

Using a business simulator with elements of machine learning to develop personal finance management skills

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Abstract

Any person, not even a financier, should be knowledgeable in the field of personal finance management. As a result of the survey, it was concluded that schoolchildren and students should be interested in the study of personal finance, even within other disciplines in the form of separate sections. Successful personal experience and knowledge of the teacher in the field of personal finance is an important component of the effectiveness of the formation of competence of pupils, students, and adults in the field of personal finance. Business simulators come in handy here. That is why the authors developed a business simulator for the development of personal finance management skills, which was developed in the form of a web service. The main features of this simulator, which are presented in different sections of the simulator, are considered. It is shown what skills of personal finance management are developed using this business simulator. Since this simulator was designed to develop personal finance management skills, an attempt was made to apply machine-learning elements to make this business simulator work even better. The proposed simulator can be used in the future to teach the elements of personal finance management to people who are not sufficiently knowledgeable in the field of such finance. Moreover, the web application can be useful even for school-age children, so the simulator can complement the educational process within the economic courses not only in higher education institutions but also in secondary education institutions of Ukraine.

Keywords

business simulator, machine learning, personal finance, personal finance management skills

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1. Introduction

Almost every day, each person spends money on housekeeping, utility bills, payment for services and purchases. It also includes debts on loans, or just borrowed money from friends. Personal finance includes all the funds available to us and the ability to manage them, so the topic of personal finance is relevant and worthy of attention for everyone who cares about their financial well-being. That is why any person, not even a financier, should be knowledgeable in the field of personal finance management. As a result, a survey was conducted to find out certain aspects of the financial literacy of first-year students as individuals who have their financial resources. In 2019, 167 respondents took part in the survey, in 2020 – 214 respondents (first-year students of the Faculty of Information and Computer Technologies of the Zhytomyr Polytechnic State University).

As a result, it was found that in 2019, 70.7% of respondents consider themselves financially literate, ready to consciously and effectively manage their own and family financial resources; in 2020 – 74.3%. At the same time, 29.3% of respondents in 2019 do not consider themselves sufficiently aware in this regard; in 2020 – 25.7% (see figure 1, a).

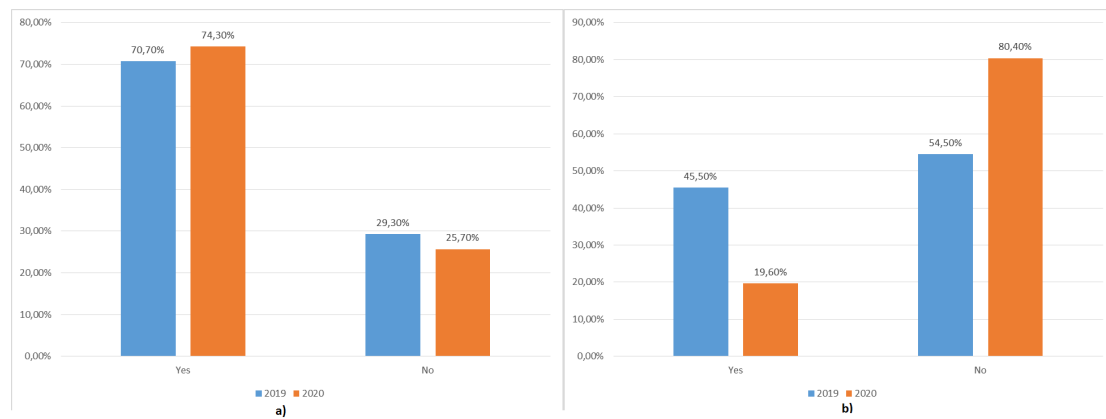


Figure 1: Financial literacy education results.

It was also found that in 2019 45.5% of respondents studied the basics of financial literacy in at least one form, in 2020 – this figure dropped to 19.6%, in 2019 54.5% – did not study in any form, in 2020 – this figure is 80.4% (see figure 1, b).

In addition, by the results of the survey, it was found that in 2019 14.4% of respondents at the highest level assess their level of readiness for conscious and effective management of own and family financial resources, in 2020 – 10.7%, 38.3% of respondents in 2019 – indicated the level of readiness “good” and “satisfactory”, while in 2020 46.7% indicated the level of readiness “good”, 35% - “satisfactory”. All others either rated the level at the lowest level or an unsatisfactory level.

As a result of the survey, it was concluded that schoolchildren and students should be interested in the study of personal finance, even within other disciplines in the form of separate sections. Successful personal experience and knowledge of the teacher in the field of personal finance is an important component of the effectiveness of the formation of competence of pupils,

students, and adults in the field of personal finance. Business simulators come in handy here.

1.1. Theoretical background

The need for personal finance competency development was analyzed in the research internationally. The challenge is relevant for both developed and developing countries. Influence of the financial literacy on the well-being of people worldwide and the need to recognize it as the fundamental right and universal need was discussed by Lusardi [1]. Another research by Lusardi et al. [2] shows that in the USA 30–40% of retirement wealth inequality is associated with the level of financial literacy alone. As for the initial personal finance management, knowledge, and skills formation, the study concludes significant influence of the high school financial literacy courses on the lower default rates and better credit scores [3].

Using business simulations in education is a shared practice now. Simulations are being used in practical training, such as flight or combat simulations as well as in economic, managerial, and financial areas. Researchers study the pedagogical significance of this type of technology-enhanced educational method. The group of researchers from the consortium of Spanish universities concluded the positive impact of business simulations on the generic competencies [4]. Farashahi and Tajeddin [5] conclude the effectiveness of business simulations in their comparative study. The study of business simulations in economic or finance evolves with the evolution of technologies available to develop immersive, attractive, and highly functional experiences. The range of use-cases differs from elementary schools to life-long learning establishments. Korgin [6] provides evidence of the effectiveness of the simulation games for kids with basic arithmetical operations literacy. Palan [7] studied the criterion and approaches to select business simulation software for asset market experiments to use in the higher education establishments.

The analysis provides evidence of the effectiveness of business simulation usage in education in general and the need to further development of business simulation for the economy and finance literacy development, assessment, and study of its behavioral aspects.

2. Results

The analysis of the analogues revealed that most part of the simulation software is appropriate for a specific area of the finance in the countries with developed financial markets. Based on the conclusions above this work represents the experiment in developing more generalized simulator for the countries with less developed market of financial instruments [?].

That is why the authors developed a business simulator for the development of personal finance management skills, which was developed in the form of a web service [8]. Consider the main features of this simulator, which are presented in different sections of the simulator (see figure 2):

1. Current account management options.
2. Savings management options.
3. Deposit management options.
4. Credit management options.

5. Non-financial investment management options.
6. Information on changes in current accounts that have occurred in the last week.
7. Analytical information on the dynamics of changes in current account funds, savings, and investments.
8. Information on current exchange rates.
9. List of recent transactions that have been made on current accounts.

Consider in more detail the section with current account management options (see figure 2, A). The “Current account” section contains a list of current accounts in the form: code and available amount.

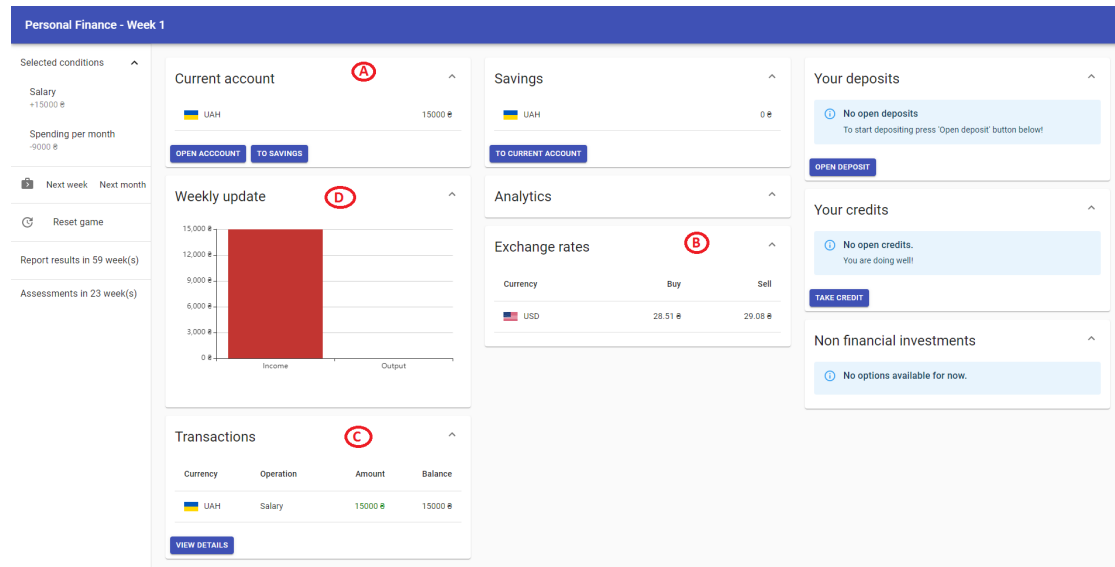


Figure 2: Business simulator.

The user has the opportunity to open a new account. To do this, click on the “Open account” button, then a window will appear where you need to select the currency in which you want to open a new account (see figure 3). Each user action in the simulator (for example, opening a new account) is accompanied by a message that appears in the lower right corner of the page (see figure 4).

After opening a new account, the “Exchange” option will be available in the “Current account” section, which allows you to exchange currencies at the rate that can be viewed in another section “Exchange rates” (see figure 2, B).

To exchange currencies, the user can enter the amount he wants to sell and the amount in the currency to be purchased will be filled in automatically. The user can also enter the amount to purchase and the amount required for the purchase will be filled in automatically. The user can also change currencies and the amounts will be automatically transferred.

In the process of performing all actions by the user, a real-time section is available with information about changes in current accounts that have occurred in the last week (see figure 2, D).

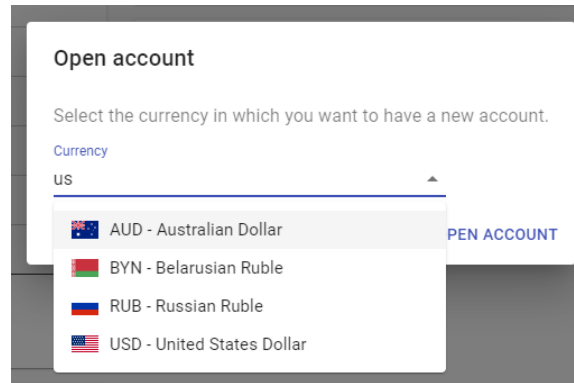


Figure 3: Example of opening a new account.

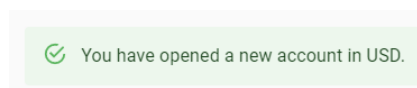


Figure 4: Example of message.

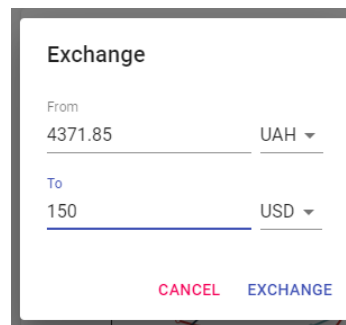


Figure 5: Example of currency exchange.

The user can choose the currency of the account for which he wants to see the relevant data (see figure 5).

In addition, in the simulator, there is a section with analytical data on the dynamics of changes in current account funds, savings, and investments since the beginning of the simulation (see figure 6). The user can select the currency of the account for which he wants to see the information. By default, to visualize the dynamics of funds in all accounts, the option “Accounts total amount in USD” is selected, which displays the total amount of funds in all accounts converted into USD.

The user also can view transaction information on all current accounts (see figure 2, C). The corresponding section contains a list of the last 5 transactions. In this case, the user can view all transactions or filter them by specific weeks in the details window (see figure 7).

At the beginning of the 4th week of the simulation, a window with a test question appears, in which the participant is asked what the amount is enough to save for savings from a monthly

Analytics

Accounts total amount in USD ▾



Figure 6: Analytical information on the dynamics of changes in current account funds, savings, and investments.

salary per month. This question is part of the assessment, and the user is obliged to answer it.






To sometimes distract the user from financial instruments and bring more of the reality into the simulation process, random events were added to the system, including various diseases, repairs, the birth of a child, and so on. Most random events last for some time and additional costs for the entire period of validity.

Some events are constant, so costs are made every week, such as the birth of a child. You can't cancel any random event, you can just accept it and close the window.

Upon reaching the 60th week of the simulation, the user will be shown a page where the participant can view analytical data on the dynamics of changes in funds on all current accounts, savings, and investments since the beginning of the simulation (see figure 8). Funds on all accounts, savings, and investments are converted into USD and shown in one chart. On this page, the user can compare their results with the results of other participants in their country, as well as from other countries, in addition, they can share their thoughts or ideas about the simulator by filling in the field at the bottom of the page.

The use of the Simulator facilitates forming of the following knowledge, skills, and competencies as well as the personal attitude towards:

- Using the diversified list of currencies.
- Forming widely-acknowledged standard of emergency savings and assessing readiness for longer-term investment.
- Using basic saving and investment instruments available in a wide range of countries such as deposits (deposit certificates), real estate, and business investments. Experiencing different types of instruments and understanding their specific.

Transactions			
Start week		End week	
21		24	
Currency	Operation	Amount	Balance
 UAH	Transfer from savings	2000 ₺	2314.24 ₺
 USD	Completed deposit 'Standard (3 months)'	400 \$	400.84 \$
 USD	Deposit 'Standard (3 months)'	0.42 \$	0.84 \$
 UAH	Regular spending	-1250 ₺	314.24 ₺
 UAH	Regular spending	-1250 ₺	1564.24 ₺

CLOSE

Figure 7: List of transactions with the filter by weeks.

- Debt-management and forming personal behavioral attitude to using debt as constructive investment leverage.

Since this simulator was designed to develop personal finance management skills, an attempt was made to apply machine-learning elements to make this business simulator work even better. This requires the creation of a system that could determine for the user an effective strategy of action in the simulator because the amount of real data of simulation participants is extremely small for analysis and identification of hidden dependencies using cluster analysis. This task is suitable for those that are solved by the latest approach in machine learning, namely reinforcement training.

Reinforcement learning (RL) is a type of machine learning in which the agent directly examines environmental data, receives rewards, and sets policies for optimal action. The goal of RL is to find the optimal policy that maximizes the expected amount of future rewards [9].

Reinforcement learning focuses primarily on how to obtain the optimal strategy [9]. Ideally, the system should determine what will be financially optimal, as well as understand what is inherent in man, given its characteristics. For example, if a person has never used investment instruments, it is not worth building a strategy for him with too aggressive investment behavior, because it is unlikely that a person will follow it.

Reinforcement learning includes an agent, a set of states S , and a set of actions by states A . By acting $a \in A$, the agent moves from state to state. Acting in a certain state provides the agent with a reward. The agent's goal is to maximize his overall (future) reward. He does this by adding the maximum reward that can be achieved from future states to the reward for reaching his current state, thus influencing the current action with a potential future reward. This potential reward is the sum of the rewards of all subsequent steps, starting from the current

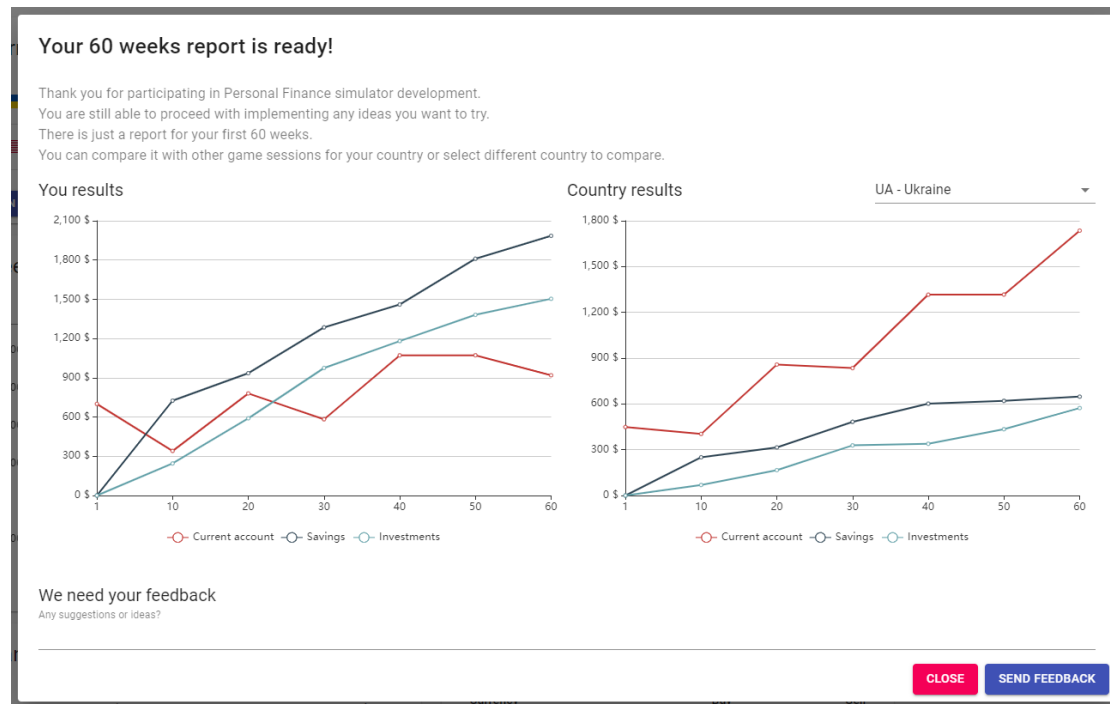


Figure 8: Example of simulation results.

state.

Formally, reinforcement learning is modeled as a Markov decision-making process (MDP). MDP provides a mathematical basis for modeling decision-making in situations where the results are partly random and partly controlled by the decision-maker [10].

One of the algorithms of reinforcement training is Q-training. The purpose of Q-learning is to learn a strategy that gives the agent information about which step is best to perform in a particular state S .

The algorithm contains the following elements:

- r_t the reward received in the transition from state s_t to state s_{t+1} ;
- α – the pace of learning, which determines the extent to which new information will override old information;
- γ – depreciation ratio, which gives the effect of valuing rewards received earlier, higher than those received later.

Before training, Q is initialized with an arbitrary fixed value (selected by the programmer), for example, 0. Then, at each point in time t , the agent selects an action a_t , receives a reward r_t , moves to a new state s_{t+1} (which may depend on both the previous state s_t and the selected action), and table Q is specified. The core of the algorithm is the Bellman equation as a simple update of values by iteration, using the weighted average old value and new information [11].

As a result, the open-source library “SharpRL” was chosen [12]. This library provides basic functionality for developing a learning environment with reinforcement based on the Q-learning

$$Q^{new}(s_t, a_t) \leftarrow \underbrace{Q(s_t, a_t)}_{\text{old value}} + \underbrace{\alpha}_{\text{learning rate}} \cdot \left(\underbrace{r_t}_{\text{reward}} + \underbrace{\gamma}_{\text{discount factor}} \cdot \underbrace{\max_a Q(s_{t+1}, a)}_{\text{estimate of optimal future value}} - \underbrace{Q(s_t, a_t)}_{\text{old value}} \right)$$

temporal difference

new value (temporal difference target)

Figure 9: Q-learning algorithm.

algorithm. The program for defining personal financial strategies is a console application. Running this program involves setting certain parameters, including:

- number of simulation passes in training mode;
- the number of simulations in the mode of compliance with the model policy after training;
- duration of the simulation in weeks;
- monthly income and expenses of the user in a certain currency, which will be determined as the main currency of this user.

At the end of the training process, the screen will display the maximum reward that was achieved during the program; data on the user in the last week, which include: funds in current accounts, amounts invested in deposits and savings of the user; the best way that was found during the operation of the system. Each step of the path is an action that is recommended for the user to perform in a particular week. For more information, user data is displayed next to each step after performing the specified operation.

To have more opportunities to analyze the results, the program saves them in a CSV file, which can be used to compare the data with data from other launches of the program.

The generated file has only two columns: the first – indicates the week of the simulation, the second – the reward received by the user this week.

As a result, the operation of the system with different initial parameters was analyzed and it was found that a small number of iterations is the cause of an untrained model, which results in unstable results. Experiments were conducted and it was hypothesized that the optimal ratio of initial parameters, namely: the number of simulation passes in the training mode and the number of simulation passes in the mode of adherence to the model policy after training, is close to 1000. It was found that best results. After attempts to increase these figures, the results remained within the statistical error. For example, figure 10 shows the result of increasing the number of training epochs to 2000, which, compared to the results of 1000 epochs, remained almost unchanged. As a result of the study, it was concluded that with the current set of possible actions in the system (for example, to open a deposit of 10% of profits, etc.), increasing the number of training epochs does not improve the result.

To test the trained model, a method of comparing the results of the system with the average values of the results of the passage of real users in the developed simulator was chosen. Thus, it was decided to take a certain period, for example, 54 weeks, and collect user data using the available functionality of the simulator. Based on the collected user data and the results of the trained model, several comparative graphs with different indicators of income and expenses were constructed.



Figure 10: Results with different number of epochs of training in the mode of adherence to the trained model.

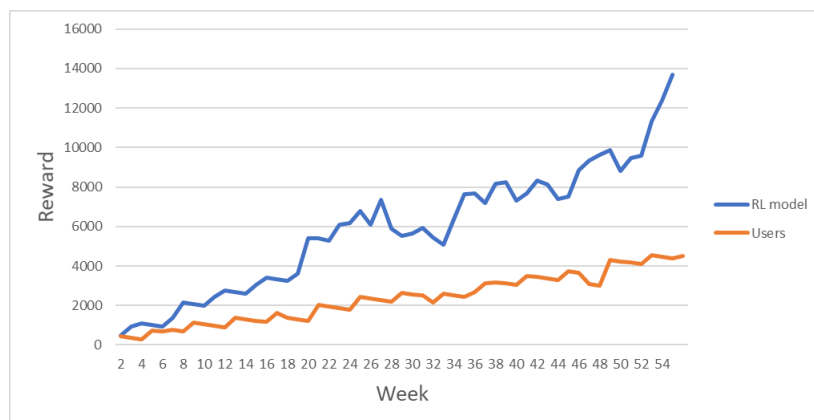


Figure 11: Comparison of model and user results with parameters of UAH 15,000 income and UAH 9,000 costs.

It was found that for 54 weeks, the system shows consistently better results than the average results of users who underwent the simulation. From the graph, you can see that the performance of the model is growing from week to week, which means that the system adapts to the environment.

After increasing the parameters of profit and expenses, the difference in the graphs becomes more significant in favor of the trained model. This is shown in figure 11, 12, 13.

Jumps can be seen in the graph showing the results of the reinforcement learning model. They can be seen more often on charts where higher incomes and a large difference between income and expenses. This is the effect of specific rules that are described to train the model

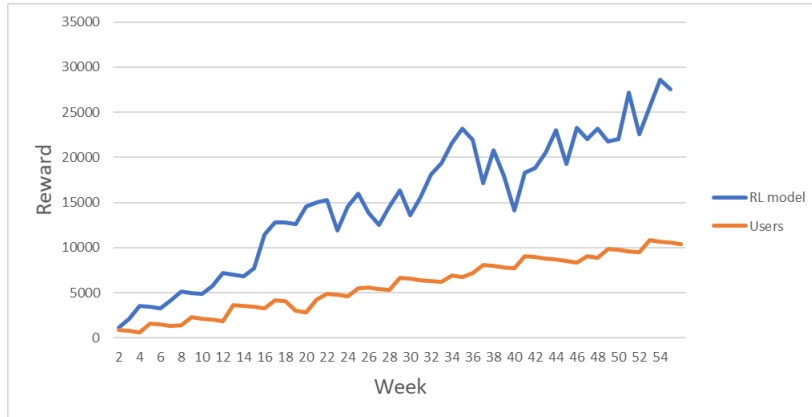


Figure 12: Comparison of the results of the model and users with the parameters of UAH 30,000 income and UAH 15,000 costs.

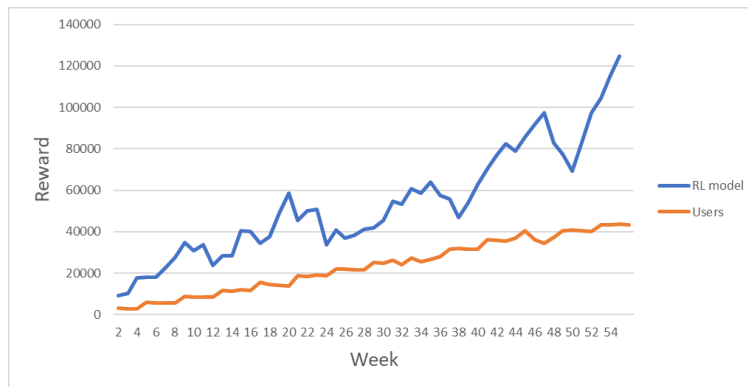


Figure 13: Comparison of the results of the model and users with the parameters of UAH 100,000 income and 30,000 UAH costs.

so that the virtual agent system follows the best path. For example, if an agent has opened a deposit for 3 months, after this period the deposit will be closed automatically and this closing of the deposit will significantly affect the user’s reward for this week. However, the system learns and “understands” where to invest or save. As a result, this leads to sharp increases in performance, as seen in the graphs. In the graphs responsible for the results of real users, such behavior is not observed, which indicates the ignorance of users with effective ways to manage personal finances within the developed simulator.

3. Conclusions

Currently, economic processes are a new topic for research into the possibilities of applying the full potential of machine learning. Scientists from around the world are just making the first attempts to reproduce such processes programmatically to use artificial intelligence to find solutions and answer various economic questions of humanity.

The proposed developed software package consists of two parts: a personal finance management simulator and a system for determining effective financial strategies, which uses reinforcement learning opportunities.

The proposed simulator can be used in the future to teach the elements of personal finance management to people who are not sufficiently knowledgeable in the field of such finance. Moreover, the web application can be useful even for school-age children, so the simulator can complement the educational process within the economic courses not only in higher education institutions but also in secondary education institutions of Ukraine.

The prospects for further research include testing the effectiveness of the proposed simulator of personal finance as a learning tool.

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