Virtual Technological Line Simulator for the Production of Chocolate

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Abstract: Authors have presented the designed simulation complex of chocolate production in this paper. There is an overview of researches which have modern programmes for training specialists in bachelor and masters degrees. Researchers have explored the information about modern tools for educational system of many industries engineers in actual databases: RSCI; Scopus; Web of Science; Ebsco; Agris and others. It has been presented the actual information solutions that can be used to train specialists in different sectors of the food industry in this work. There are advantages and disadvantages of the created software package in this article. Authors have used the tools of Blender 3D, Unity 3D, Autodesk Inventor software. Also researchers have used C# for setting the system. Article will be interested for lecturers in field of food production.

1 INTRODUCTION

In the modern world, all sectors of the national economies are developing dynamically. The food industry is not an exception. The industrial security of the country depends on its ability to meet new challenges and support human life. It is necessary to use current digital solutions for training the specialists in educational institutions. Also companiesmust introducethe high-level complexes in production.

There are3 main growth points for any industries: increasethe production efficiency by using automation and dispatching of technological processes at mostly production stages; reducing additional costs by redistributing production lines to improve the efficiency of each stage; training staff in modern technologies by using advanced didactic methods. All these points are possible through the transition from the «Industry 3.0» approach to «Industry 4.0». The main element of it is the digitalization and automation of control systems.

Automation systems of technological elements is necessary for each stage of food production. It could increases the accuracy of ingredients consumption, increases the reliability of production equipment, reduces raw materials and wear of the main mechanisms and also the risks of deviations from the manufacturing method (Fedosenkov, 2015). It is possible to use both existing software packages and create your own packages based on well-known program codes, for example, matlab simulink in these systems (Khvostov, 2018).

The developed programs can have a self-learning modular type, where each food production unit has its own independently configured, debugged mode and type of operation. There are the possibilies to change each element of the system, which expands the possibilities of using the complex for a large number production lines types (Wauters, 2012).

Almost every food production line include a mixing process. Moreover, it will be excellent for the production of, for example, coffee and viscous food products (Santos Cunnighan, 2019; Blagoveshchenskaya, 2020; Balykhin, 2018). The

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main differences are the operating mode, the type of mixing elements and the power of the devices. There are other mechanical and nature (thermal, electromagnetic, etc.) processes which could be used as part of mixing with the main equipment and separately: centrifugation, vibration, heating, etc. (Ivanets, 2015; Krakhmalev, 2022; Vanderroost, 2017). They require an automation process with unique parameters according to technical requirements like other elements of the technological process. The production of food can also include the stage of finished productspackaging, where is necessary the automation of packaging lines (Mel'nikova, Ponomareva, Bogdanova, 2017).

Technologist must monitoring each stage in the process of food production. Each type of production line requires a unified approach to maintaining the necessary control conditions because of the wide availability of different food range types. Programs are also used to control the chemical and taste parameters of solid and liquid products (kefir, juices, confectionery) in the modern food industry (Petryakov, 2018; Aly, 2023; Muzyka, 2022). The work of Aly B. and other authors provides an overview of modern information technologies use in the meat processing industry, where special attention was to the automation of the primary cutting meat process and different problems of introducing modern devices and software into production (Al Balushi, 2019).There are newtechnical vision tools which become widespread (Blagoveshchenskiy, Petryakov, Sumerin, 2020; Vignali, 2017). These elements area new area in the «Industry 4.0», which is called digitalization. Today these things affects not only the control stage, but also to other components of the production technological line.

The key area of digitalization is the Virtual reality (VR). VR is a set of technologies which could be used to create and modernize the real world with augmented reality. The virtual space which was created by application software with the special controllers support, allows a person to experience all reality changes. An augmented reality complex refers to those devices that can simulate and reproduce virtual space, using all the connected data for the interaction of a person and the created augmented space. That reality systems are divided into several subtypes: virtual system, where all objects which have created in a certain environment are developed and realized into a single program with models; an augmented system, where the system allows person to view the familiar world with changes; a mixed system that combines the first two systems with reference to real objects. Domestic researches which are related to this topic is mainly focused at the industrial use of virtual reality, but an important common problem in that articles is not enough comple of published materials.

The main functions of complexes after the VR introduction in industry are: design and collection of information; modeling of structures; testing and use of a digital model on active structures; training in a virtual environment; use of simulators to train workers in industry for minimize costs on devices operations; control and quality management system using developed materials for presentation and informing in production; quick response in case of differnet systems breakdown at an industrial facility to minimize costs to achieve set production tasks. There are some systems which were developed to assist in the maintenance of existing equipment, for example, in the production of juices (Barricelli, Casiraghi, Fogli, 2019). These complexes are a virtual reality system with the characteristics of the used equipment.

The virtual and real objects binding and similarity is important for simulation modeling of technological processes (mixed system). The development of action scenarios is the main part. Therefore, today the main directions in creating models are digital twins and mathematical modeling. The creation is carried out in all sectors of the national economy (Rasheed, San, Kvamsdal, 2020; Jones, 2020; Kaychenov, 2022; Zheleznov, 2021). The practical results of these activities were the created models of buildings, engineering equipment, mechanisms and other equipmnet (Zheleznov, 2021; Johra, 2021; Volkov, 2018; Trenfield, 2022). These systems provide capabilities and increase reliability of assembly processes, diagnostics and different complexities testing. Introduction of information technologies in medicine and pharmaceuticals will help to improve the quality and speed of logistics services (accelerating the issuance of prescriptions, sending reports of medical tests, etc.) (Gao, 2022), and other medical operations. The medical operations include the determination of preliminary diagnoses, interpretation of the computed tomography and other analyzing machines results. Educational interactive medical simulators can improve the quality of specialists work and plan complex surgical operations in a virtual environment to minimize costs. It is planned that their use in practice and in training will reduce the duration of surgical operations and will make it possible to simulate the actions of a doctor with the elaboration of each stage of operations. Digital technologies are used to work out scenarios for different critical, non-standard situations and improve the qualifications of company employees in non-industrial sectors. These applications has made possible to increase website traffic and sales for many companies several times. There are programs that are used to present a company products sells or the organizations themselves. However, problems remain with all digital systems. The main types are: ensuring system performance and information security.

The objectives of this work are: find out real software systems which are using virtual reality technology for training specialists in the food industry and present the developed simulation environment for the manufacture of chocolate products.

2 MATERIALS AND METHODS

There is an analysis of publications from domestic and leading foreign databases. It includes the study of modern tools for training different specialists of industrial enterprises. It was carried out in following databases: RSCI, Scopus, Web of Science, Ebsco, Agris and others. The key search criterion was the use of virtual reality technology.

The use of digital augmented space in industry has increased several times because of the large-scale development of information technology and free platforms. They allow person to create for production fully constructed virtual models of the equipment operating processes and their individual parts (Wauters, 2012). The development of the food industry depends on many factors, for example, the modernization of law or the ability of consumer needs. New requirements for production processes and requirements for personnel safety, sanitary and hygienic standards in production appear every year. There is a need to change the recipe, rebrand the logo and packaging, and create new products. All these phenomena require manufacturers for quickly respond to changes. Therefore, the use of different simulators is need in production. Connected sensors that collect information about problems in the operation of equipment allow the simulator to make a prediction: how the production line will perform under certain tasks and conditions. As a result, introducing such digital models into food and beverage production provides companies with great benefits: optimizing production and costs at the design stage; analyze instruments and devices about the state of operation; test different scenarios in a virtual environment. Person can create a digital model of the product when using a simulator in the food industry. This opportunity will make it possible to make a forecast of the final product, check the product's compliance with the stated regulatory requirements and planned indicators (Muzyka, 2022; Blagoveshchenskiy, Petryakov, Sumerin, 2020). Digital simulators will allow person to quickly upgrade old recipes to new equipment. Another solvable problem which facing for food manufacturers is organizing production lines that could be installed in a small space and maintain the same performance as the original ones. Digital reality solutions also help to visualize belts, conveyors, machinery for possible optimal conditions.

Most studies on this topic are devoted to existing production modernization by using information systems. At the same time, less attention is paid to the educational process. Education is an integral part of the production process in other industrial fields. Educational virtual platforms are focused at training the skills of rolling stock and machines operators in the transport infrastructure and mining industry (Xie, Liu, Wang, 2022; Palmer, 2022). There are conducting seminars use systems for digital twins of existing laboratory equipment and programming languages in the basic sciences (Aliev, Ivanova, Borodzhieva, 2022; Razakov, 2023). Virtual laboratory complexes are most often used in engineering disciplines (including the food industry) which can completely replace real laboratory work and not complement them like other educational programs (Volkov, 2018; Yan, Jia, 2022). There are interdisciplinary researches that cover the fields of biology, psychology, sociology, medicine in the food industry. Virtual reality is focused at determining the effects of the food type on a person. Researches show the influence of the human senses (vision and hearing) on the uprise effect of the food products taste perception. It can be attributed to any type of food and have both positive and negative effects on taste (Stelick, 2018; Wang, 2020; Crofton, 2019;Padiotis, Mikropoulos, 2010).

Only a few studies were identified have virtual models of technological processes for educational purposes in the food industry during the search for works (Al Balushi, 2019; Yan, Jia, 2022). Main characteristics of them have been described previously. The last research, which is a completely educational product, can be used to train specialists in the food industry. It is a work that describes the use of the solo complex for a depth study of the milk pasteurization process. It describes the physical component of the process and the visualized elements of the technology. It can be concluded that existing simulator programs for food production lines do not fully describe the features of this industry. Therefore, it is necessary to develop simulator programs for training specialists in accordance with the field of training.

There is a presentation of the created simulator chocolate production line for training specialists in the confectionery industry. The simulator was implemented in 4 software environments. The creation of three-dimensional digital twins of all devices was done in the Autodesk Inventor environment. All models were loaded into the Blender 3D editor, where it was developed animation and simulated the mechanical elements actions of the devices after primary detailing. Direct settings of the system was carried out in C# in a special plugin. All developed components were loaded into the cross-platform Unity 3D environment after all the actions. It is usually used to create gaming applications on different platforms. In this project, this particular platform was chosen because of the fact that it has a modular system of components, which is necessary for the animated applications stable operation.

3 RESULTS AND DISCUSSION

The developed technological line for the production of chocolate has been implemented in the form of an animated simulator which is designed for employees at enterprises and for students who are receiving higher education. The main functional elements of the developed complex are presented in Figure 1. An engineer establishes all the main indicators of production data in order to determine their possible values and work out different situations. The main characteristics are calculated automatically and based on the collected data as a result of working process with the subtasks completed by students.

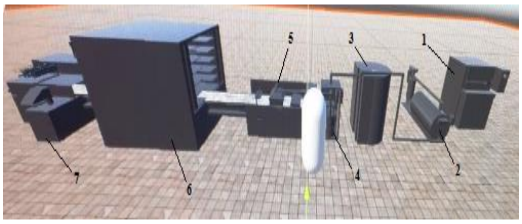

Figure 1: The main structural elements of a chocolate production line simulator: 1 – oven for melting cocoa beans; 2 – conching equipment; 3 – storage tank; 4 – machine for applying glaze; 5 – filling machine; 6 - refrigerator; 7 – packaging machine.

The process of technology operation in the virtual environment has been visualized in program. The routines are implemented that analyse and collect data which has been collected from the student in the simulator by system. Authors have developed the main points of the industrial lineinteraction in the complex which are necessary for setting up and performing the main tasks of operations that arise in production. There is the appearance of the equipment for chocolateheat treatment at the final productionstages in Figure 2.

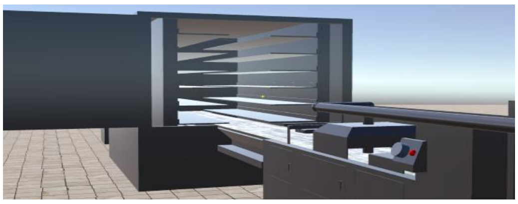

Figure 2: Refrigerator equipment for cooling process of chocolate.

The key features of the current version are: visual remote inspection of an industrial line with the ability to customize it to increase (decrease) the quality of the work performed; research of all work processes; processing and storage of received information in different forms (creation of a specific database for all tests performed in the simulator); receiving a detailed analysis of the created product characteristics at each stage of the life cycle. One of the current version simulatordisadvantages is the inability of the program to work in automatic mode for the all-data complete transfer. Also, there is an imperfect detailing of theproduction line main elements because of the limited information about modern devices in the public domain. It is necessary to improve it in the field of data transmission and develop real, highly detailed main equipment digital twins from a certain company producing or information from an existing chocolate production. Current version of program can improve the quality of thecreated products, reduce the cost of components and get a new specialization (qualification profile) for employees at the enterprise. During the creation of the software package, the simulation of the main chocolate production line was included the real processwithout any deviation.A virtual production line will not be able to manufacture a product without an exact sequence of actions that are crated in the programmed technical specifications. This information corresponds to the ideal production process according to recipe and characteristic data.

Element of the developed chocolate production line simulator program code has presented below:

```
using System. Collections;
using System. Collections. Generic;
using System. UnityEngine;
public class LineTest :MonoBehaviour
{
private bool I = false;
public float scrollSpeed = 0.15f;
Renderer rend;
private float delay_start = 0.4f;
public GameObjectLight_Bulb_Line;
public GameObjectLine;
public Texture texture;
private float offset;
private float temp;
```

```
   void Start ()
   {
   rend =
Line.GetComponent<Renderer>();
   }
   void Update ()
   {
   if(i == false)
   Light_Bulb_Line.GetComponent<Rendere
r>().material.color=Color.red;
   }
   else if (i == true)
   {
   rend.material.mainTexture = texture;
   offset = Time.time * scrollSpeed;
   rend.material.SetTextureOffset("_Mai
nTex", new Vector2(offset,0));
   Light_Bulb_Line.GetComponent<Rendere
r>().material.color = Color.green;
   }
   }
   void OnMouseDown()
   {
   if(i == false)
   {
   i= true;
   }
   else
   {
   i = false
   }
   StartCoroutine(Delay_COR());
   }
   IEnumeratorDelay_COR()
   {
   transform.Translate(0,4,0);
   yield return new
WaitForSeconds(delay_start);
   transform.Translate(0,-4,0);
   }
   }
```

Inthe appendix article there is a video which was recordedin testing process of the software complex by a test operator. It imitates the work of a chocolate production line. If specialized equipment (virtual reality helmet, control panels, etc.)is available in educational institutions, this program could beused by it.

4 CONCLUSIONS

Food industry is a fairly independent industry which in recent years has demonstrated the technological growth and the potential for introducing digital solutions into production lines. The modern software solutions could be used at all stages of any production. The development and implementation of virtual simulators will minimize production losses, as well as train qualified personals on devices that are close to reality. Future researches in the field of food industry digitalization are associated with the modernization and detailing of existing models, the development of new algorithms and hardware components of systems and the creation of new scenarios for the operation of industrial lines.

Developed simulator of a chocolate production line can be implemented into existing educational programs for training specialists in the field of confectionery products in the food industry. Advantages of using the created a chocolate production line virtual simulator: flexible configuration of educational materials in accordance with the production line used; creation of automatic forecasting and assessment of students tasksperformance; generating reports and recommendations to the student during the operation of the industrial line; structuring the main visual indicators and collected information on production control and engineering skills during the use of the simulator.

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APPENDIX

Link to video of developed chocolate production line simulator working in Google Drive: https://drive.google.com/file/d/1P5xVcFZRuMhJoUtaQ3l1KfwkIKCs1R9x/view?usp=sharing.