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AGENT BASED MODEL OF YOUNG RESEARCHERS IN HIGHER EDUCATION INSTITUTIONS

Josip Stepanić[1,] *, Mirjana Pejić Bach[2] and Josip Kasać[1]

[1]Faculty of Mechanical Engineering and Naval Architecture – University of Zagreb
Zagreb, Croatia

[2]Faculty of Economics and Business – University of Zagreb
Zagreb, Croatia

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ABSTRACT

Group of young researchers in higher education institutions in general perform demandable tasks with relatively high contribution to institutions' and societies' innovation production. In order to analyse in more details interaction among young researchers and diverse institutions in society, we aim toward developing the numerical simulation, agent-based model.

This article presents foundations of the model, preliminary results of its simulation along with perspectives of its further development and improvements.

KEY WORDS

young researchers, innovation, higher education institutions, HEI, universities

CLASSIFICATION

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*Corresponding author, η: josip.j.stepanic@fsb.hr; +385 1 6168592;
FSB, I. Lučića 1, HR – 10 000 Zagreb, Croatia

INTRODUCTION

The meaning of the universities in contemporary culture and in forming of fundaments of our civilisation, can hardly be overestimated. Since their importance continues, it is of interest to analyse processes underlying universities' dynamics. As a result, one may expect deepening the cause-consequence relationship among mutually interconnected processes, maximising the efficiency of the processes, along with the preservance of leading role that universities have in development of science, humanities and arts and shaping of our culture. In that sense, in triple helix approach, universities, government and industry are three elements of a system that is important for science and technology development in society. In other approaches, universities are considered responsible for the substantial part of innovations in science and technology, research and development, and overall they are the means for latency and development of scientific thought and values. Within a broader frame, universities should constantly adapt themselves [5, 6, 7] within the contemporary knowledge-based society [8, 9].

However, two general characteristics of university' dynamics prevent straightforward fulfilment of augmenting its efficiency and our understanding of it. First, being part of a social system the universities are unique, here in the strict sense of non-repeatability of their current state. While one may argue about repeating trends, about similarity of processes occurring in different countries and regions thus in different universities, such cases are completely separated from the notion of purposefully repeatable scientific experiment, one of the cornerstones of developing, testing and demonstrating the understanding of a system. Secondly, processes occurring in universities generally are manifestations of the complex system-character that is generally considered to be of a much slower dynamics than e.g. the dynamics of companies. In that sense even if some change, e.g. a newly formulated measure, is introduced experimentally in some part of a university, clear manifestation of its consequences will develop gradually. Usually the accompanied time scale is too long to utilise such an approach in defining university policy and predicting university dynamics. One may argue that methods such as *in silico* simulations, in particular the simulation modelling, overcome deficiencies presented by stated two characteristics.

Simulation modelling is a powerful means for deepening understanding of a simulated system. In particular, it makes possible both the virtual shortening of the time scale, and the repeatability of a modelled system. However, it introduces different problems, such as is a problem to formulate reliable model. Reliability of the model is demonstrated through its validation, so in short, uniqueness and slowness of the realistic system is exchanged for questionable validation of its model.

Stated characteristic of universities considered in total are manifest when its parts are considered. For example, young researchers in a university form a group that is unique, the dynamics of which develops slowly, yet who are important for the overall contribution to the mass of innovations that universities provide the society with [3, 4]. Here by young researchers we consider novices to universities which work toward obtaining their Ph.D. thesis. Before proceeding, let us emphasise the meaning of the slow dynamics of the group of young researchers, the slowness that may seem as an oxymoron having in mind the large number of professional requirements that young researchers have to fulfil during rather short time-period. The slowness refers to the set of norms, values, rules, laws and customs of the young researchers' professional life, since these are the defining frames of their work and in overall of their contribution to the universities' function in the society. These norms change rather gradually, and are usually unchanged during processing of several generations of young researchers in a given university.

The important contribution of the group of young researchers onto the overall innovation content of universities, as well as the importance of the status of young researchers onto the future carriers of all university lecturers and a lot of experts, point to the importance of developing the validated, thus reliable, simulation model for analysing their dynamics.

Such a model would clarify relative importance and interconnectedness, processes that are regularly encountered in complex systems, of a variety of observed processes. Moreover, the model could enable interested parties, such as government, university administration etc. to predict the consequences of possibly implemented changes in university policy, in a more reliable and complete way than today.

Having in mind the stated importance of the group of a university' young researchers, it came as a surprise to us that we were unable to find a lot of already conducted simulation modelling approaches to it. To the best of our knowledge, modelling related to universities presumably covered other segments, sometimes tackled or implicitly assumed young researchers, but did not put the focus onto it. To emphasise that point, since prevalent number of university lecturers are researchers, it is interesting to note that these researchers have extensively researched a myriad of topics but not themselves.

In this article we present basic considerations of an agent-based model of the group of university's young researchers, discuss its elements, analyse its preliminary results and present the near-future perspective of its further development.

Second section of this article defines the building elements of the model, third section presents preliminary results of simulations ran, while the fourth section concludes the article with analyse of its perspective.

ELEMENTS OF THE MODEL

Modelling in the context of this article means abstraction of reality which brings about formal prescription of conceptualisation, assumptions and conditions. It is a simplified representation of an extracted part. Simulation modelling is a modelling for observing (i.e. running) the model dynamics, and is prevalently numerical. Agent based modelling (ABM) is a particular kind of simulation modelling in which actions and interactions of autonomous agents are analysed [11, 12]. It has prescribed micro-level, linked by numerical simulation with observables at macro-level. While it is always of importance to bridge the micro-macro gap, in many occasions it would be more useful to reveal micro-level from observed macro-level than the other way around. However, in practice it is exactly that other way around in that one must prescribe micro-level and subsequently, through simulation modelling, obtain the macro-level. Thus, finding micro-level causes of previously observed macro-level dynamics is by no means simple, since it is in practice many times time consumable trial and error approach.

Let us summarise main characteristics of an agent based model. It consists of the agents, environment and rules. An agent is a software entity which interacts within virtual environment. Environment is a collection of data which are not about agents but are necessary for unique agent dynamics. An extracted part of environment, which agents collect part of the time, is called the resource. Rules are statements which relate states of agents and environment in different time units. There are agent-environment and agent-agent interactions.

In our model, an agent corresponds to individual young researcher. The environment corresponds to their affiliation and a broader society. Rules refer to activities at work and private activities of young researchers. Rules in realistic systems are realised either through their adoption by an individual or by other societal institutions. In particular regarding young researchers, much of the rules governing their work are implemented by actions of young researchers' supervisors. The supervisors are prevalently senior researchers from universities, such as are professors. Their individualities and methodologies represented influence the overall level of young researchers' achievements and a lot of research has been conducted in order to try to extract the effective corresponding supervision strategies [1] since the young researcher-supervisor relationship has the potential to be wonderfully enriching and productive, but it can also be extremely difficult and personally devastating [2]. In this model we aggregate the individualities of supervisors, and treat them implicitly as an unspecified source of rules. In that way, our approach resembles approaches originating in diverse contexts such as are mean field approach in theoretical physics or Lewin's force field approach and is insensitive to issues such as is (de)centralisation [10].

Young researchers are complete personalities, of unique characteristics in a number of dimensions. The model set includes young researchers' achievements and corresponding changes, in the following dimensions: scientific (to be denoted by index *s*), educational (denoted by index *e*) and additional (denoted by index *a*). The additional dimension includes popularisation, professional and private activities.

Change of scientific achievement s is denoted as Δs. It is determined for a given time unit Δt as:

$$\Delta s = \eta_s r_s \Delta t, \tag{1}$$

where η_s is normalised amount of a change and r_s the probability of its realisation. As a representative time unit we chose $\Delta t = 1$ month. Similar equations are valid for achievements in the educational and additional dimensions. Before proceeding let us emphasise that η_s combines all the influences onto young researchers from environment, along with the efficiency of transforming these influences into experience, knowledge, skills and motivation change. All these changes in general manifest themselves in changes of the model's parameters. Therefore, in subsequent text we will refer to η as to efficiency.

Further assumption in the model is that young researchers constantly aim to rise their achievements maximally, and that overall time span of the simulation is rather small in that health, private and other behavioural characteristics of young researchers can be considered as constant, not influencing their total efficiency. Thus one has

$$\eta_s + \eta_e + \eta_a = 1 \tag{2}$$

The efficiency η is modelled as follows

$$\eta_s = f(s,e,a)\frac{1}{2}\left(1 + \frac{n}{1+n}\right), \tag{3}$$

in which $f(s, e, a)$ is a function which asymptotically normalises efficiency and n is a randomly generated variable. Function $f(\cdot, \cdot, \cdot)$ is a measure of accumulation of achievements and is taken as strictly monotonically growing in time. It is modelled as a linear function of achievements

$$f(s,e,a) = c_0 + c_1(s+e+a), \tag{4}$$

in which $c_{0,1}$ are constant coefficients of linear growth. In expression (3), number 1 in parenthesis refers to periodic contribution to efficiency which is supposed to have period of one week. Since that periodic contribution is written after averaging during 1 month time unit, it turns into a constant. The other part of parentheses in (3) is aperiodic change in efficiency, the reasons for which are out of the scope of this model. Thus it is intuitively modelled as a smooth, finite function of one, random variable n. Variable n has the following probability density function $p(n)$

$$p(n) = \frac{\lambda^n}{n!}\mathrm{e}^{-\lambda}, \tag{5}$$

which is a Poisson distribution with expectation λ. Expectation λ is considered to be one order of the magnitude smaller than 1, so that prevalently during simulation, a value of the parentheses in (3) is 1, or 2. This accounts for the fact that in case of approaching deadline for a project, etc. efforts for achieving predicted results enlarges. In particular, in our model we took $\lambda = 1/6$ which accounts for average one deadline during half a year. Naturally, that does not exclude larger values of parentheses in (3), but makes them considerably rarer than values 0 and 1. Before proceeding, let us note that parentheses in (3) are not normalised so factor 1/2 accounts for normalising the periodic and aperiodic parts in (4).

Initial conditions are that all achievements all the young researchers are of equal value. While that is an artificial assumption, its transformation into equilibrated or stationary values makes possible inference about the time unit of propagating of the disturbances in the model.

Boundary conditions are that environment conditions are constant. That is implicitly included in the constant values of all coefficients introduced, i.e. of $c_{0,1}$ and λ. Moreover, agents are generated in every time unit during simulation in a constant number. Achievements of the agents range from 0 to 100. Within that interval all changes are considered quantitative, i.e. number of agents is constant and only their achievements change. After reaching value of 100 for any of the achievements, the qualitative change occurs in that the agent leaves the considered group, reflecting the fact that young researchers eventually change their status. That leaving the group has different meanings depending on the dimensions the achievement of which reached the value 100. We consider that scientific achievement equal 100 means promotion of a young researcher into the teacher status. Professional achievement equal 100 means transfer of a young researcher from a university into other social structures such as industry. Finally, additional achievement equal 100 means that corresponding young researcher started to work in non-scientific education institutions or other similar institutions such as are school or colleges.

RESULTS AND DISCUSSION

Simulations were conducted for initial number of 500 agents, with 15 new agents introduced in the model in every subsequent time unit. All agents had the initial scientific achievement equal to 20, initial educational achievement equal to 5 and additional achievement equal to 15. Parameters of the model were $r_\mathrm{s} = 0{,}031$, $r_\mathrm{e} = r_\mathrm{a} = 0{,}026$, $c_0 = 0{,}125$, $c_1 = 0{,}1$ and $\lambda = 0{,}17$. Simulations were run during interval 240 time units, which corresponds to 12 years.

Based on the curves in Fig. 1, one may argue about the two different processes. First process or set of processes includes rapid change of achievements which is caused by equilibration of the initial distribution of achievements among agents. It is approximated to stop around 80th time unit. In that sense, in this model it is to be expected that consequences of a sudden change within a part of the system be equilibrated in approximately 60 months – 5 years. For the rest of the dynamics of distributions, one may argue that underlying processes are well balanced. All stated is applicable to results in Fig. 2: number of agents achieves stationary value after approximately 60 months, as a consequence of balanced number of agents entering and exiting the system. Note that stationary total number of young researchers in the system is consequence of the model set, in particular a consequence of the presumption that every agent, who achieves amount of 100 in any of dimensions, automatically is either promoted or transferred to other groups out of the modelled one.

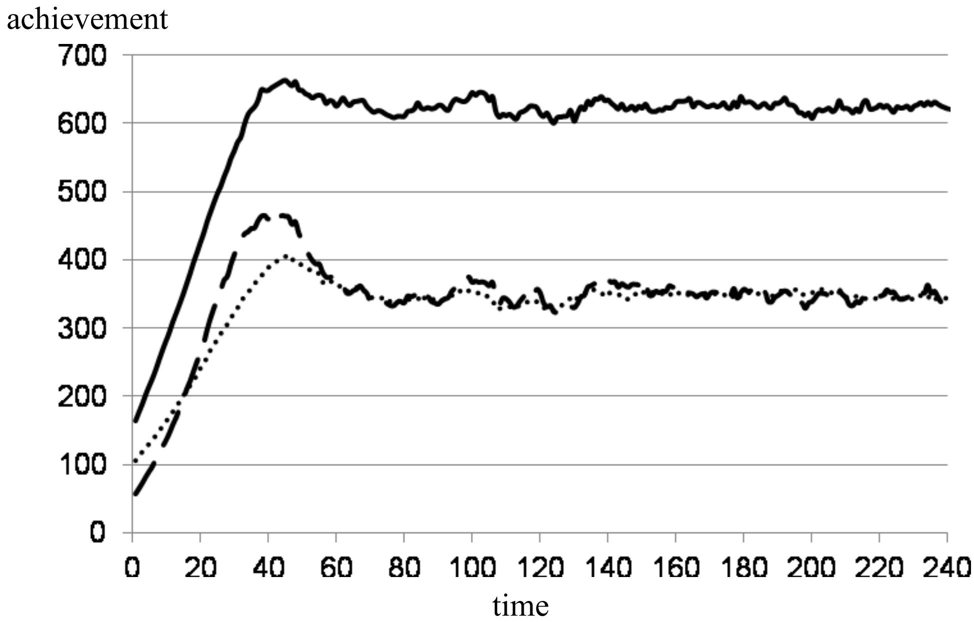

Figure 1. Average achievements as function of time. Solid line – scientific achievements, dashed line – educational achievements and dotted line – additional achievements.

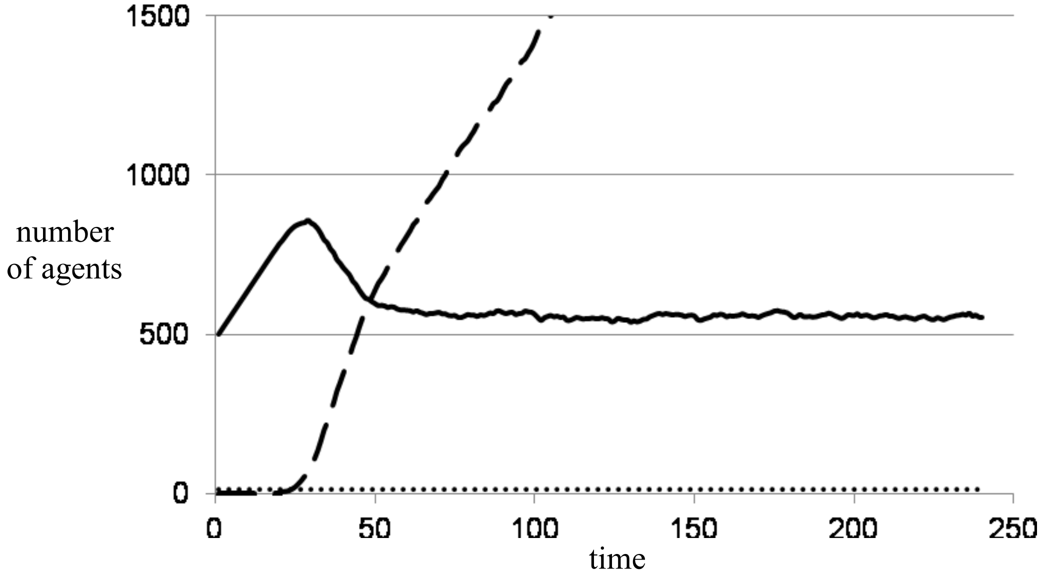

Figure 2. Number of young researchers as function of time. Solid line – total number of agents in a given time interval, dashed line – total number of agents who left their group and dotted line– total number of agents who were not initially in the group but were introduced during the simulation. Note the different character of quantities shown: agents who left the group are shown as cumulative quantity, while for other two groups of agents their changes in a given time unit are shown.

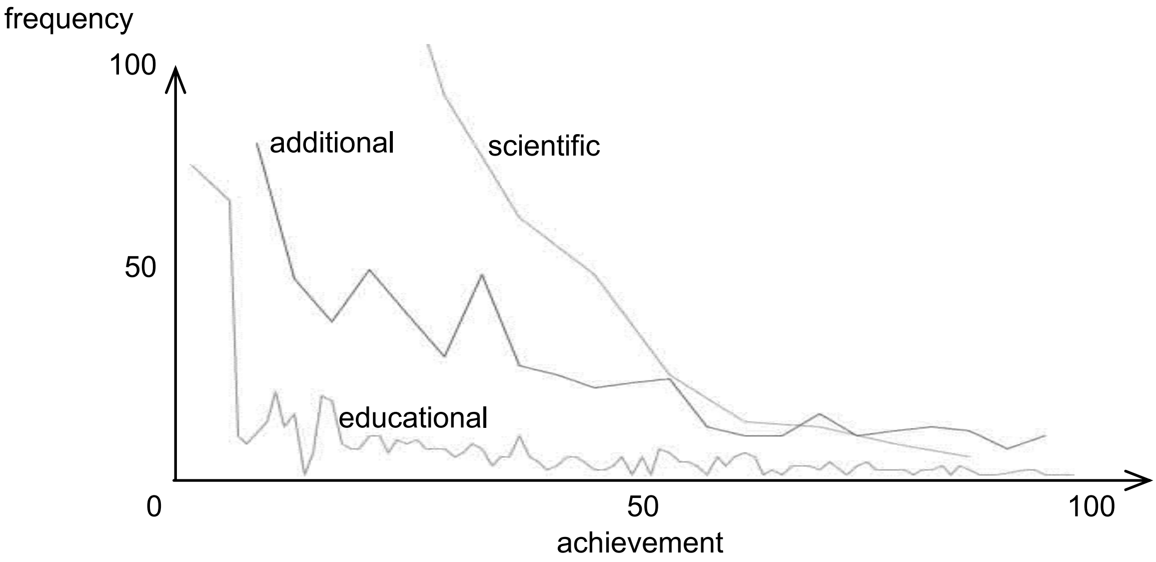

Figure 3. Typical distributions of achievements among agents at the end of simulation.

CONCLUSIONS AND PERSPECTIVES

The model presented is conceptually partially developed and partially implemented. The perspective is to simulate dynamics of more than one group (e.g. teachers, ...), cooperation of agents (both the cooperation solely among young researchers and the cooperation among different groups implemented). Indicators of achievement should be implemented in more details, e.g. differentiate amount of achievements brought about by published journal article, presentation held as a conference, doctoral study exams passed, etc. There are other assumptions of the model that will have to be changed in order to make the model more realistic. One of these is the assumption that young researchers automatically change their status after achieving 100 in any of dimensions. Realistically, promotions can be delayed, or impossible despite fulfilment of necessary conditions. Similarly, because for majority of young researchers it is to be expected that promotion it the most desired outcome, delaying of the status change can be caused either by the system or by the very young researcher considered.

We did not tackle the important question of how to measure some quantity relevant to the model. In addition, model should be validated.

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SIMULACIJSKI MODEL SKUPA ZNANSTVENIH NOVAKA NA INSTITUCIJAMA VISOKOG OBRAZOVANJA TEMELJEN NA AGENTIMA

J. Stepanić[1], M. Pejić Bach[2] i J. Kasać[1]

[1]Sveučilište u Zagrebu – Fakultet strojarstva i brodogradnje
Zagreb, Hrvatska

[2]Sveučilište u Zagrebu – Ekonomski fakultet
Zagreb, Hrvatska

SAŽETAK

Mlađi istraživači u visokoškolskim institucijama općenito provode zahtjevne zadatke koji u znatnoj mjeri doprinose produkciji inovacija u institucijama i društvu. Kako bismo analizirali potankosti međudjelovanja mlađih istraživača i različitih institucija u društvu razvijamo model utemeljen na agentima za numeričku simulaciju.

Rad sadrži opis temelja modela, preliminarne rezultate simulacije i perspektive njegovog daljnjeg razvoja i unaprijeđivanja.

KLJUČNE RIJEČI

znanstveni novaci, inovacije, visokoškolske institucije, HEI, sveučilišta