Simulation of Clinical Functioning Processes as Complex Network

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Abstract: - The paper focuses on presenting the functioning and efficiency of the public medical system in Ljubljana, Slovenia, from two points of view; firstly relying on the flowchart technique, and secondly using the framework of complex networks. The data on professional positions of 96 employees were obtained and used to represent the clinical system as a complex network. As we show, the system shows a clear modular structure, reflecting the division of patient processing in medical sub-units (teams). We hypothesize such structure to be responsible for global functionality of the medical system.

Key-Words: complex networks, modular networks, clinic, business process, flowchart, process simulation

1 Introduction

The efficient and reliable public medical system is the core ingredient of high standard of living in modern Western countries. On the other hand, generally such systems are simply used to support the bureaucratic processes that run in such organizations and for storing patients' medical data rather than being exploited fully by providing analytical value to those processes. This is mainly due to the lack of such interest by the management levels on one hand as well as personnel on the other as they would be the majority users of such system. The fact still remains that majority of processes were developed over time or badly modelled. Such processes became ineffective and need to be improved. For this reason, business process modelling and simulation became an important way of ensuring changes in an organization's functioning in order to create a better and successful organization, hence various approaches on how to obtain that have been set (Maruster et al., 2009). Furthermore, the efficiency of any complex system depends on the way its internal units interact. The functioning of a medical system is determined by the work organization among the hospital's personnel, which critically influences the efficiency of patient processing. For the purpose of this paper the authors do not differentiate between individual-profit organizations or non-profit organizations such as companies, administrative institutions, NGOs, etc. as do other researchers (Roncevic et al., 2010).

The aim of this work is to present a business process from two very specific approaches: firstly, by using process simulation tools such as flowchart and iGrafx, and secondly by using the complex network approach.

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The paper consists of six sections. Section 2 discusses business process simulation. Section 3 introduces the flowchart technique as a tool used by different software packages to run the simulation. Section 4 presents the data both approaches used to present to distinct point of views. Section 5 explains the network analysis approach and the final section contains some useful remarks and conclusions.

2 Business Process Simulation

Conceptual modelling of processes is deployed on a large scale to facilitate the development of software that supports the processes, and to permit the analysis and re-engineering or improvement of them (Aguilar-Saven and Olhager, 2002). Processes are modelled with the aim of analysing their current states within the organization, as well as improving them through the execution of potential "what-if" simulation scenarios. A process model consists of a set of activity models and execution constraints between them (Weske, 2007).

Currently, few organizations maintain a formal model of their process network (Weyland and Engiles, 2003). Even so, these formal models were usually the product of a series of interviews, reviews, examinations, etc. conducted at a time when the organization encountered apparent and serious problems. Construction of a process model makes use of several accepted modelling constructs: delays associated with performing work, statistical distribution of these delays to represent observed variability, dependence of processes on completion of earlier processes, queuing of input entities waiting to be "processed", decision logic that directs entities into alternate flow paths depending on their characteristics, application of resources to the work of a process, and the costs associated with these resources (Weyland and Engiles, 2003).

Consequently, an "as-is" model encompasses the above constructs with the aim of imitating the real process under inspection within the organization. Discrete event simulation deals with the attribute time only when the event actually happens. According to Laguna and Marklund (2005) such a perspective of the events and time enables significant time compression because it makes it possible to skip through all time segments between events when the state of the system remains unchanged. Simulation packages enable simulation runs of vast and various numbers of events that may in reality happen over a long period of time. Hence, when executing the simulation run, the simulation clock jumps between the events and regards the system as staying the same in the meanwhile. A simulation model is normally based on a set of assumptions regarding the system's operation. After a simulation model has gained form and been validated, it is deployed to examine various "what-if" questions regarding the real-world system, so that any future alterations of the system are first simulated and as a result it provides forecasts about the impact of the alterations on systems effectiveness.

3 Flowchart

A flowchart is a simple diagram used by different software packages such as iGrafx to model and run the simulation of a process under discussion. iGrafx software was used in this work to run the simulation of the health care process Surgery.

A flowchart is defined as a formalized graphical representation of a program logic sequence, work or manufacturing process, organization chart, or similar formalized structure (Lakin et al., 1996). A flowchart is commonly used to show the flow of a process from its start to its end. It usually consists of different symbols connected by lines, arranged in such a way to lead us in correct sequence order through a series of steps. Process flow is traced by following the connecting lines between the symbols drawn. These symbols include start and end, activity, input and output, decision, and department. A flowchart begins with a starting point and finishes with an ending point. The terminus symbol is commonly used in flowcharting to designate the beginning and the end. An activity is represented by a rectangle and means an elementary task or a sub-process. The path by which processes flow through the diagram consists of connecting lines between activities. A set of activities could be contained by a container called a department. An input is indicated by an arrow, which enters an activity. An output is shown by an arrow, which leaves an activity. An arrow connects one activity to another, showing the movement of the diagram. A decision specifies alternative paths based on some Boolean expression and is shown by a diamond. There can be only one input path to a decision, but there can be many output paths (Arlow and Neustadt, 2002). A decision is a point at which the process flow can take one of several possible paths based on a defined criterion.

To model a task performed simultaneously by different departments or to model parallel activities, we define different outputs from an activity as split outputs. A split is made by defining multiple paths from a single activity to a set of activities. After parallel tasks have been performed, outputs of those activities which performed the parallel tasks could be modelled to enter a single activity; this is called a joint input.

According to Agular-Saven (2003), flowcharts are built to offer an enhanced comprehension of the process, which is a requirement for process improvement. By grouping tasks into logical areas of activity (processes) and drawing flowcharts of the events which occur, it is possible to get a concise picture of the way particular processes are completed within the organization[1]. The flexibility of the flowchart technique is argued by some authors to be its advantage as it allows each modeller to unite various pieces of the process together to obtain the overall picture as he/she feels they fit best. On the other hand, other authors argue that the technique is too flexible, describing large models without illustrating the hierarchy of different layers.

4 The data

We obtained the data on functionality of medical system in Ljubljana. The dataset contains the relationships among 96 personnel of varying ranks: doctors (surgeons), interns (specializing students), nurses, medical technicians, and administrators. The data were gathered from Ljubljana University Medical Centre (UMC).

The process Surgery leads the patient which requires surgery, through a number of activities in different departments of the hospital such as Reception Office, Clinic, Laboratory, X-Ray, Anesthesia and Surgery Block as is shown in Figure 1.

The results of running the simulation of the health care process Surgery were as follows:

- Average cycle time for one patient is 14.68 days;
- Elapsed time for carrying out surgeries for 30 patients is 25.57 days. This is understandable because the software needed 10 days to enter 30 patients into the Clinic (3 patients per day);
- Average time for performing different activities before surgery is 2.94 days. This is 1.43 days for performing various medical examinations in the Reception Office and Clinic, and 1.51 days waiting for surgery;
- Average time for performing anaesthesia, surgery and post surgery recovery in the Surgery block is 7.1 hours;
- Average time for recovery in Intensive care is 4.26 days;
- Average time for recovery in Clinic is 6.39 days;

Average time for creating a release form is 0.78 hour.

5 Network analysis

We formulate the network as follows: each employee is represented as a network node. A link exists between two nodes, if the two corresponding employees are in daily professional communication. The network hence contains 96 nodes, representing employees for various hierarchical ranks, as noted above.

The network obtained from our data is visualized and shown in Figure 2. The patient node symbolizes the typical interaction of a patient with various units, during his/her treatment. Different shades denote different employees, as noted in the legend. Patient-processing units are marked with text.

The network displays a clear modular structure, since different processing units (teams) are structurally well separated. UMC operates in three shifts, each containing three teams: two larger and one smaller. The largest teams are in the morning shift, which is the only that includes interns. Afternoon and night shifts have smaller teams, similarly organized. PC operates with two teams only, working in the morning shift. Interestingly, the ratio of doctors to nurses to medical technicians is not the same in all teams. Also, the top-down communication differs among teams.

1 http://www.hci.com.au/hcisite2/toolkit/flowchar.htm

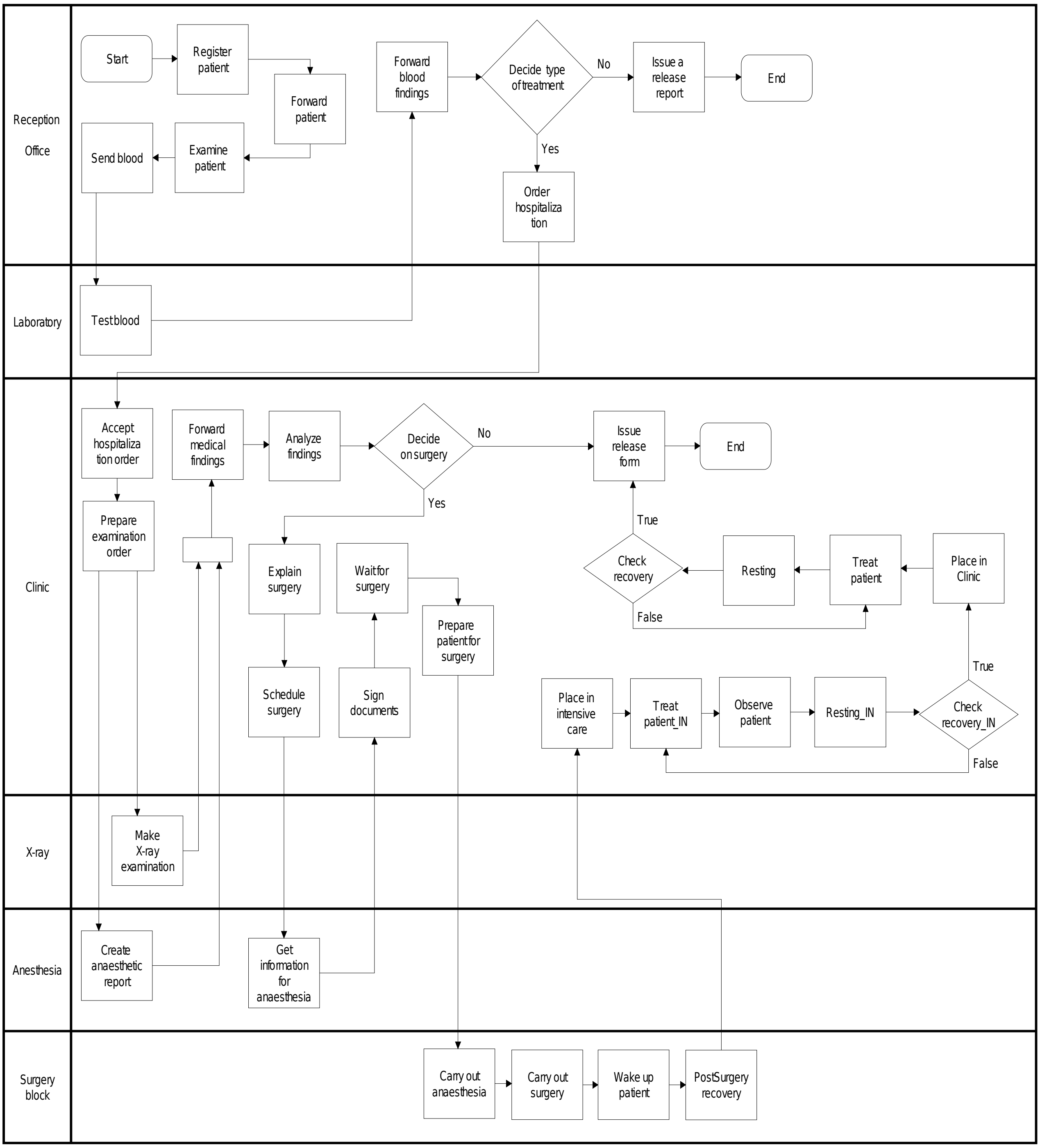

Figure 1: Flowchart of the health care process Surgery

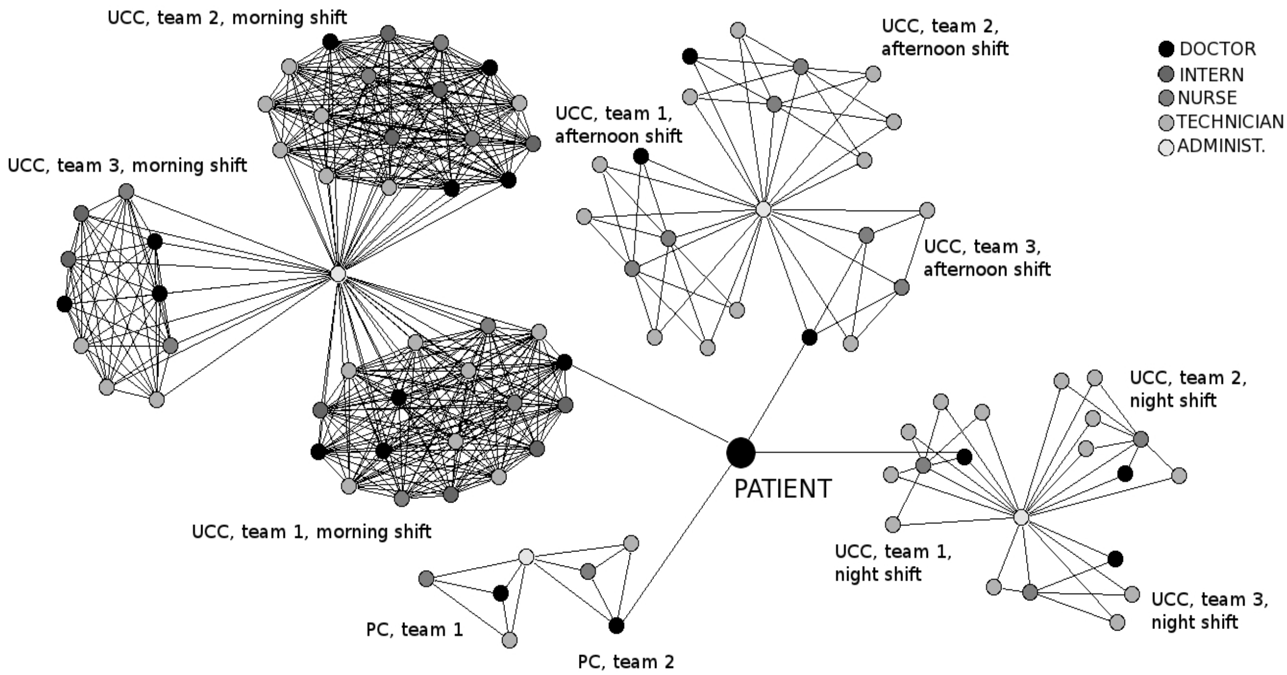

Figure 2: Complex network analysis of the health care process Surgery

6 Conclusion

The focus of this paper was to present a busy business process that is running in a public medical organisation in Ljubljana, Slovenia. The healthcare process Surgery was illustrated from two very different point of views, firstly by using flowchart technique and secondly by using the complex network analysis approach. As the first is a traditional way to present business processes, the latter presents a new perspective on how business processes can be viewed as well as enables organizations to gain new knowledge of the activities and actors that are defined in such processes.

The results of running the simulation of health care process Surgery show that the process considered is well modelled. Representing complex systems as networks allows for their easier modelling and analysis. We hope our approach traces a new methodology in investigating public services and as we demonstrated, the process shows a clear modular structure, reflecting the division of patient processing in medical sub-units (teams). We hypothesize such structure to be responsible for global functionality of the medical system.

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References:

1] Aguilar-Saven R, Business Process Modeling - Review and Framework, *International Journal of Production Economics*, 2003; 90(2), pp. 129–149.

2] Aguilar-Saven R, Olhager J, Integration of Product, Process and Functional Orientations - Principles and a Case Study, Preprints of the I*nternational Conference on Advanced Production Management Systems*, *APMS* 2002, IFIP, The Netherlands, 2002.

3] Arlow J, Neustadt I, *UML and the Unified Process - Practical Object-Oriented Analysis & Design*, Pearson Education, Boston, 2002.

4] Laguna M, Marklund J, *Business Process Modeling, Simulation, and Design*, Pearson Education, Inc. New Jersey, 2005.

5] Lakin R et al., *BPR Enabling Software for the Financial Service Industry*, Management Services, ISSN: 0307-6768, 1996.

6] Maruster, L., van Beest, N.R.T.P., Redesigning business processes: a methodology based on simulation and process mining techniques. *Knowledge information systems*, Vol. 21, No. 1, 2009, pp. 267-297.

7] Rončević, B., Makarovič, M., ‘Towards the strategies of modern social processes’, 2010, Innovation: The European Journal of Social Science Research, 23:3, p. 223—239.

8] Weske, M., *Business Process Management: Concepts, Languages, Architectures*, New York: Springer, 2007.

9] Weyland JH, Engiles M, Towards Simulation-Based Business Process Management, Proceedings of the 2003 *Winter Simulation Conference*, (eds) Chick S, Sanchez PJ, Ferrin D, Morrice DJ, 2003, pp. 225-227.