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The Development of Cellular Automata-based Entrepreneurial Growth Simulator

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***Abstract*— Entrepreneurship plays an essential role in the economic growth of a country. These roles include creating jobs, reducing unemployment, increasing people's income, combining production factors (nature, labor, capital, and expertise), and increasing national productivity. For the economy to thrive and healthy, it requires at least 4% of the population who work as entrepreneurs. Due to this vital role, entrepreneurial growth must be maintained. One of the efforts to do this is by monitoring growth directly and continuously. Besides that, another way is to do a simulation. By knowing the condition of entrepreneurship at one time and all the factors that affect entrepreneurial growth, simulations can be carried out to determine or predict future conditions. Based on this simulation, essential steps can be taken, or policies can be made to maintain profitable entrepreneurial growth. This paper presents a mathematical model that can simulate and visualize entrepreneurship's growth in six provinces of Sumatra Island, Indonesia. This mathematical model uses cellular automata as its basis and is called Entrepreneurial Cellular Automata (ECA). One of the advantages of Cellular Automata is that it is easy to visualize. The entrepreneurial model used as a reference is a model from the Global Entrepreneurship Monitoring (GEM). This mathematical model has been implemented in a simulator program. This paper describes the simulator development and the use of simulator to simulate and visualize the entrepreneurial growth of the six provinces.**

***Keywords*— Simulator; entrepreneurial growth; entrepreneurship; GEM; cellular automata.**

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I. INTRODUCTION

Entrepreneurship is a person's ability to do a business that starts from zero until the business is truly successful. Of course, this has a positive influence on national economic growth because entrepreneurship also creates jobs for the community. Besides, entrepreneurship also reduces unemployment, increases people's income, combines production factors (nature, labor, capital, and expertise), and increases national productivity.

Entrepreneurship has been recognized as a critical contributor to the economic development of a country [1]. Many studies are dedicated to studying the relationship between entrepreneurship and economic growth or other financial aspects [2], [3]. Like other countries, Indonesia also needs entrepreneurs to strengthen the economy [1], [4], [5]. According to the Director-General of Small and Medium Industries and Miscellaneous Industries at the Ministry of Industry of Indonesia, Indonesia still has to reach four percent of entrepreneurs from the total population. Currently, the number of entrepreneurs in Indonesia is only about three percent of the total population. At least four million new entrepreneurs are still needed to stimulate economic strengthening.

Due to the substantial role of entrepreneurs, the number of entrepreneurs needs to monitor. The government should do continuous monitoring to advance the economy in Indonesia. Besides, monitoring needs to carry out by any institutions that are interested in entrepreneurship issues. One of the institutions is GEM (Global Entrepreneurship Monitor). GEM is a consortium that aims to measure and monitor entrepreneurial activities.

Apart from monitoring real conditions, one of the activities that support monitoring is indirect observation. Simulation is one alternative for doing the observation by creating a mathematical model of entrepreneurial growth and then using it to simulate the model. We have introduced a mathematical model called Entrepreneurial Cellular Automata (ECA) [6]. This model is inspired by Cellular Automata (CA), first proposed by Ulam and von Neuman [7]. As one of the models that are still the foundation of most modern modeling approaches [8], Cellular Automata have been widely used to model complex dynamic systems, such as disease spreading

[9], [10]. One of the advantages of CA is that it is easy to visualize.

We have presented ECA's definition and conducted a simple simulation to illustrate the model's use [6]. We have reported ECA's application in a more prominent case study, namely micro and small enterprises in some provinces of Sumatra Island, Indonesia [11]. A simple computer program implementing ECA was developed [12]. This first version of the simulator is capable of gives the visualization of the simulation. By assuming all parameters are constant, this first version of the simulator can visualize the simulation. In this work, we have expanded the capability of the simulator by removing some of the assumptions. In this version, the user can change some parameters' values to generate various simulations.

The rest of the paper is organized as follows. The following section presents some material related to this work, including the reference model of entrepreneurship by Global Entrepreneurship Monitoring (GEM), Entrepreneurial Cellular Automata, and the simulator's development. Section III discusses the implementation and functionality testing of the simulator. Section IV concludes the paper.

II. Material and Method

A. *Entrepreneurship Model by GEM*

Global Entrepreneurship Monitor (GEM) is an institution that monitors and measures entrepreneurial growth in various countries. This institution was founded in 1997 by Michael Hay and Bill Bygrave. GEM has studied entrepreneurship in more than one hundred countries' economies and has received wide recognition as the most authoritative longitudinal research entrepreneurship globally.

GEM does its research based on three premises [13]. The first premise is related to the economic condition of a country. If the economic situation is difficult, then the presence of entrepreneurship can help expand employment (motivating people to become entrepreneurs is also increasing). If the economy is running well, then entrepreneurship is not needed (motivating people to become entrepreneurs is already less attractive). The second premise is related to individuals' ability and motivation to start a business and their entrepreneurship views. Third, entrepreneurship is a significant contributor to new jobs in an economy. Also, national competitiveness depends on entrepreneurial ventures that are innovative and cross-border.

As shown in Fig. 1, GEM classifies entrepreneurs into four groups. The first group is the group of people who have the potential to become entrepreneurs. The second group is newborn entrepreneurs, who have started a new business but are still very early (<3 months). The third group is entrepreneurs whose business age is between 3 months until 3.5 years. The last is the group of entrepreneurs whose business is more than 3.5 years old. We name each group potential, nascent, new business manager, and established business manager, respectively.

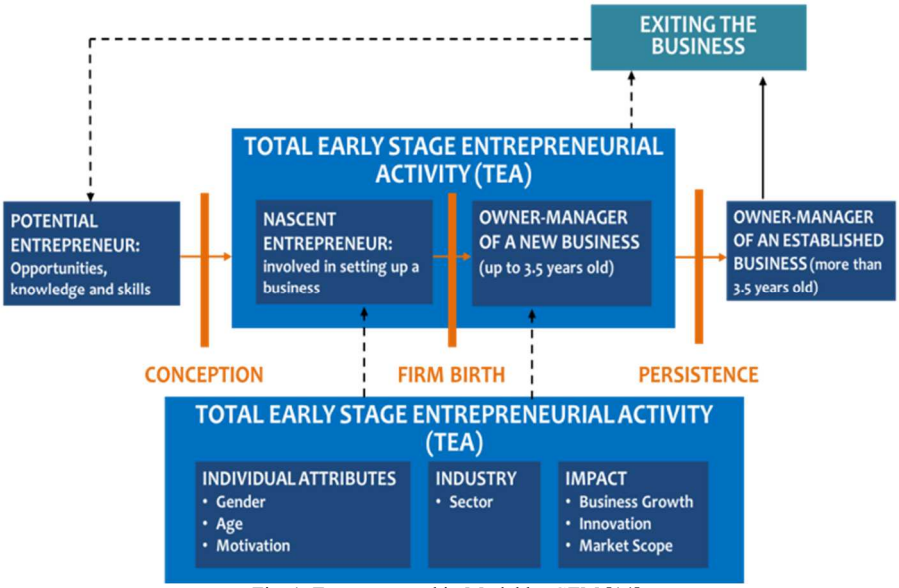

Fig. 1 Entrepreneurship Model by GEM [14].

At each phase, there is a possibility that the entrepreneur will stop running his business. Various factors may influence this entrepreneurship's sustainability. Some of the factors are socio-demographic conditions, industrial sector, entrepreneurial growth, and innovation. Every entrepreneur is related to two types of internal attributes. The first type is general attributes such as age, income, education, and business line. The second type is GEM's attributes, which are used as indicators of entrepreneurship [9]. The group or level of an entrepreneur may change from time to time. To change from one level to another, an entrepreneur must meet certain conditions determined by internal and external factors consisting of the situation of other entrepreneurs and other external factors.

GEM defines several individual attributes such as Perceived Opportunities, Perceived Capabilities, Role Model, Entrepreneurial Intention (High Status of Successful Entrepreneurship and Public Media Attention for Entrepreneurship), and Fear of Failure. Whereas for external attributes, GEM has defined finance related to some aspects, such as entrepreneurship, government policies related to the economy, government policies related to taxes, government

programs. For each attribute, GEM has assigned a number. Each year, each country member of GEM conducts a research/survey for finding the values of those indicators that hold for every country. These reports are open to the public and can be used by researchers as case studies [15], [16], [17]. To explain this issue, the reader may consult the GEM Global Report [18] or access its website (www.gemconsortium.org).

B. Entrepreneurship Model by GEM

Cellular Automata (CA) is a mathematical model used to model a dynamic system [7]. These automata are widely used to model traffic, with the primary purpose usually to study the load from roads in a particular area [7], [19]. CA is also often used in the health sector for modeling the spread of diseases, such as influenza and other virus diseases [9], [10]. CA can also be used for modeling in the environmental field [20][21]. Examples of cellular automata's application in the environmental sector are simulation and modeling of land-use change [22], [23]. In science, in particular, CA physics can be used to model the motion of particles and other problems related to quantum physics [24]. In the field of biology, CA is used to model biological cells [25].

Entrepreneurial Cellular Automata (ECA) uses Cellular Automata as its basis. However, the underlying structure of ECA is a graph instead of a one- or two-dimensional list. In ECA, cells will represent entrepreneurs, and the neighborhoods will model the relationships between entrepreneurs. Every entrepreneur has two attribute types: static attributes (e.g., gender, business area, business category, and geographic location) and dynamic attributes (e.g., age, level/class of entrepreneurship, and business age).

The definition of Entrepreneurial Cellular Automata, ECA, is as follows [6].

Definition 1. Given p sets of attribute values $A_1, \ldots, A_p$, and a set of public indicators $Pub = \{p_1, \ldots, p_m\}$, an ECA M is a tuple

$$M = (E, \alpha, N, \omega, \rho, \delta, \sigma)$$

where:

- $E = \{e_1, \ldots, e_n\}$ is a finite set of entrepreneurs,
- $\alpha = \{a_1, \ldots, a_p\}$ is a finite set of attribute labeling functions where each a_i is defined as $a_i : E \rightarrow A_i$,
- $N = \{N_1, \ldots, N_k\}$ is a finite set of neighborhood functions where each N_i is defined as $N_i : E' E \rightarrow \Re$,
- $\omega = \{w_1, \ldots, w_k\}$ is a set of neighborhood weight functions where $w_i : N_i \rightarrow \Re$ assigning a real value to each neighborhood function,
- $\rho = \{\rho_1, \ldots, \rho_m\}$ is a set of public indicator function where each ρ_i is defined as $\rho_i : p_i \rightarrow \Re$,
- $\delta : \beta \rightarrow \beta$ is a state transition function, and
- $\sigma : N' A \ 'R \rightarrow N$ is a neighborhood transformation function, where A is a set of attributes and R is a set of relation symbols.

The transition function δ is a rule that changes the entrepreneurial level from the present time to the future (next) time. According to GEM's entrepreneurship model, there are four entrepreneur levels: *potential*, *nascent*, *new business manager*, and *established business manager*. We add one level: *retired*, to represent individuals with age more than 64 years old. The transition from one level to another level of entrepreneurship is depicted by a finite transition diagram in Fig 2. The terms *new_bm* and *est_bm* are used for denoting *new business manager* and *established business manager*, respectively.

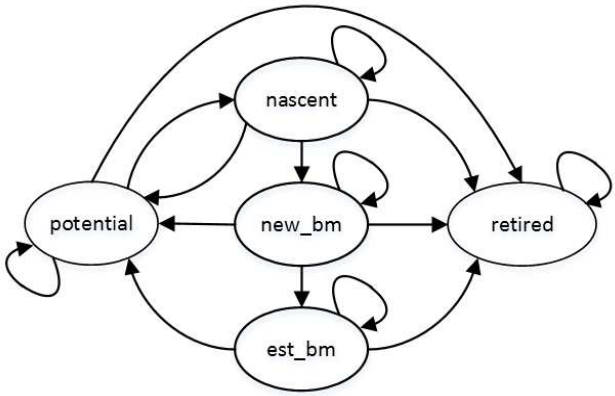

Fig. 2 The transition diagram for entrepreneur level [6].

For the transition function, we define a number called the Continuity Index (*CIdx*). *CIdx* is used as a reference for determining whether an entrepreneur will continue his business within a specific time. The *CIdx* of an entrepreneur is not only influenced by internal factors but also by external factors. External factors are influenced by neighbors and public factors such as government policies, world economic conditions, and pandemics.

The formula for the continuity index is as follows:

$$CIdx_i(t) = a.CInt_i(t) + b.CNeg_i(t) + c.CPub(t) \quad (1)$$

where a, b, c are real numbers such that $0 \leq a, b, c \leq 1$ and $a + b + c = 1.0$.

$CIdx_i(t)$ is the *CIdx* for individual entrepreneur i at a particular time t. $CInt_i(t)$ and $CNeg_i(t)$ is the internal and neighborhood condition value of an individual entrepreneur $i$at a specific time t. The value of $CInt_i(t)$ comes from the sum of the values of individual attributes. $CNeg_i(t)$ is calculated by summing up the number of entrepreneurs who are neighbors of entrepreneur i. Two entrepreneurs are called neighbors if they satisfy the relationship for a particular neighbor attribute. For example, assume two entrepreneurs: a 35 years old entrepreneur A and a 40 years old entrepreneur B. If the neighbor relationship for the attribute age is less than or equal (≤), then A and B are neighbors. Otherwise, if the relationship is equal to (=), then A and B are not neighbors.

$CPub(t)$ is the public condition value a specific time t. This value is obtained by summing up the value of the public factors. The value $CPub(t)$ is the same for every individual entrepreneur at time t.

An entrepreneur will continue his/her business if his/her *CIdx* meets a specific threshold value and two attributes, namely age and business age. These two attributes are considered to fit the GEM model. The detailed rules for this transition can be found in [1].

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An entrepreneur will continue his/her business if his/her *CIdx* meets a particular *threshold* value and two attributes,

namely *age* and *business age*. These two attributes are considered to fit the GEM model. The detailed rules for this transition can be found in our previous study [6].

C. Simulator Development

This section describes the development of the ECA simulator. In [12], we have presented a program for visualizing the simulation of six provinces' entrepreneurial growth in Sumatra Island, Indonesia. The six provinces are Aceh, North Sumatra, West Sumatra, Riau, South Sumatra, and Lampung. The simulator is very simple that enables the user to select a province and display the simulation growth corresponding to the selected province. The user cannot change or modify the values of *a*, *b*, and *c* and the threshold and any other parameters. In this work, we extend the simulator so that the user can change some parameters. With this simulator, users can select a province, determine parameter values, and run a simulation. This feature is reflected in the use case diagram in Fig. 3.

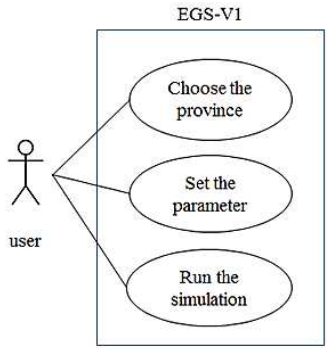

Fig. 3 The use-case diagram of the simulator.

Fig. 4 shows the state diagram of the simulator for modeling the simulator's behavior. After activated, the simulator will remain idle, waiting for an action taken by the user. The possible actions are selecting a province, setting the ECA-related parameters, setting the GEM-related parameters, starting the simulation, or ending the simulator. Based on the action taken by the user, the simulator will react by performing the corresponding reaction.

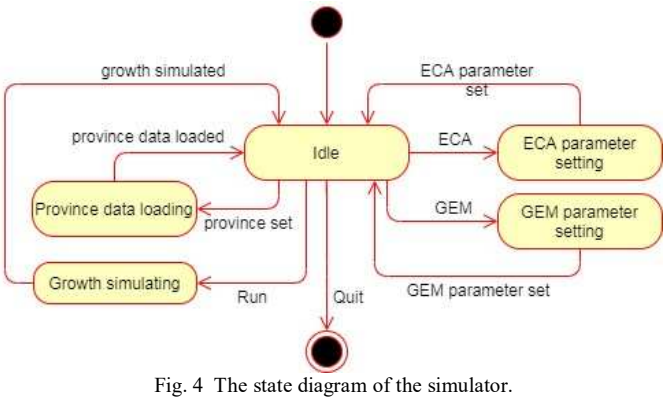

Fig. 4 The state diagram of the simulator.

Following a previous study [12], we have implemented the simulator with Python to ease visualization. The simulation display is similar to the previous simulator, as shown in Fig. 5.

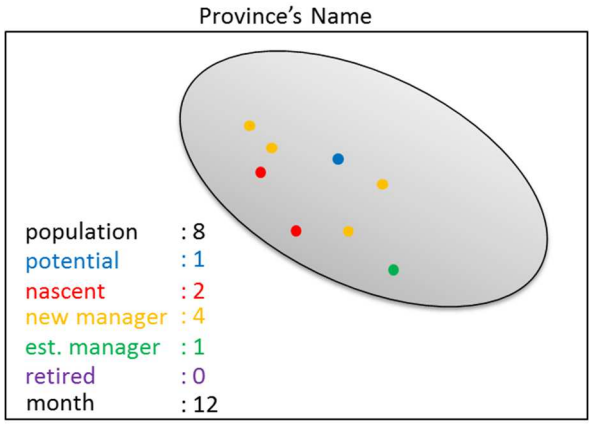

Fig. 5 The design of the simulation output display. [12]

III. Results and Discussion

A. Entrepreneurial Growth Simulator

The simulator has three menus, namely Simulation, Province, and Parameter, as shown in Fig. 6. The simulation menu contains two menu items: Run for starting a simulation and Quit for ending the program. The Province menu is composed of six menu items representing the provinces. The last menu, Parameter, consists of two menu items: ECA and GEM.

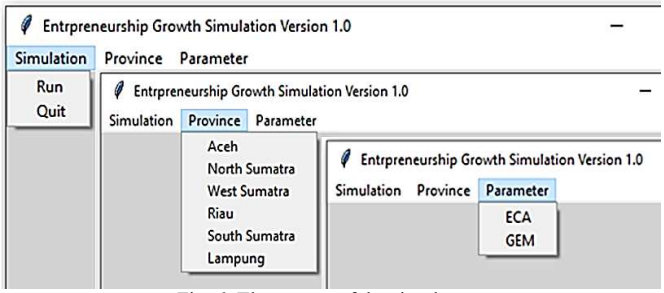

Fig. 6 The menus of the simulator.

Fig. 7 shows ECA-related parameters to be set by the user. Fig. 8 shows GEM-related parameters and the corresponding relations to be set by the user.

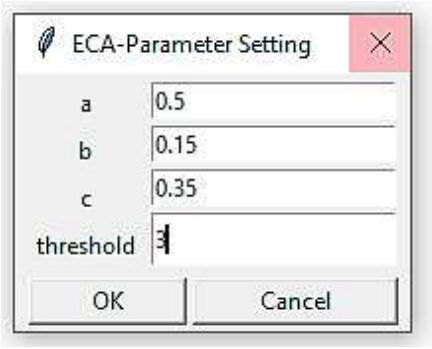

Fig. 7 ECA-related parameter setting.

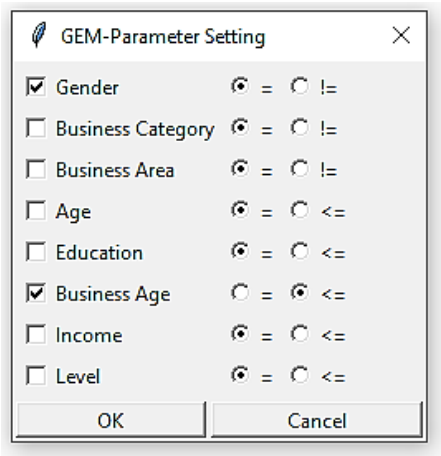

Fig. 8 GEM-related parameter setting.

B. *Functionality Testing Results*

We have conducted black-box functionality testing to test whether the program works according to its specifications or not. Testing is done by trying all the available menus. The result of this testing is that all functions have been running as expected. Fig. 8 shows an example of the display generated by the simulator for each province option. The program displays each province correctly. The proof of displaying the correct maps is shown in Fig. 9. We also ran some simulations in each province with different parameter settings. As an illustration, Fig. 10 shows the simulation results in Riau province with a specific parameter setting. We also ran some simulations in each province with different parameter settings. As an illustration, Fig. 10 shows the simulation results in Riau province with a specific parameter setting.

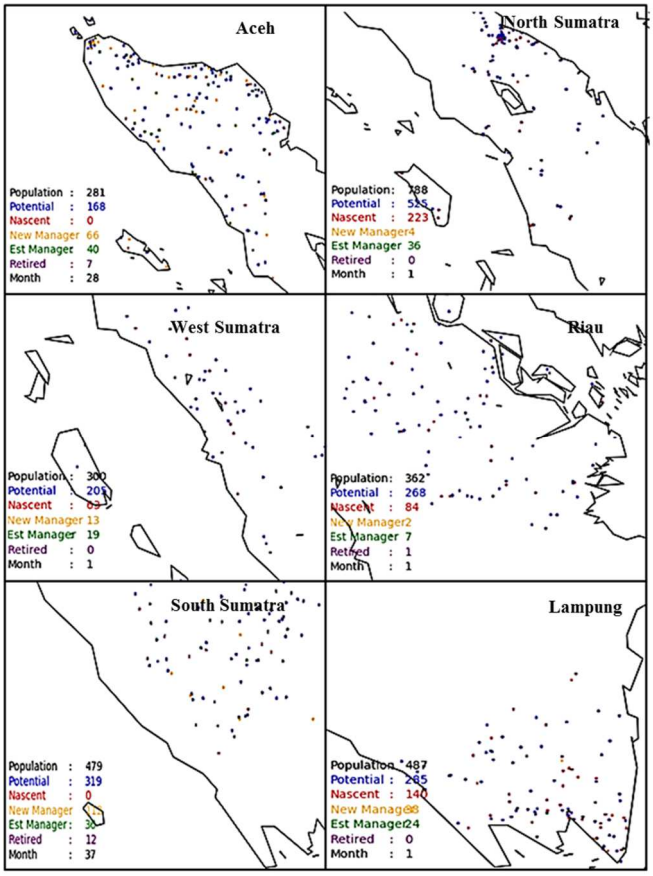

Fig. 9 The display of each province.

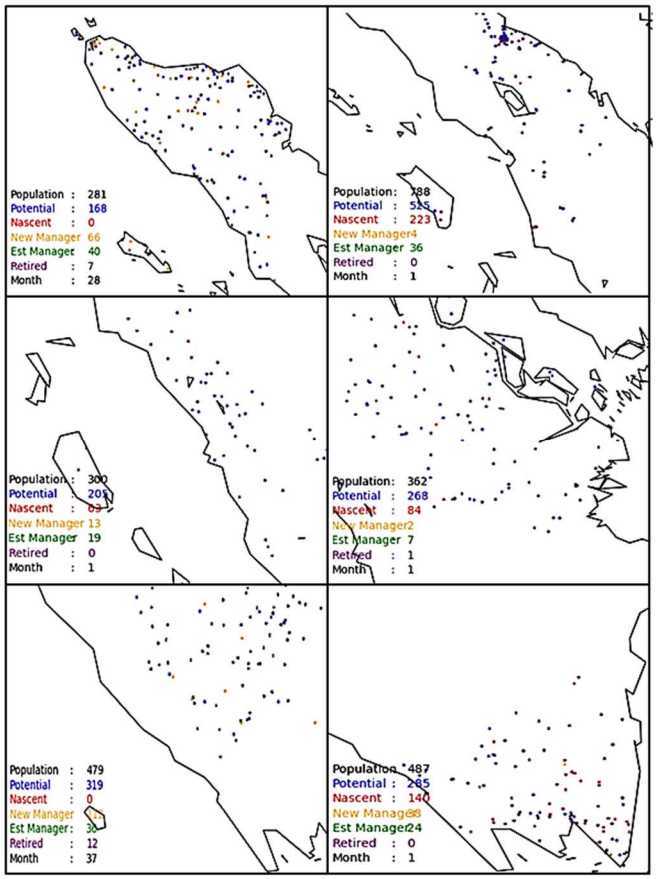

Fig. 10 Some snapshots of simulation with a = 0.3, b = 0.1, c = 0.6, threshold = 3, relation for gender =, Business Area =, Business Age <=11.

IV. Conclusion

This paper presents the development of an entrepreneurial growth simulator. This simulator implements ECA, Entrepreneurial Cellular Automata, a mathematical model for modeling entrepreneurship growth in a specific area. With entrepreneurship data from six provinces in Sumatra Island Indonesia provided by the simulator, the user can do simulation by setting the ECA-parameters and GEM-parameters.

We are currently working on an extension of the ECA. With this extended version, more parameters to take into consideration. The purpose of this extension is to allow a wider variety of simulations to perform. Besides, we also collect entrepreneurial data from other regions to enrich the entrepreneurial database.

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REFERENCES

[1] G. Pawitan, C. B. Nawangpalupi, and M. Widyarini, "Understanding the relationship between entrepreneurial spirit and global competitiveness: Implications for Indonesia," Int. J. Bus. Soc., vol. 18, no. S2, pp. 261–278, 2017.

[2] B. S. Sergi, E. G. Popkova, A. V. Bogoviz, and J. V. Ragulina, "Chapter 1 Entrepreneurship and Economic Growth: The Experience of Developed and Developing Countries". 2019.

[3] J. Doran, N. McCarthy, and M. O'Connor, "The role of entrepreneurship in stimulating economic growth in developed and developing countries," Cogent Econ. Financ., vol. 6, no. 1, pp. 1–14, 2018, doi: 10.1080/23322039.2018.1442093.

[4] I. N. Rachmania, M. Rakhmaniar, and S. Setyaningsih, "Influencing Factors of Entrepreneurial Development in Indonesia," Procedia Econ. Financ., vol. 4, no. Icsmed, pp. 234–243, 2012, doi: 10.1016/s2212-5671(12)00338-3.

[5] F. Setiawan and A. F. Aritenang, "The impact of fiscal decentralization on economic performance in Indonesia," IOP Conf. Ser. Earth Environ. Sci., vol. 340, no. 1, pp. 1–10, 2019, doi: 10.1088/1755-1315/340/1/012021.

[6] C. E. Nugraheni and V. Natali, "Cellular Automata Based Entrepreneurial Growth Model," vol. 24, no. 12, pp. 9410–9413, 2018, doi: 10.1166/asl.2018.12286.

[7] U. Sahin, S. Uguz, H. Akın, and I. Siap, "Three states von Neumann cellular automata and pattern generations. Appl. Math. Model, no. October, 2014, doi: 10.1016/j.apm.2014.10.025.

[8] P. Christen and O. Del Fabbro, "Cybernetical concepts for cellular automaton and artificial neural network modeling and implementation," arXiv, pp. 4124–4130, 2019.

[9] I. Tiwari, P. Sarin, and P. Parmananda, "Predictive modeling of disease propagation in a mobile, connected community using cellular automata," Chaos, vol. 30, no. 8, 2020, doi: 10.1063/5.0021113.

[10] S. Bin, G. Sun, and C. C. Chen, "Spread of infectious disease modeling and analysis of different factors on spread of infectious disease based on cellular automata," Int. J. Environ. Res. Public Health, vol. 16, no. 23, 2019, doi: 10.3390/ijerph16234683.

[11] C. E. Nugraheni, V. Natali, and V. Sukamto, Entrepreneurial Growth Simulation Using Entrepreneurial Cellular Automata, LNEE vol. 565. Springer International Publishing, 2019.

[12] C. E. Nugraheni and V. Natali, "Visualization of entrepreneurial cellular automata. IJAST vol. 29, no. 02, pp. 311–321, 2020.

[13] C.B. Nawangpalupi, G. Pawitan, A. Gunawan, M. Widyarini, and T. Iskandarsjah, (2014) Global Entrepreneurship Monitor 2013 Indonesia report.

[14] N. Bosma, "Working Paper Series Nr. 12-01 The Global Entrepreneurship Monitor (GEM) and its Impact on Entrepreneurship Research Niels Bosma," no. August, 2014, doi: 10.1561/0300000033.

[15] A. I. Voda, G. I. Butnaru, and R. C. Butnaru, "Enablers of entrepreneurial activity across the European union-an analysis using GEM individual data," Sustainability, vol. 12, no. 3, 2020, doi: 10.3390/su12031022.

[16] E. R. Sarreal, "Motives of entrepreneurs in entering the informal economy using the global entrepreneurship monitor (GEM) data," DLSU Bus. Econ. Rev., vol. 28, no. 3, pp. 131–144, 2019.

[17] M. Y. Arafat and I. Saleem, "Examining start-up Intention of Indians through cognitive approach: a study using GEM data," J. Glob. Entrep. Res., vol. 7, no. 1, 2017, doi: 10.1186/s40497-017-0073-3.

[18] N. Bosma, S. Hill, A. Ionescu-somers, D. Kelley, J. Levie, and A. Tarnawa, Global Entrepreneurship Monitor. 2020.

[19] F. Mazur and M. Schreckenberg, "Simulation and Optimization of Ground Traffic on Airports using Cellular Automata," Collect. Dyn., vol. 3, pp. 1–22, 2018, doi: 10.17815/cd.2018.14.

[20] N. Falah, A. Karimi, and A. T. Harandi, "Urban growth modeling using cellular automata model and AHP (case study: Qazvin city)," Model. Earth Syst. Environ., vol. 6, no. 1, pp. 235–248, 2020, doi: 10.1007/s40808-019-00674-z.

[21] Gouveia Freire and C. Castro Dacamara, "Using cellular automata to simulate wildfire propagation and to assist in fire management," Nat. Hazards Earth Syst. Sci., vol. 19, no. 1, pp. 169–179, 2019, doi: 10.5194/nhess-19-169-2019.

[22] K. Islam, M. F. Rahman, and M. Jashimuddin, "Modeling land use change using Cellular Automata and Artificial Neural Network: The case of Chunati Wildlife Sanctuary, Bangladesh," Ecol. Indic., vol. 88, no. May, pp. 439–453, 2018, doi: 10.1016/j.ecolind.2018.01.047.

[23] E. A. L. Pinheiro, N. A. Camini, M. R. S. Soares, and S. S. Sumida, "Cellular Automata Model - Landscape Dynamics Simulation Tool in the Process of Change in Land Use and Cover in the City of GaÚCha Do Norte - Mt," 2020 IEEE Lat. Am. GRSS ISPRS Remote Sens. Conf. LAGIRS 2020 - Proc., pp. 225–229, 2020, doi: 10.1109/LAGIRS48042.2020.9165590.

[24] B. Hellouin de Menibus and M. Sablik, "Self-organisation in Cellular Automata with Coalescent Particles: Qualitative and Quantitative Approaches," J. Stat. Phys., vol. 167, no. 5, pp. 1180–1220, 2017, doi: 10.1007/s10955-017-1760-8.

[25] G. K. H. Zupanc, J. R. Monaghan, and D. L. Stocum, "Adult Neural Stem Cells in Development, Regeneration, and Aging," Dev. Neurobiol., vol. 79, no. 5, pp. 391–395, 2019, doi: 10.1002/dneu.22702.