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INTERACTIVE GAMING AS A SUPPORT FOR SYSTEM DYNAMICS LEARNING WITH THE USE OF VENSIM

Summary. This article presents the process of learning with the use of interactive gaming described on “Accidental Adversaries” archetype model, thus providing a new method of research than can be conducted on vast number of SD models. Authors selected an already well researched archetype to show a different approach in the process of model optimization. This gives the opportunity to share the knowledge about the possibilities of practical application of interactive gaming.

INTERAKTYWNE GRY PROGRAMU VENSIM JAKO WSPARCIE PROCESU UCZENIA SIĘ W DYNAMICE SYSTEMOWEJ

Streszczenie. W artykule opisano proces uczenia się z wykorzystaniem interaktywnych gier przedstawiony na archetypie „Przypadkowi przeciwnicy”, pokazując w ten sposób nową metodę badania, która może być zastosowana w ogromnej liczbie modeli dynamiki systemowej. Autorzy wybrali dokładnie zbadany i opisany w literaturze archetyp, aby zilustrować nowe podejście do procesu optymalizacji modelu. Przykład prezentuje nowe możliwości praktycznego zastosowania interaktywnych gier symulacyjnych.

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1. Introduction

System Dynamics (see: [1–28,30,31]) was developed in the late 1950s and early 1960s at the Massachusetts Institute of Technology Sloan School of Management by Jay W. Forrester. This approach can be applied to dynamics problems arising in complex social, managerial, economic or ecological system. The main purpose of System Dynamics is an attempt to discover the structure that conditions the observed behavior of the system over time. System Dynamics tries to pose dynamic hypotheses hat endogenously describe the observed behavior of system. Many authors have undertaken the proper principles formulation problem for successful use of System Dynamics. Let's summarize the main of them:

- Development of a model solving a particular problem, not to imitate the whole system (looking for a solution to the problem of someone concern is the clear purpose of research. Modelers must exclude all factors not relevant to the problem to ensure the projects scope is feasible and the results timely. The goal is to improve the performance of the system as defined by the client. Focus on results.);

- System Dynamics does not stand alone. Use other tools and methods as appropriate (most modeling projects are part of a longer effort involving traditional strategic and operational analysis, including benchmarking, statistical work, market research, etc. Effective modeling rests on a strong base of data and understanding of the issue. Modeling works best as a complement to other tools, not as substitute);

- Focus on implementation from the start of the project (Implementation must start on the first day of the project. How will model help the client make decisions?);

- Validation is a continuous process of testing and building confidence in the model (Client and modelers build confidence in the utility of a model gradually, by constantly confronting the model with data and expert opinion their own and others! Thought this process both model and expert opinion will change and deepen. Seek out opportunities to challenge the models ability to replicate a diverse range of historical experiences);

- A broad model boundary is more important than a great deal of detail (Model must strike a balance between a useful, operational representation of the structure and policy levers available to the clients while capturing the feedbacks generally unaccounted for in their useful models);

- Implementation does not end with a single project (Models and management flight simulators are applied to simulator issue in other settings. The modelers develop expertise they applied to related problems and client moved into new position and new organization, taking the insight they gained and, sometimes, a new way of thinking, with them. Implementation is a long-term process of personal, organizational and social change).

Like prof. Sterman said (see: [29–31]): there is no cookbook recipe for successful modeling, no procedure you can follow to guarantee a useful model. Modeling is inherently creative. Individual modelers have different styles and approaches. Yet all successful modelers follow a disciplined process that involves the following activity:

1) Articulating the problem to be addressed.

2) Formulating a hypothesis or theory about the causes of the problem.

3) Formulating a simulation model to test the dynamic hypothesis.

4) Testing the model until you are satisfied, it is suitable for your purpose.

5) Designing and evaluating policies for implementation.

After that introduction in the next paragraph the authors are intending to formulate some remarks about knowledge management and relationships between: user – computer – model – real world.

2. Some remarks about the knowledge management relationships between: user – computer – model – real world

On Figure 1 we can see the relationships between: user – computer – model – real world, from the Vensim possibilities perspective. Let's pay attention on some of these relationships. The realization of sophisticated experiments type simulation – optimization – game, gives opportunity to choose optimal decision or estimate parameters (calibration). The helpful tool in this activities can be so called "system archetypes".

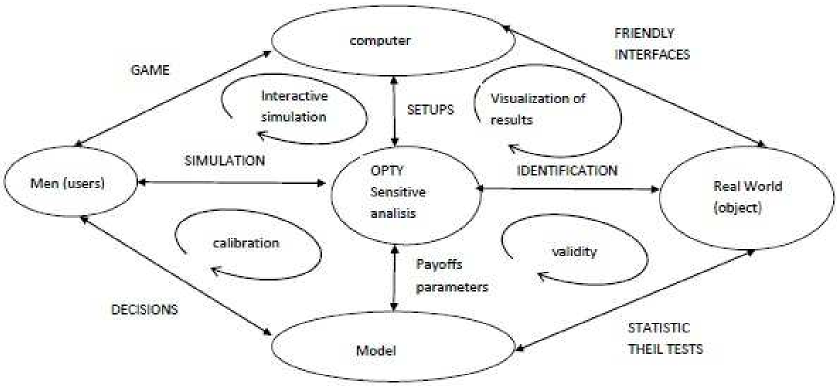

Fig. 1. Knowledge Management relationships between: user – computer – real world (from Vensim possibilities perspective, source: own idea)
Rys. 1. Schemat relacji w zarządzaniu wiedzą pomiędzy: użytkownikiem – komputerem – światem realnym (z perspektywy możliwości programu Vensim, źródło: opracowanie własne)

Authors paid attention on archetypes in papers [18, 19, 22, 26]. We can notice that mathematical relations can be visualized in so called casual – loop diagrams. One of such graphical form of archetype is presented on Figure 2 (Vensim tools are also applied in this presentation).

It looks rather complicated, but using graphical capabilities of Vensim is not so difficult like it seems, even in case of complex large scale models with many equation, parameters and inputs. Making use of such graphical expressions during communication of: model builders, users, informatics, management staffs, is very important taking into consideration the sharing of knowledge between participants of whole process of model building, simulation and implementation. Teaching of using such "toys", like arrows, icons, etc., takes few hours and is rather pleasant and attractive and worth the trouble. One of the key options highlighted in black rectangle on Figure 2 is named "Game". One of the internet definitions describes gaming as "an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context". In Vensim convention interactive gaming is a way of actively engaging in the progress of a simulation – it's an example of the "flight simulator" approach, where the user participates in decisions that affect the simulation outcome for each step in time. A Vensim simulation model can be run as a game by stepping through time and making changes to gaming variables along the way. In contrast, a normal simulation model runs through the complete time span based on the initial setup of the model. Such approach helps in finding different regularities in the behavior of many models, thus accelerating the process of learning described in next paragraph.

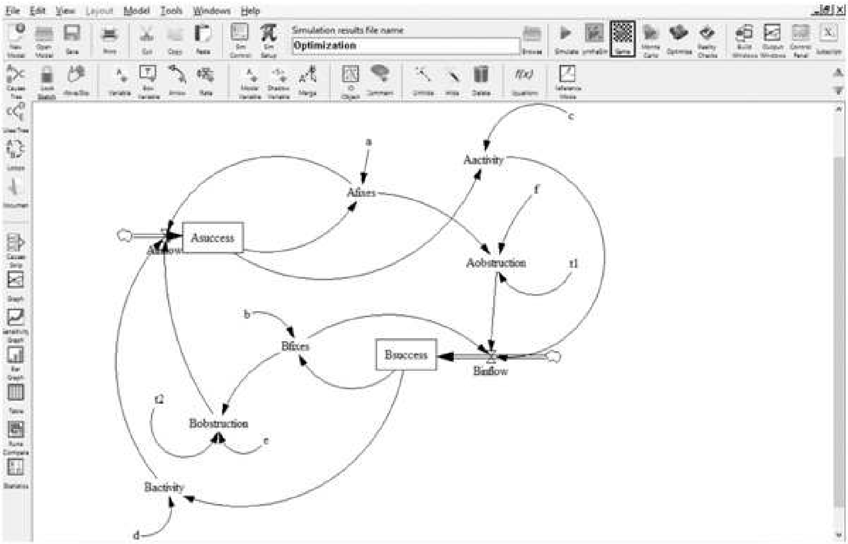

Fig. 2. Visualization of relation between objects in simplified "Accidental Adversaries" archetype model by Vensim (source: own results on base of [20])

Rys. 2. Wizualizacja relacji pomiędzy obiektami w uproszczonym archetypie „Przypadkowi przeciwnicy" w programie Vensim (źródło: opracowanie własne na podstawie [20])

3. The process of learning with the use of interactive gaming described on "Accidental Adversaries" archetype model

Firstly we must understand the concept of our model, which is thoroughly described in [20]. Briefly – there are two persons A and B, both want to succeed making own decisions (represented by parameters from a to f) and have appropriate success values, but each decision they make has an impact on themselves correspondingly. Figure 3 shows the outcome of basic simulation (A and B don't work together – they make independent decisions realized in parameter values listed below figure).

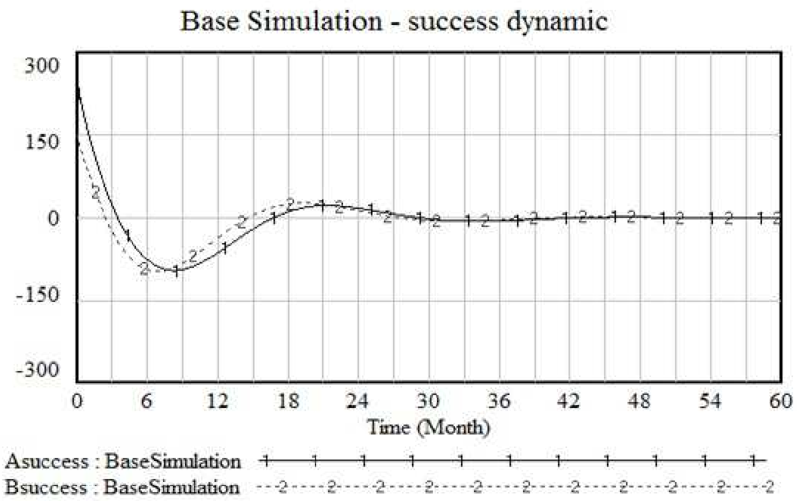

Fig. 3. Simulation for "Accidental Adversaries" archetype model in Vensim (source: own idea)

Rys. 3. Bazowa symulacja działania archetypu „Przypadkowi przeciwnicy" w programie Vensim (źródło: opracowanie własne)

List of model parameters and inflow mathematical descriptions:

- a = 0,4,
- b = 0,4,
- c = 0,2,
- d = 0,2,
- e = 0,6,
- f = 0,6,
- t1 = 5,
- t2 = 10,
- Asuccess(0) = 250,
- Bsuccess(0) = 150,
- Ainflow(t) = -Afixes(t) + Bactivity(t) - Bobstruction(t),
- Binflow(t) = -Bfixes(t) + Aactivity(t) - Aobstruction(t).

As we can see both A and B became adversaries to each other resulting in terrible losses. Now let us pose a question: how improve operating of any model (in our case "Accidental Adversaries" archetype model) by proper changes in parameter values that represent pivotal decisions (undertaken by A and B)? To answer the question we used interactive gaming provided by Vensim. From the inflow mathematical descriptions presented above we can assume that better results can be achieved by minimizing parameters corresponding with A, Bfixes and A,Bobstruction and subsequently by maximizing A,Bactivity. Utilizing the game mechanism built in Vensim we performed a simulation experiment by changing some parameters every 10 month time period (parameter changes are presented in table below). Figure 4 shows the influence of those changes.

Table 1
Parameter changes in time during interactive gaming in Vensim
(source: own idea)

Time (Months)	a	b	c	D
Base value	0,4	0,4	0,2	0,2
0 – 10	0,3	0,3	0,2	0,2
10 – 20	0,2	0,2	0,2	0,2
20 – 30	0,1	0,1	0,2	0,2
30 – 40	0,1	0,1	0,3	0,3
40 – 50	0,1	0,1	0,4	0,4
50 – 60	0,1	0,1	0,5	0,5

As we can observe after initial losses A,Bsuccess increased to very high values (the graph shows changes to max time 50 months because values in time 60 months were too high to be shown – over 39.000). This experiment confirmed our suspicions on how to improve success level for both A and B person. The way we achieved that goal through interactive gaming is one of the possible answers to the posed question. For final and conclusive proof let's perform an optimization using another Vensim tool. First we specify the parameter values that we want to maximize then the parameters that must be optimized (Figure 5).

The outcome of optimization process is shown on Figure 6.

As we expected the best result is achieved when values a and b are close or equal to zero, values c and d are equal one.

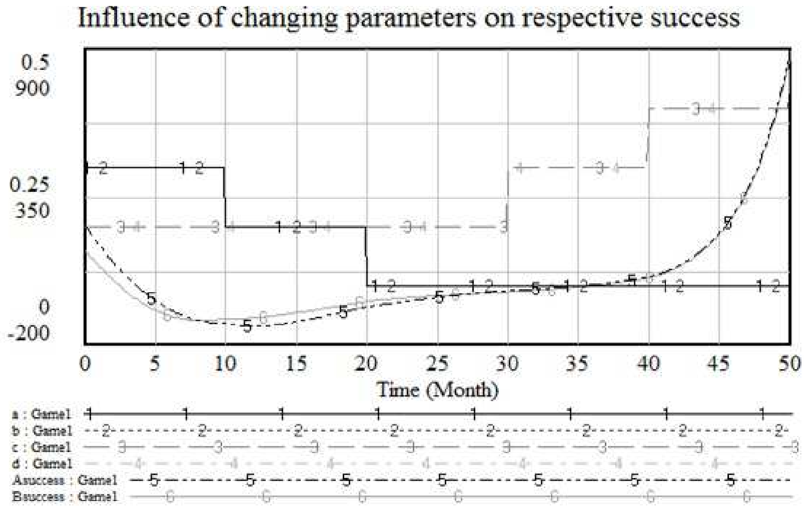

Fig. 4. Graph representing the influence of parameter changes in "Accidental Adversaries" archetype model (source: own idea)

Rys. 4. Wykres prezentujący wpływ zmian wartości parametrów w archetypie „Przypadkowi przeciwnicy" (źródło: opracowanie własne)

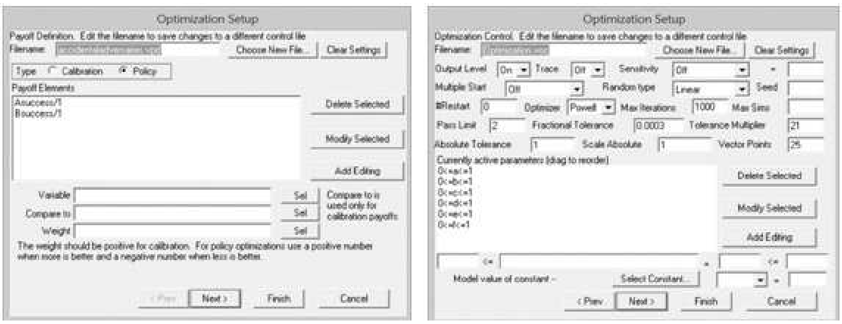

Fig. 5. Simulation for "Accidental Adversaries" archetype model in Vensim (source: own idea)

Rys. 5. Wybór parametrów do optymalnej symulacji archetypu „Przypadkowi przeciwnicy" w programie Vensim (źródło: opracowanie własne)

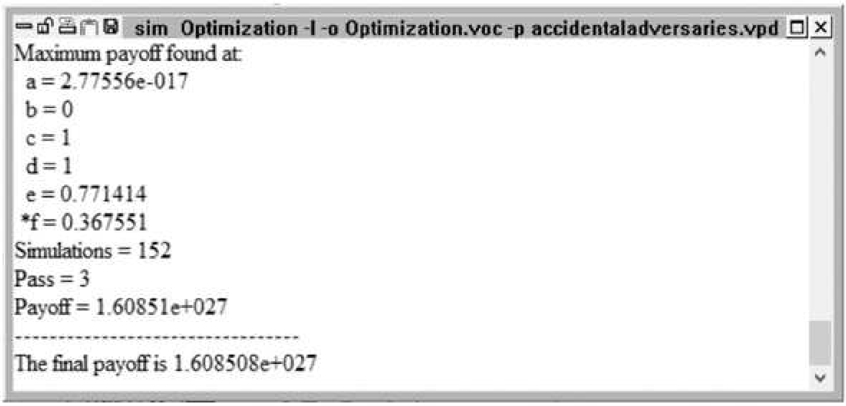

Fig. 6. Optimization result by Vensim (source: own idea)

Rys. 6. Wynik optymalizacji przeprowadzonej w programie Vensim (źródło: opracowanie własne)

4. Conclusions

The aim of this paper was to show and express some remarks about interactive gaming and its supportive role for learning with the use of Vensim. The vast number of real life systems, modelled according to System Dynamics convention, can be thoroughly examined by using gaming functionality. Obviously we can't forget about other functionalities like sensitivity analysis, but taking advantage of gaming tools generally gives us preliminary analysis in the considered model. Knowledge gained in that process help us find a solution, thus providing invaluable help in a scientific research.

References

1. Coyle R.G.: *Management System Dynamics.* John Wiley & Sons, New York 1977.
2. Coyle R.G.: *Cosmic and Cosmos. User Manuals.* The Ccosmic Holding Co. 1994.
3. Coyle R.G.: *System Dynamics Modeling. A Practical Approach.* Chapman & Hall, London 1996.

4. Coyle R.G.: *The practice System Dynamics: milestones, lessons and ideas from 30 years experience.* System Dynamics Rev. **14**, no. 4 (1998), 343–365.
5. Coyle R.G.: *Simulation by repeated optimization.* J. Oper. Res. Soc **50** (1999), 429–438.
6. Coyle R.G., Exelby D.: *The validation of commercial System Dynamics models.* System Dynamics Rev. **16** (2000), 27–41.
7. Forrester J.W.: *Industrial Dynamics.* MIT Press, Massachusetts 1961.
8. Forrester J.W.: *Urban Dynamics.* MIT Press, Massachusetts 1969.
9. Forrester J.W.: *World Dynamics.* Wright – Allen Press, Massachusetts 1971.
10. Forrester J.W.: *Principles of Systems.* Cambridge Press, Massachusetts 1972.
11. Forrester J.W.: *Collected Papers of Joy W. Forrester.* Cambridge Press, Massachusetts 1975.
12. Forrester J.W.: *Economy theory for the New Millennium.* Proc. **21**st Int. Conf. System Dynamics Society, P.I. Davidsen, E. Mollona, U.G. Dicker, R.S. Langer, J.I. Rowe (eds.), System Dynamics Society, New York 2003, 1–27.
13. Kasperska E.: *System dynamics method and supporting decisions in economic organization.* Proc. 7th Int. Conf. of Int. Society for Decision Support Systems. DSS in the Uncertainty of the Internet Age. T. Bui, H. Sroka, S. Stanek, J. Gołuchowski, eds., University of Economic Katowice, Katowice 2003.
14. Kasperska E.: *Hybrid models on the base of system dynamics – some simulation and optimization aspects.* Second Int. Conf. Applied Mathematics, D. Bainow, S. Nenov (eds.), SICAM, Plovdiv 2005, 122–123.
15. Kasperska E.: *Modeling embedded in learning the acceleration of learning by the use of the hybrid models on the base of System Dynamics paradigm.* Systemy Wspomagania Organizacji, T. Porębska-Miąc, H. Sroka (eds.), Wyd. Uniwersytetu Ekonomicznego, Katowice 2005.
16. Kasperska E.: *Metodologia budowy i wykorzystania modeli ewolucyjnych w aspekcie uczenia się (w) organizacji społeczno-gospodarczej.* Wyd. Politechniki Śląskiej, Gliwice 2009.
17. Kasperska E., Kasperski A., Bajon T., Marjasz R.: *Visualization for learning in organization based on the possibilities of Vensim.* Proc. KM Conference 2014, International Institute for Applied Knowledge Management, Blagoevgrad 2014, 21–34.
18. Kasperska E., Kasperski A., Mateja-Losa E.: *Sensitivity analysis and optimization on some models of archetypes using Vensim – theoretical issue.* Cognition and Creativity Support System **153** (2013), 33–52.

19. Kasperska E., Kasperski A., Mateja-Losa E.: *Sensitivity analysis and optimization on some models of archetypes using Vensim – experimental issue.* Cognition and Creativity Support System **153** (2013), 53–82.
20. Kasperska E., Mateja-Losa E.: *Archetyp „przypadkowi przeciwnicy" – symulacja i optymalizacja.* Pr. Nauk. Inst. Org. Zarz. Pol. Wrocławskiej **80** (2005), 181–188.
21. Kasperska E., Mateja-Losa E.: *Simulation embedded in optimization – a key for the effective learning process in (about) complex, dynamical systems.* Lect. Notes Comput. Sc. **3516** (2005), 1040–1043.
22. Kasperska E., Mateja-Losa E.: *Extended sensitivity analysis of parameters and structure in system dynamics models – some case study.* Proc. 24th Int. Conf. System Dynamics Society, A. Grossler, et al. (eds.), System Dynamics Society, New York 2006.
23. Kasperska E., Mateja-Losa E.: *Analiza wrażliwości przy użyciu języka symulacyjnego Vensim, jako element rozwoju wiedzy o źródłach dynamiki złożonego nieliniowego systemu (na przykładzie archetypu „Tragedia użytkowania").* Technologie i systemy informatyczne w organizacjach gospodarki opartej na wiedzy, E. Ziemba (ed.), Wyd. Wyższej Szkoły Bankowej, Poznań 2008, 281–289.
24. Kasperska E., Mateja-Losa E., Bajon T., Marjasz R.: *"Did Napoleon have to lose the Waterloo Battle?" – some sensitivity analysis and optimization experiments using simulation by Vensim.* Ambient Technology and Creativity Support Systems, M. Pańkowska, J. Palonka, H. Sroka (eds.), Wyd. Uniwersytetu Ekonomicznego, Katowice 2014, 97–118.
25. Kasperska E., Mateja-Losa E., Marjasz R.: *Sensitivity analysis and optimization for selected supply chain management issues in the company – using system dynamics and Vensim.* J. Entrepreneurship Management and Innovation **9**, no. 2 (2013), 29–44.
26. Kasperska E., Słota D.: *Optimization embedded in simulation on models type system dynamics – some case study.* Lect. Notes Comput. Sc. **3514** (2005), 837–842
27. Kasperska E., Słota D.: *Parallel dual problem of optimization embedded in some model type system dynamics.* Proc. 24th Int. Conf. System Dynamics Society, A. Grossler, et al. (eds.), System Dynamics Society, New York 2006.
28. Marjasz R.: *Wspomaganie logistyki produkcji w firmie z użyciem narzędzi symulacyjnych.* Systemy wspomagania organizacji, SWO 2014, T. Porębska-

Miąc, H. Sroka (eds.), Wyd. Uniwersytetu Ekonomicznego, Katowice 2014, 58–70.

29. Rahmandad M., Sterman J.D.: (2013). *Reporting guidelines for simulation – based research in social sciences*. System Dynamics Rev. **28**, no. 4 (2013), 396–411.
30. Sterman J.D.: *Business Dynamics – System Thinking and Modeling for a Complex World*. Mc Graw-Hill, Boston 2000.
31. Sterman J.D.: *All models are wrong: reflections on becoming a system scientist*. System Dynamics Rev. **18**, no. 4 (2002), 501–531.
32. Ventana Systems Inc.: *Vensim User'S Guide Version 5*. Ventana Simulation Environment 2002.
33. Ventana Systems Inc.: *Vensim Version 6.1*. Ventana Simulation Environment 2013.