Do Excel and iGrafx provide the same healthcare process simulation results?

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Abstract: The paper examines process simulation from two perspectives – using spreadsheet Excel and iGrafx is order to investigate the difference in results. Process simulation is an important task for modelling of healthcare systems. One of the leading process simulation environments, iGrafx, allows modelling of complex processes, including healthcare. However, it is expensive and often unavailable for the common users. On the other hand, almost every computer user has at least once used spreadsheets. Their vast usage is due to its simplicity to work with spreadsheets and their availability in the companies. This paper presents a comparison of two approaches for healthcare process Surgery simulation based on iGrafx and spreadsheets. We show that for modelling of a relatively complex healthcare process, one may use spreadsheets, which provide as reliable results as iGrafx.

Key-Words: healthcare process simulation, spreadsheet Excel, simulation tool iGrafx.

1 Introduction

Simulation is the imitation of the operation of a real-world process or system over time. It involves the generation of an arbitrary data observations that help in drawing inferences concerning the operating characteristics of the real system [1].
Creating a simulation model and simulation scenarios of a real life processes requires observation and understanding of processes behaviour expressed as process models taking into account the full complexity of the systems and strategies prepared in their context (taking into account the broader social complexity as exemplified by [24, 25, 26, 27, 28, 29, 30]).The process model has to be checked and validated in order to find out whether it reflects the real process. Then the simulation scenarios are prepared carefully using different "what-if" questions and scenarios [2] to test several options and possibilities concerning the functioning of the process. Such process models are then simulated with the aim to identify the optimal improvement of the analyzed process.
A discrete system is one in which the state variable(s) changes only at discrete set of points in time; consequently the same applies to discrete-event system simulation [1] e.g. business process simulation. The goal of discrete simulation model is to portray the activities in which the entities engage and thereby learn something about the system's dynamic behavior. Simulation accomplishes this by defining the states of the system and constructing activities that move from state to state. The beginning and ending of each activity are represented as events. The state of the model remains constant between consecutive event times, and a complete dynamic portrayal of the state of the model is obtained by advancing simulated time from one event to the next [1].
Process modelling and simulating enable the analyst to understand process behavior, discover problems accumulated within it, and obtain knowledge and new ideas that could be very important in improving the process. This is usually achieved by making necessary changes in the process functioning. This technique leads us to discover which changes are essential for process improvement.
Business process simulation has an essential role in the process of improvement of the business process in the public and private sector. It is a tool, which companies use to get feedback regarding their performances under different conditions. Hence, they can plan their development in terms of

increasing the available resources versus the demand on the market. Regardless of the fact that business process simulation is acknowledged as relevant and highly applicable, in reality the use of simulation is limited [1] for two reasons. Firstly, there are more than one hundred available tools for process simulation, each one with different specifics; however, there is a lack of guidance of how to choose a particular tool for simulating a specific task. Secondly, most of these tools are either too expensive to buy for the small companies and start-ups or require a great knowledge for their setup.

The main objective of this paper is to provide an alternative to iGrafx Process for business process simulation by using spreadsheets. The reason for selecting iGrafx Process from all available simulation tools is twofold. It is a widely used software especially in large companies. It is easy to install and it does not require high computer knowledge in order to use it. Its main drawback is its high price. Spreadsheets on the other hand, are commonly used today. They are easy to install and do not require high programming experience to use them.

In order to provide an alternative tool for iGrafx this work presents a comparison analysis of the use of iGrafx and MS Excel for healthcare process simulation.

The paper is divided into 5 sections. In Sections 2 the process simulation using iGrafx is discussed. Section 3 shows an approach of process simulation using a spreadsheet. Section 4 shows a comparison analysis the use of both tools. The final section contains some useful remarks and findings. Throughout the paper, the healthcare process of carrying out surgery in the Abdominal Surgery Department (Clinic) of the University Clinical Center in Ljubljana, Slovenia, is illustrated.

2 Process Simualtion using iGrafx

iGrafx Process is used for designing and analysis of new business procedures as well as for their management and simulation. However, the usage of iGrafx Process for modelling and simulations has rarely been mentioned in the literature. iGrafx Process offers a similar technique to the unified modelling language (UML) swimlane- like diagram. The comparison of modelling with swimlane diagrams and UML has already been described in [3]. The main advantage of iGrafx Process is its simplicity, which offers a fast and easy understanding of its modelling and simulation approach even for the beginners. iGrafx can be used to model and simulate variety of processes, in particular, it is a powerful tool for discrete event simulations. At the same time it provides a graphical user friendly interface for visualization of the activities and their interconnections.

3 Process Simulation using Spreedsheets

The creation of a simulation model enables us to define the process discussed by representing its activities, attributes, and the entities related to them. Below we list some of the major concepts of a discrete-event model of a system, as they are defined in [1]:

- System: A collection of entities (e.g., people and machines) that interact together over time to accomplish one or more goals;
- Model: An abstract representation of a system that describes a system, usually containing structural, logical, or mathematical relationships which describe;
- The system in terms of state, entities and their attributes, sets, processes, events, activities, and delays;
- State: A collection of variables that contain all the information necessary to describe the system at any time;
- Entity: Any object or component of the system which requires explicit representation in the model (e.g., a server, a customer, a machine);
- Attribute: The properties of a given entity (e.g., the priority of a waiting customer, the routing of a job through a job shop);
- Activity: A duration of time of specified length (e.g., a service time or arrival time), which is known when it begins (through it may be defined in terms of a statistical distribution);
- Delay: A duration of time of unspecified indefinite length, which is not known until it ends (e.g., a customer's delay in a last-in, first-out waiting line which, when it begins, depends on future arrivals);
- Clock: A variable representing simulated time.

3.1 Process Modelling using Spreadsheets

There are two main drawbacks of iGrafx Process. Firstly, for small simulation processes, one may be additionally interested to have an overview of the whole process at the minimal time instance defined by the model. Secondly, the price of the iGrafx Process is relatively high. Both issues can be overcome to a certain extend by using spreadsheets for modelling and simulation. The advantage of spreadsheets is that almost all companies have installed a software for spreadsheets, such as MS

Excel, which offers seamless dissemination of the project results.

Research papers that describe modelling and simulations using spreadsheets are much more frequent than those for iGrafx. For example, one can find papers that deal with simulations using spreadsheets in healthcare [4, 5, 6], simulation of pharmacokinetic processes [7], and for simulation of optimization process of control parameters [8]. Spreadsheets have been widely used in many companies for various simulations. Hence, the long-term corporative survival of 30.000 companies in England that use spreadsheets for different purposes is discussed in [9]. Most of the companies use spreadsheets for Monte Carlo simulations [10, 11], and optimization purposes [9]. Spreadsheets have been used even for simulation experiments in complex physical phenomena, such as calculation and simulation of magnetic field of solenoids [12], or for finite difference time domain simulations for propagating electromagnetic waves [13], and for simulation of microprocessor systems [14]. They are used for simulation of functions by simulating basic blocs that are interconnected into a graphical interface [15], for simulation of the work of components of an analog computer, so that a simulation of the whole system is obtained [16]. A recent publication in bioinformatics that uses spreadsheets simulates the consequences of varying parameters on measurement results of trace amounts of non-authorized genetically modified organisms (GMO) in feed [17]. In addition, spreadsheets have been used to simulate the cardiac action potential [18], and for simulation of Cognitive modelling [18]. In Chemistry, spreadsheets are used for simulation of Chromatography [20]. Most of the simulation of the processes in these papers is performed using macros. The processes are usually expresses with equations that are interconnected, or by diagrams obtained by linked different shapes, offered by the spreadsheets.

3.1 Process Simulation

In this paper, we use the resent approach that deals with healthcare process simulations. The simulated models in MS Excel consist of three modelling elements: an activity, a transaction, and a gate. An activity in this approach is defined similarly as in iGrafx. It is a description of a task that has a duration and requires resources for its execution. Transactions are flow units that move through the process model from one activity to the next ones [21]. A Gate is a modelling element that is activated at a particular time of the day. It means that the transactions that arrive at the gate have to wait until the gate's door opens at the time defined. A gate does not have time duration nor resources, therefore it is not considered as an activity.

Table 1. Excel simulation input data worksheet

Table 2a

Number of beds	75

Table 2b

Parameters of triangular distribution	Activity 18	Activity 24
a	1	3
b	5	5
c	4	4

Table 2c

Activity ID	Activity Name	Resource	Duration (Minutes)
01	Confirm surgery date	1	10
02	Patient reception	1	15
03	View and organize documents	1	10
04	Fulfill care documents	1	15
05	Explain surgery	1	10
06	Sign surgery documents	1	5
07	Sign anaesthesia documents	1	5
08	Prescribe medications	1	10
Gate1			Every morning
09	Prepare patient for surgery	1	30
10	Carry out anaesthesia	1	Between(30;45)
11	Carry out surgery	1	Between(60;240)
12	Wake up patient	1	30
13	Place in intensive care	1	30
14	Prescribe therapy	1	10
15	Addition-al tests	1	10
16	Order additional tests	3	10
17	Carry out care	1	Between(90;180)
18	Check recovery	2	TringDist(1;5;4)
IntG			Every morning
19	Place in Clinic	1	20
20	Prescribe therapy	2	10
21	Addition-al tests	1	10
22	Order additional tests	2	10
23	Carry out care	1	Between(90;240)
CliG			Every morning
24	Check recovery	2	TringDist(3;5;4)
Gate2			Every morning
25	Inform about release	1	10
26	Prepare release report	1	30
27	Organize transport	1	10
28	Need transport	1	10

Each modelling element is defined in one spreadsheet. Each row in these spreadsheets represents the state of the modeling element at a particular moment of time. A process in Excel is defined through interconnecting the spreadsheets with formulas that leads to simulation of transactions that moves from one modelling element to the next ones. The configuration data for each modelling element, such as duration time, and all initial set ups, such as number of starting transactions, and their interconnected start up time are given in a separate worksheet called Input data worksheet. One example of an Input data worksheet is given in Table 1.

The Input data organizes the configuration parameters into three tables. The first table defines the constraints of the model, which for the simulation model of abdominal surgery clinic is presented with the maximum number of available

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beds. The second table provides various data about parameters of the modeled activities, described with different distributions.

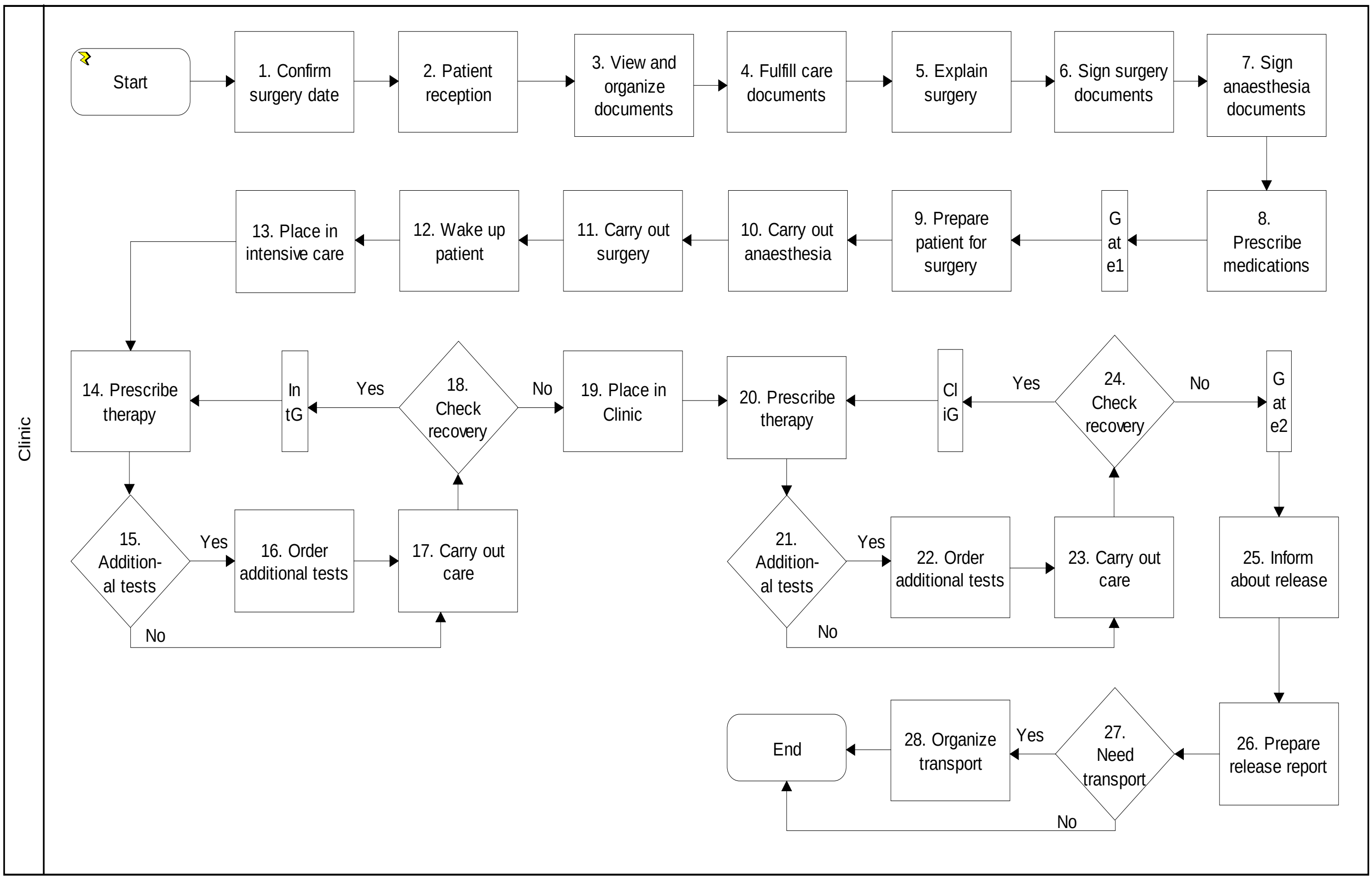

Fig. 1. iGrafx model of the process of abdominal surgery

The last table shows for each activity its properties, such as ID, number of resources, and duration.
The results are presented in a separate worksheet in a tabular format and by using graphs.

4 Comparison Analysis

4.1 Model description of the abdominal surgery process

To compare the two simulation approaches the paper introduces a real case study of the abdominal surgery process taken from the abdominal clinic in Slovenia. Firstly, the Activity table modeling technique [22] is used to model the abdominal surgery process, resulting in the model presented in Table 2. This table divides the surgery process into five work processes, each one consisting of several activities.

The proposed spreadsheet model represents the whole process by modeling each of its 28 activities in a separate worksheet. These are interconnected as in reality, so that a patient is directed from one activity to the next one automatically.
The proposed model is implemented in iGrafx and is presented in Figure 1, while in input data worksheet for the Excel simulation model is given in Table 2. In this example, the process simulation is carried out over a period of four weeks, where a week consists of five working days and eight working hours per day. Consequently, we defined 9,600 rows in each spreadsheet (1 working day consists of 8 hours; 8h*60min*20working days=9600min). In the proposed models, patients have the role of transactions.

4.2 Results and validation of the simulations

The most commonly modeled characteristics of a process are the time and resources. In this paper, we compare the average cycle times of both models for the process of abdominal surgery. Then we observe for how much the average cycle time increases when the workload increases (number of beds in the Clinic) under unchanged resources.

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4.2.1 Measurement variables

Cycle Time is the simulated amount of time that a transaction spends in the process diagram, starting with the first activity, and ending with the last one. A cycle time may differ from one activity to the other due to the different paths in the process diagram, and due to the different activity durations, calculated from their distributions. Cycle time includes work time and wait time.

Work Time is the simulated amount of time that activities actively perform on transactions. It is directly calculated as a sum of the activities duration times. Wait Time is the simulated amount of time that transactions are waiting. The waiting may occur due to different reasons: waiting for a resource, or because of a gate. Work and wait time are connected to the cycle time with the equation:

Cycle time = Work time + wait time.

Term average refers to the total time that all transactions spent for each activity, divided by the number of completed transactions for each activity.

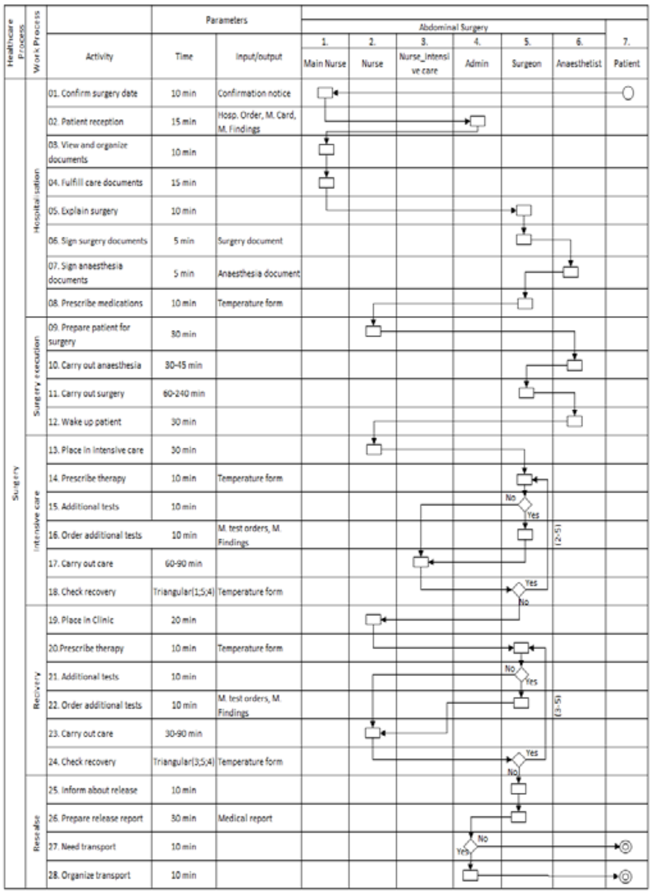
4.2.2 Validation of the model

To validate the Excel model, we have compared the average cycle times for different bed settings with those obtained from the iGrafx model. In particular, we measured the Pearson's coefficient r given with

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}}$$

where (X_i,Y_i) denote the data values from the two data sets X and Y and n is the number of available data. The sample mean of the two data sets are denoted as $\overline{X}$ and $\overline{Y}$.

Table 2. Activity diagram for abdominal surgery process simulation



4.3 Comparison of results obtained with Excel and iGrafx

The average cycle times obtained with Excel and iGrafx, calculated over 100 iterations are presented in Figure 2. The horizontal axis shows different number of beds in the hospital, while the vertical axis shows the average cycle times measured in days. The small differences in the average cycle times of the two models are due to the random component of several of the activities, such as 10, 11, 13, 17, 19, 23 and 24. The calculated Pearson's coefficient for the two datasets given in Figure 2 is 0.9737. The high value of Pearson's coefficient implies high correlation of the two models, and consequently one may conclude that the model as validated.

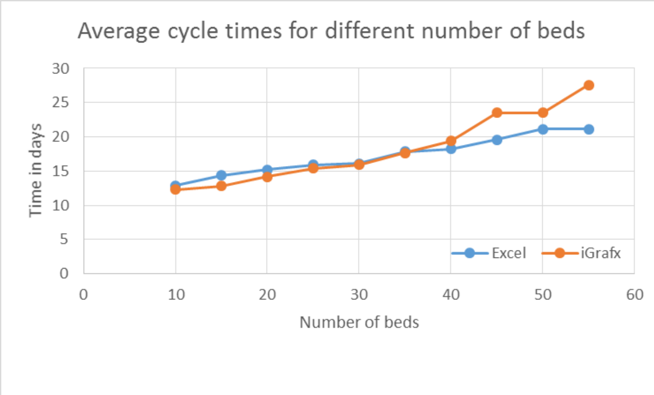


Fig. 2. Differences in average cycle times

One of the benefits of using Excel is the possibility to observe the cycle time of each transaction separately, hence to draw conclusion regarding the trend of the measured values. For example, the Figure 3 shows the cycle times of all transactions that finished during the simulation, for different bed settings. In particular, the model allows observation of the cycle times depending on the number of beds. The Figure 3 shows seven lines for simulation of a Clinique with different number of beds: from 10 to 40. The positive trend in Figure 3 shows how the cycle time increases given the same resources, while increasing the number of patients.

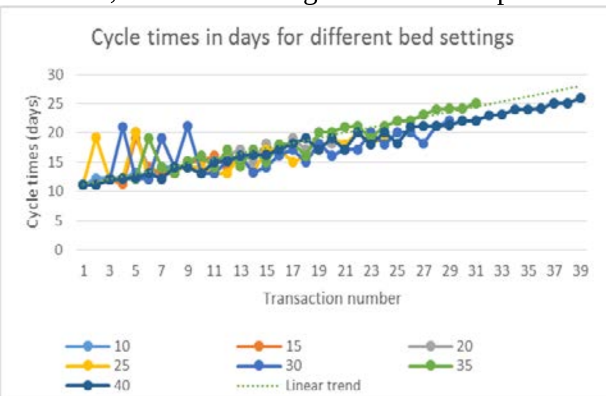


Fig. 3. Cycle times in days for different bed settings

5 Conclusion

Simulation is a powerful tool for process analysis because of which more than one hundred different software tools are developed. The main difficulty that practitioners of BP face is choosing the right simulation tool for a given business process because of two reasons: the price of the offered tools and the limited literature on comparison of these tools. In this paper, we chose two softwares: iGrafix Process and spreadsheets and compared them. The first one is expensive and requires little programming knowledge to be used. The second one is widely accessible practically to all computer users, and also requires little programming knowledge, however requires a suitable initial time to build the model. We show that both tools provide very similar results demonstrated on simulation of a healthcare process in an abdominal Clinique. The process is relatively complex as it consists of 28 modelling elements that have to be incorporated into the spreadsheet model for simulation purposes. Based on the obtained results we propose usage of spreadsheets in cases of a need for medium complexity of processes and financial limitations.

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