CHALLENGES OF BUILDING A SIMULATION MODEL OF THE GERMAN MENTAL HEALTH CARE SYSTEM

Kristina Dammasch[(a)], Benjamin Rauch-Gebbensleben[(b)], Christfried Tögel[(c)], Graham Horton[(d)]

[(a), (b), (d)]University of Magdeburg, Department of Simulation and Graphics, Germany
[(b)]Salus gGmbH, Salus Institute for Trend Research and Therapy Evaluation in Mental Health, Magdeburg, Germany

[(a)]kristina@dammasch.net, [(b)]ben@sim-md.de, [(c)]c.toegel@salus-institut.de, [(d)]graham@sim-md.de

ABSTRACT
We are currently developing a simulation model of the German mental health care system. We believe that it might support analyses of the provision system and evaluations of possible future trends. But trends cannot be unified easily. Relevant parameters of health care providers diverge strongly even in similar areas considering demographic and economic aspects. A suitable mathematical description for these parameters could not have been obtained. Interdependencies between parameters are very complex and therefore hard to observe. For that reason, we decide to change our focus from the complete German system to a smaller geographical area in eastern Germany that seems to be suitable for our study. We expect the parameters of interest to be more stable allowing us to gain the necessary mathematical relationships. If we succeed in building a model of a smaller system we might be able to derive information for a model of the complete system.

Keywords: mental health care, process analysis, data analysis, trend research

1. INTRODUCTION

Computer simulation is a well-established method for modeling and analyzing systems. It enables an objective view on relevant processes and gives the opportunity to evaluate different optimization and planning strategies. This is of special interest for planners and researchers of systems in many application fields.

One of these application fields is mental health care, although the usage of computer simulation there is still more uncommon compared to other fields (Sanchez, Ogazon, Ferrin, and Sepulveda 2000). Nevertheless, a suitable simulation model of mental health care services might support analyses and planning tasks concerning the system and its possible evolution in the future.

For that reason, we are currently developing a simulation model of the German mental health care system that will allow the definition of a variety of different scenarios that are to be evaluated. The collaboration with the holding company of a group of German psychiatric facilities, that is also initiator of this research project, enables us to analyze the processes of mental health care and to collect and interpret some of the necessary data for our simulation model.

For being able to build that model we first have to identify the parameters that are crucial for the system's behavior and determine the boundary of the system. Furthermore, we have to describe the processes and interdependencies within this boundary.

In this paper we would like to present some of the performed analyses and challenges we had to face. Afterwards we explain the consequence arising and close the paper with a short summary and outlook on our future work.

2. METHODOLOGICAL APPROACHES

There were two approaches possible for deciding which parameters are relevant for a description of the system: On the one hand, results from a broad data analysis such as mathematical correlations could reveal which processes are determining the system's behavior. An advantage is the objectivity of the data disregarding subjective opinions about the system. But the approach also specifically entails the risk of mistaking a mathematical correlation as logical relationship between two or more parameters. That way the resulting process model might be falsified.

On the other hand, we could perform a system and process analysis first. Then the derived information could be used to observe only selected parameters identified during the analysis. The main challenge here is to distinguish between different subjective opinions about the system processes. A possible manipulation by one side or the other may cause important influencing parameters to be disregarded.

Due to the complexity of the system, we decided to start with a system analysis for getting an impression of the main processes. We conducted interviews and workshops involving experts from different parts of the health care system such as physicians, controllers or planners of the provision system. We also expected to get an impression of the expectations about the simulation model we are about to develop.

The analyses showed that there are a lot of different questions that are to be answered with the aid of simulation experiments. Therefore, we first had to make some restrictions about the model range. The different aspects of interest concern different levels of detail and require different modeling techniques. In summary we specified two levels:

1. Forecasts about the basic data of the health care providers.
2. Forecasts about the course of the patients' treatments in consideration of different circumstances and influences.

Based on these examinations also different conceptual models are considerable. If the behavior and future development of a rather abstract model of the system is of interest, logical process chains might not have to be modeled. In this case a system of difference equation might be sufficient, as the system does not evolve continuously.

If the "flow" of patients through the system has to be modeled more detailed and also visualized a stochastic Petri net would be a sufficient choice although the computational effort would increase due to the high number of moving entities modeling the patients. Nevertheless, a Petri net would be of advantage for many other reasons (Dammasch and Horton 2007).

If a description of a patient in a psychiatric treatment is required for a simulation scenario, a Petri net might be also an appropriate choice. Based on the concept of hybrid tokens (Dammasch and Horton 2008) it enables a detailed model of the moving entities with discrete and continuous attributes in a simple discrete-event-system.

We decided to have the main focus on the first level mentioned above and perform an analysis of the mental health care system as a whole including its involved providers and their possible development and connections in the future. The conducted interviews also helped us defining the output parameters of our simulation model that are of special interest for possible users. Afterwards, we proceeded with a detailed process and data analysis.

3. ANALYZING THE SYSTEM'S PROCESSES

A system is defined as the total entity to be evaluated. It must include all people and things interacting within the system (Medina 1981).

The input of the system influenced by external parameters from the environment is transformed into the system's output that has an influence on the environment and also back on the system's input.

This simple description of a system is shown in Figure 1.

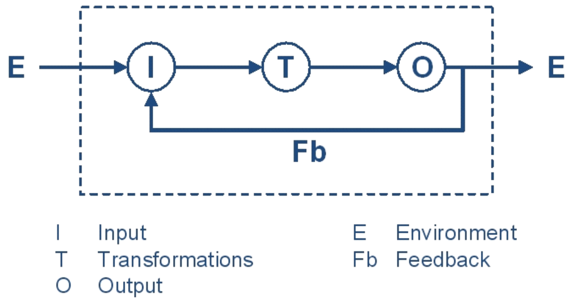

Figure 1: Simple System Model

This means for our research work that we have to find the input parameters of the system such as the number of patients for example or the probability for suffering from a certain disease. And we have to find those parameters that have an influence on the input parameters. Remaining with the examples, we have to find out which parameters from the environment might have a positive or negative influence on the number of patients or the probability of being taken ill.

Second, possible output parameters have to be determined for the system definition. Parameters we carried out from the conducted interviews and workshops are among others the costs of treatment per patient and the quality of care. Third, we have to determine how the output results from the input.

We let the overall system be defined as the complete German mental health care system. As this system is too large and complex to evaluate as a whole we tried to decompose it into a more workable structure and divide the system into smaller subsystems.

A proper subsystem must be a system itself (Medina 1981) located in an environment, i.e. the superior system, from where the subsystem receives input and delivers output. Additionally, the output of one subsystem can in turn be the input of another subsystem. Figure 2 shows a simplified scheme of a system containing several linked subsystems.

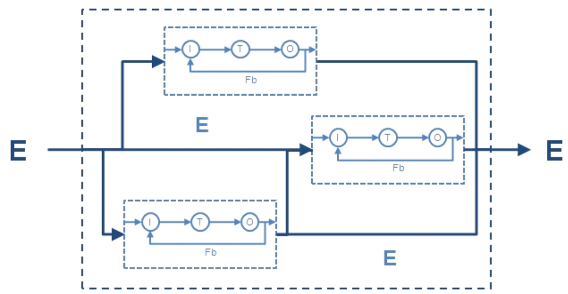

Figure 2: Model Of Subsystems With Connected Inputs And Outputs Within A System Boundary

Our first idea was to divide the complete mental health care system into subsystems representing the different health care providers and super-ordinate or regulating organizations such as ministries or health insurances. Therefore, we had to analyze the interaction of the providers and the patients' flow.

3.1. Mental Health Care in Germany

The German mental health care system involves different providers connected to each other. A patient is usually not treated in only one kind of treatment facility, e.g. a hospital, but is sent from one facility to the next depending on mental and physical state as well as the individual objectives of a treatment (Schädle-Deininger 2006). One possible course is shown in Figure 3. Other common ways are illustrated by dotted arrows

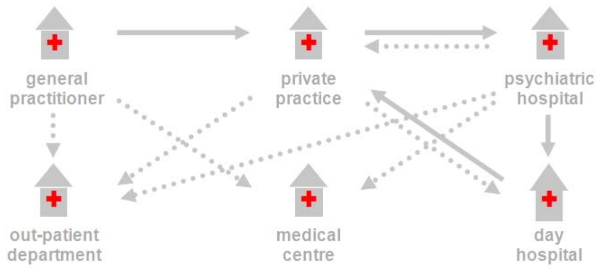

Figure 3: Example Course Of A Psychiatric Treatment

In the example shown in Figure 3, the patient is treated by a general practitioner who suspects a mental disorder. For an exhaustive examination the patient is sent to a private practice where a diagnosis is proposed. If the patient suffers from serious disturbances a stationary treatment is suggested and the patient is admitted to a psychiatric hospital. Otherwise the patient will stay under ambulant treatment.

At the psychiatric hospital a therapy form is chosen depending on diagnoses and the patient's condition. A therapy usually consists of different combinations of treatments. After finishing a stationary therapy, other treatments follow in an ambulant facility such as a day hospital, private psychiatric or psychotherapeutic practice.

The admission and treatment process is very complex. Beside the described example there are many other courses possible whose regulations are frequently non-transparent. And there are different additional influences either from the external environment of the system or from within the system, i.e. from other subsystems, or both. These might be among others laws or regulations determining for example financial influences.

3.2. Challenges

When analyzing the system's processes and regulations we came across two difficulties. First, processes are usually well-defined but indeed often not clearly documented. An example is the decision what kind of facility a patient is admitted to. Referring to Figure 3, it has to be decided if the patient is admitted to a day hospital, a medical centre, an out-patient department or a private practice, if an ambulant treatment is suggested. And a lot of different factors have to be taken into account for this decision. To be able to do that a standardized procedure is defined but it takes persistent inquiries to find out that there are regulations at all.

By contrast, there are processes without any definitions or at most soft guidelines. An example is the choice of a therapy for a certain mental disorder. Instead of following clinical pathways that are not established in mental health, the therapy form is within the sole discretion of the therapist. However, surveys indicate that different treatments of the same mental disorder can lead to different therapeutic outcomes (Reinecker 2003). In turn, this has an influence on our specified output parameters of the model.

4. DATA ANALYSIS

One objective of our work is to create a tool that allows the simulation of user-defined scenarios answering a variety of what-if-questions. Questions of interest concerning the system might be: "What if the length of hospital stay for diagnosis X is shortened to 14 days?" or "What if clinical pathways are to be implemented determining to treat all patients with diagnosis X with therapy form Y?".

When considering external parameters that might have an influence on the system such as the age distribution of the population or unemployment, further questions might be: "What if the rate of the over-60s is up to 50 percent?" or "What if the rate of unemployment is down to 1 percent?".

For being able to simulate one of these scenarios we have to analyze among others the effects of different forms of therapy on the therapeutic outcome for diagnosis X in different facilities in Germany. Second, the influence of the length of hospital stays on different output parameters such as quality of care or treatment costs has to be examined. Furthermore, the influence of the German population structure and unemployment rate has to be found and quantified.

Therefore, we had to find different reliable data sources covering information about the population and its structure and about economical parameters. Furthermore, we had to find information about medical facilities and their basic economic data as well as the treated diseases and forms of therapies.

4.1. Data Sources

One main data source for a data analysis is the German Federal Statistical Office offering a large database for economic, demographic and social parameters. But the size of the data sets is very different from parameter to parameter. While some data sets contain information for more than 40 years, some others start at 1991 after German reunification and some sets, especially concerning health care, reach back for only four to five years. The reason is the re-structuring of data management and recording systems in the health care sector. Unfortunately, data prior to that is not available. But a statistically reliable data analysis requires more than four or five samples.

A second source has to be data from different German health care providers covering mental health care of any kind of facilities as well as data from regulating organizations. As explained in Section 3.1 a patient runs through different treatments at different health care providers depending on the patient's physical and mental state. That means that different providers treat patients in different conditions, e.g. stationary care for serious disturbances and ambulant care for patients in better condition. Therefore, the parameters of interest differ among the providers.

As a result all kinds of providers have to be taken into account and examined separately. They cannot be considered as similar. But there are providers, especially smaller ones such as psychiatric or psychotherapeutic practices, where data management and recording is not structured and partly not even done in a digital manner. Collecting and analyzing data from those providers is nearly impossible. This strongly decreases the available amount of data and the reliability and completeness.

For the parameters where we were able to gain a suitable data sample we performed statistical analyses for deriving frequencies and mathematical correlations as well as trends.

4.2. Results of the Performed Analyses

As a first result, we found out that a parameter and its development over time in one part of Germany can be completely different from its development in another part. An example is the trend of the German population that increased nearly steadily during the last 15 years. On the one hand, there are states showing the same trend but on the other hand, some German states have a very high migration rate resulting in a steady decrease of the population. As the migration rate of younger people is higher than of the older ones, the rate of the over-60s there is higher than the overall German rate. This, in turn, has an influence on the number of people with age-related disorders such as dementia. And thus it has a crucial influence on the input parameters of our model.

In almost the same manner it is also possible that the range of one and the same parameter of psychiatric facilities could be exceedingly wide. Although we expected the parameters of facilities located in similar geographical areas to be similar, we found examples where our expectation did not apply. An example from two hospitals in Saxony-Anhalt, both located in rural areas, is shown in Figure 4 and 5. The diagrams show the relative frequency of the six most frequent classes of mental disorders in one psychiatric hospital in Figure 4 and in another hospital in Figure 5.

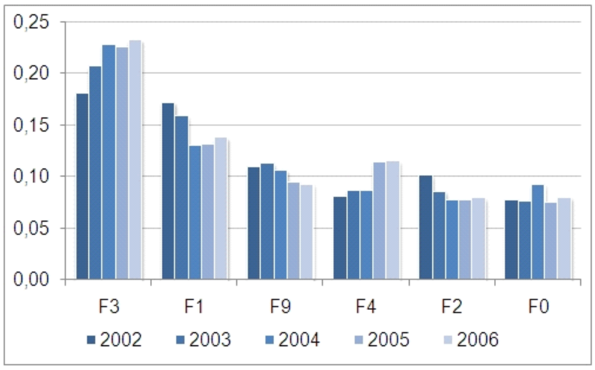

Figure 4: Frequencies Of Diagnoses In A German Psychiatric Hospital Between 2002 And 2006.

For both hospitals we evaluated the frequencies of all occurred classes of disorders in the years 2002 till 2006. Then we determined the six most common classes and compared the frequencies and development over the years. Appendix A explains the classes of mental and behavioral disorders based on the WHO International Classification of Diseases (ICD).

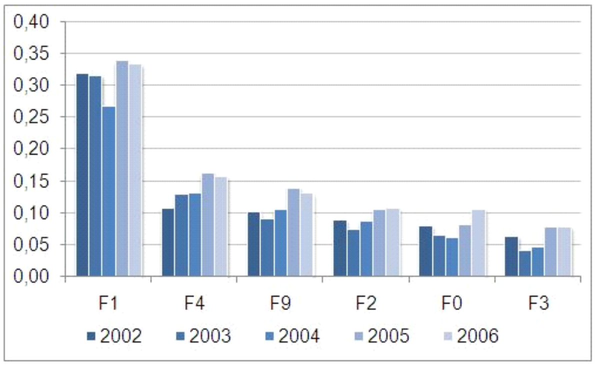

Figure 5: Frequencies Of Diagnoses In A Second German Psychiatric Hospital Between 2002 And 2006.

First, it is conspicuous that in both hospitals the most frequent classes of disorders are equal but in a different ranking covering F0, F1, F2, F3, F4 and F9. Second, the number of patients suffering from a mental disorder of class F3 in hospital 1 is approximately 50 percent higher than in hospital 2 when adding up all cases between 2002 and 2006. And the frequency of F1 diagnoses is higher in hospital 2 than in hospital 1.

Furthermore, the development over time of the frequencies is different in both hospitals. When comparing for example classes F0, F2 and F9 the trend in hospital 1 is mainly a slight decrease or nearly steady while the number of patients in hospital 2 has been increased since 2004. However, a complete analysis of possible trends would require a much larger sample size.

A further result of our examination of the German health care system was that many correlations can be found but it is not possible to find out if it is a direct or spurious correlation. One example is the high positive correlation between the gross domestic product and the number of patients per year treated in psychiatric facilities. Sample data from years 2000 till 2006 is shown in Figure 6.

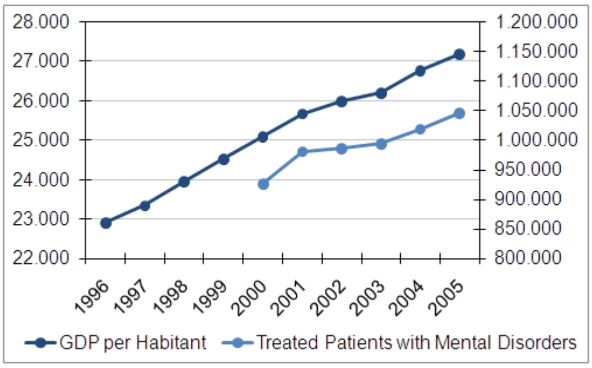

Figure 6: Gross Domestic Product and Number of Patients per Year from 2000 till 2006.

The coefficient of correlation r^2 is about 0.92. There could be either a logical connection or not. Although there are approaches trying to explain that connection directly, it cannot be proven completely. It is probable that the correlation could result from a relation to a third or more other variables having an influence both on the gross domestic product and on the number of patients with mental disorders. Second, it has to be kept in mind that the limited sample size is not a suitable basis for a reliable statistical analysis. Although information about the gross domestic product of Germany is available since 1991, information about mental health only reaches back to the year 2000 and is not yet available for the last 2 years.

5. CONSEQUENCES

While the second mentioned problem concerning correlations is a general one, the first problem is a result from the chosen system size. There are many reasons conceivable for explaining for example the previously described differences between the two German psychiatric hospitals.

First, the different frequencies of patients with disorder of class F3 and F1 may depend on the education of the attending physician or the focus and specialization of the medical facility. It is possible that hospital 1 is specialized in the treatment of mental disorders of class F3 as well as hospital 2 is specialized in the treatment of disorders of class F1. But furthermore, it is also possible that the differences result from dependencies on parameters such as demographical or economical ones.

Therefore, we decided to take a step back: Instead of building a model from the complete German mental health care system we choose to start with a part of it by analyzing the mental health care system of a small area in the middle of eastern Germany.

Regarding the previously mentioned considerations about the definition of subsystems we defined a new level of subsystems. The whole system describing the mental health care system now consists of subsystems representing different areas in Germany that can be divided again into smaller areas if necessary. These subsystems themselves include the previously defined subsystems based on the health care providers and influencing organizations.

Advantages of the chosen area are among others that there is only one psychiatric hospital belonging to our collaborating partner as do many other facilities such as a day hospital. A limited geographical size with a limited number of providers allows us to contact each provider of interest and even health insurances and regulating organizations directly and personally. That way, relevant processes and rules often being well-defined and structured but at the same time not described clearly can be cleared up, documented and finally transformed into a model.

6. SUMMARY AND OUTLOOK

The results and output values of a simulation experiment can only be as good and reliable as the input values are. When trying to model a complex system it is crucial for the success to understand the underlying processes and interdependencies between involved parameters. To be able to describe the system with the aid of a computer model logical and mathematical relationships have to be analyzed.

The main challenges of the process analysis are that

- processes and rules are often well-defined but not clearly documented
- there are processes without definitions

Thus the transparency of the system is not guaranteed and the observation is difficult.

The main challenges of the data analysis are

- collecting a suitable amount of reliable and consistent sample data
- finding correlations and identifying correlations as either direct or spurious
- developing a description of the processes covering the wide range of possible values and trends within the system

Based on our examination of the German mental health care system we came to the conclusion that, with respect to the data currently available, it would require an immense effort to build a universally valid simulation model of the system. Therefore, we chose to stop our work and repeat our examinations for a geographically smaller and bounded part of the system. There we have a suitable amount of data samples available or at least are able to collect it with smaller effort.

We now have to face the challenges again but expect to be more successful in coping with them. A smaller system resulting in a simpler model also gives the opportunity for a more exhaustive validation including reconcilements with experts about the system's processes and behavior.

Eventually, results from analyses of a smaller system and the simulation output might enable us to shift the gained information back to a model describing the overall German mental health care system.

ACKNOWLEDGMENTS

The research presented in this paper was funded by the Salus gGmbH (Magdeburg, Germany) as part of the project "Building a Simulation Model of the German Mental Health Care System". We would like to thank all contributing hospitals, physicians and organizations for their valuable input and cooperation.

APPENDIX

Appendix A

- F0 Organic, including symptomatic, mental disorders
- F1 Mental and behavioral disorders due to psychoactive substance use
- F2 Schizophrenia, schizotypal and delusional disorders
- F3 Mood (affective) disorders
- F4 Neurotic, stress-related and somatoform disorders
- F5 Behavioral syndromes associated with physiological disturbances and physical factors
- F6 Disorders of adult personality and behavior
- F7 Mental retardation
- F8 Disorders of psychological development
- F9 Behavioral and emotional disorders with onset usually occurring in childhood and adolescence

REFERENCES

Dammasch, K., Horton, G., 2007. Active Tokens for Modelling Mental Health Care with Coloured Stochastic Petri Nets. *Proceedings of the 4th International Congress on Innovations in Information Technology*. 18th-20th November 2007, Dubai, United Arab Emirates.

Dammasch, K., Horton, G., 2008. Entities with Combined Discrete-Continuous Attributes in Discrete-Event-Driven Systems. *Proceedings of the 20th European Modeling and Simulation Symposium*, 368-373, 17th-19th September 2008, Campora San Giovanni, Amantea (CS), Italy.

Medina, B.F., 1981. *Structured System Analysis: A New Technique.* New York: Gordon and Breach Science Publishers.

Reinecker, H., 2003. *Lehrbuch der Klinischen Psychologie und Psychotherapie: Modelle psychischer Störungen*. Göttingen: Hogrefe-Verlag.

Sanchez, S.M., Ogazon, T., Ferrin, D.M., Sepulveda, J.A., Ward, T.J., 2000: Emerging issues in healthcare simulation. *Proceedings of the 2000 Winter Simulation Conference*, 1999-2003. 10th-13th December 2000, Wyndham Palace Resort & Spa, Orlando, FL, USA.

Schädle-Deininger, H., 2006. *Fachpflege Psychiatrie*. München: Elsevier.

AUTHORS BIOGRAPHY

Kristina Dammasch graduated from the Otto-von-Guericke University of Magdeburg with a German University diploma in Computational Visualistics in 2006. From 2006 till 2008 she worked as research assistant at the Simulation and Modeling Group at the same university. Since 2008 she is simulation engineer at Audi and continuing her research as external PhD. Her research interests include the modeling and simulation of human attributes and hybrid modeling techniques.

Benjamin Rauch-Gebbensleben studied Computational Visualistics at the Otto-von-Guericke University of Magdeburg. He was awarded his German University diploma in 2005. From 2005 till 2006 he worked as simulation engineer in German industry. Since 2006, he is research assistant at the Group “Simulation and Modeling” at the University of Magdeburg.

Christfried Tögel studied Clinical Psychology at the Humboldt University in Berlin. He obtained his PhD in 1981 and his "Habilitation" in 1988, both in the field of psychology at the Humboldt University. In 1988 he became associate Professor and in 1994 Professor at the Department of History and Philosophy of Science at the Bulgarian Academy of Science. After different engagements from Sofia over Vienna and London he became the director of the Salus Institute for Trend Research and Therapy Evaluation in Mental Health (Magdeburg, Germany) in 2004.

Graham Horton is Professor for Simulation and Modeling at the Computer Science Department of the University of Magdeburg since 2001. He studied Computer Science at the University of Erlangen, graduating in 1989 with a German University diploma in Computer Science. He obtained his PhD in Computer Science in 1991 and his “Habilitation“ in 1998 at the same university in the field of simulation.