. INTERVENTION PLAN ANALYSIS

Intervention plan analysis can be done from many viewpoints. In the INPANEX GUI different user groups (healthcare manager, medical expert/practitioner) can do analysis both on individual, or on a large set of intervention plans.

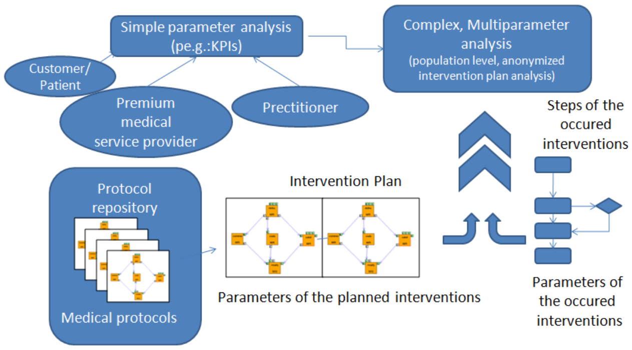

Fig. 3. Intervention plan vs. realized intervention comparison

A. Analysis process

Two types of analysis have been identified: simple analysis (individual intervention plan vs. realized intervention set of a single patient) and population scale analysis (intervention plan comparative analysis of a set of patients):

- Simple analysis compares the intervention plan's graph structure with almost 150 different, pre-defined performance indicators to the occurred interventions (and the measured parameters). We try not only to compare the parameters, but assess the impact of the difference.

- Population scale analysis can be a handy tool for practitioners and healthcare managers to create statistical analysis about protocol usage, average statistical parameters and expected patient outcomes.

B. Analysed parameters

We have identified a large set of intervention task parameters (P_i), which support during evaluation to objectively measure how the plans are matching the real world:

- Sequence of the intervention steps
- Amount of intervention steps
- Intervention step sub-parameters
- Conditional path decision accuracy
- Iterations
- Service resource consumption

Logically, an intervention step parameter can be arbitrary complex, and can contain undefined number of sub-parameters in a recursive form.

C. Used algorithms

We are using different type of algorithms to do comparison between intervention plan and realized interventions:

- Boyer-Moore algorithm [8], which is basically a string searching algorithm.

- Needleman-Wunsch algorithm [9], which is an algorithm used mainly in bioinformatics to align protein or nucleotide sequences using dynamic programming. It provides global sequence alignment with penalties.

- Smith-Waterman algorithm [10], which is also a bioinformatics oriented matching algorithm. It provides local sequence alignment using penalties.

D. Parameter difference evaluation

After the analysis process we are evaluating the parameter value differences. We denote the P intervention process's i-th parameter as P_i. We have defined the impact score matrix, and assigned an impact score ($0<K_{Pi}<1$) to each member of the parameter set. We are using a simplified linear evaluation function to calculate the impact of the differences (*I*):

$$\Delta P_i = P_i - P'_i,$$

where P_i holds the planned and P'_i is the really occurred intervention values.

$$I = K_{Pi} * \Delta P_i,$$

simply calculates the weighted difference of the planned and occurred intervention tasks, even if we can note here the subjective impact score value definitions. The larger *I* means larger distance between the plans and the real world scenarios. We can use the calculated values to search for alternative intervention graph paths or simply to optimize between the alternatives. Multiple impact score matrices can be used to analyze the intervention graphs from different viewpoints (medical service provider has easily different subjective impact values, than patients).

In the current version of INPANEX only similar interventions process parameter types can be compared. This is caused by the fact, that we are not using any substitution matrix, to define mapping possibilities between the different intervention processes and their parameters. The evaluation results provide us a handy solution to compare and analyze intervention plans with the occurred intervention records. Similarities are helping to define real consensus intervention paths. The measurable differences are interesting investigation points where a premium medical service provider can gain vital information about sits service quality, and patients requirements.

VI. SUMMARY

The aim of our research was to define a medical intervention plan analyzer software framework with accurate intervention evaluation algorithms. We are able to compare arbitrary complex intervention graph structures with occurred interventions received as patient health records or intervention logs. Planned intervention task parameters are mapped to the occurred intervention parameters. We have defined the weight of each intervention parameter, and calculate the impact of the differences (which is basically an absolute distance of the two parameter values.

From the parameter evaluation a lot of “hidden” information can be extracted such as information about the planning accuracy of the medical professionals, the difference between the implemented intervention plans and the official so called consensus intervention protocols or the correlation factors between the (really) occurred interventions and the patient outcomes, or the user satisfaction level and the occurred interventions. The developed framework solution is a generic intervention plan analyzer. It can be used or adapted easily to a large set of medical domains. We have validated successfully the system within the premium diabetes and dental care medical service domains in Hungary.

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