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Розроблено структуру контролера фіксації пасажиропотоку громадського транспорту, алгоритм його функціонування, спеціалізоване програмне забезпечення для реалізації функцій контролера та модель на основі мереж Петрі, яка дає змогу дослідити динаміку роботи системи. Розроблено та реалізовано технічне забезпечення контролера на базі одноплатного комп'ютера Raspberry Pi, що забезпечує низьку ціну проектного рішення та є оптимальним рішенням з широкими функціональними можливостями

Ключові слова: "Розумне" місто, контролер фіксації пасажиропотоку громадського транспорту, мережі Петрі, Raspberry Pi

Разработана структура контроллера фиксации пассажиропотока общественного транспорта, алгоритм его функционирования, специализированное программное обеспечение для реализации функций контроллера и модель на основе сетей Петри, которая дает возможность исследовать динамику работы системы. Разработано и реализовано техническое обеспечение контроллера на базе одноплатного компьютера Raspberry Pi, что обеспечивает низкую цену проектного решения и является оптимальным решением с широкими функциональными возможностями

Ключевые слова: "умный" город, контроллер фиксации пассажиропотока общественного транспорта, сети Петри, Raspberry Pi

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DEVELOPING A CONTROLLER FOR REGISTERING PASSENGER FLOW OF PUBLIC TRANSPORT FOR THE "SMART" CITY SYSTEM

O. Boreiko
Lecturer
Department of Computer Engineering
Ternopil National Economic University
Chekhova str., 8, Ternopil, Ukraine, 46003
E-mail: bor@tneu.edu.ua

V. Teslyuk
Doctor of Engineering, Professor
Department of Computer Aided Design
National University "Lviv Polytechnic"
S. Bandery str., 12, Lviv, Ukraine, 79013
E-mail: vtesliuk@polynet.lviv.ua

1. Introduction

We live in a period of wide scale implementation of computer systems and intelligent technologies in all spheres of human life, one of which is the Smart City system [1–4]. Smart City is a complex system designed to provide up-to-date quality of life of residents through the use of new technologies, which involve economic and ecological use of the urban subsystems of life activity. Accordingly, for the implementation of such a system, "smart" solutions in all its subsystems, in particular in transport, are required [5]. The solutions can be: "smart" management of the transportation

flows for solving the problems of traffic jams, calculating the passenger flow of public transport to enhance its efficiency, tracking the motion of public transport and creating "smart" stops for the convenience of passengers.

In general, accounting passengers and tracking the motion of public transport ensure transparent use of a transportation vehicle by bus drivers, compiling schedules and efficient management of traffic to improve security, convenience and comfort of the residents of a "smart" city.

Accordingly, it is a relevant task to design a controller for registering the passenger flow of public transport in the system of management of traffic flows of a "smart" city, which is characterized by wide functional capacities, low price and high accuracy of determining passenger flow.

2. Literature review and problem statement

An analysis of the scientific literature on this subject gives us a reason to argue that well-known world companies, which are involved in the development of specialized equipment for registering passenger flow of public transport, are German companies "Iris" and "Dilax" [6], Canadian company "Infodev" [7], and Italian company "Eurotech" [8]. The listed manufacturers use different kinds of embedded computers and modules, intelligent devices and cameras, cloud technologies and supercomputers, various sensors and controllers [9].

In Ukraine there are also a number of companies that deal with the problems of creating "smart" transport as well. In particular, they include "Protection-Group" (Ternopil) [10], "Gemicle" (Vinnytsa) [11], "SVT Navigator" (Lviv) [12], "GPS Systema" (Kyiv) [13], and city councils of a number of cities [14].

A classic example of calculating passenger flow is the systems, built with the use of the control step at the entrance and meters based on the infrared sensors [15]. Such systems have a number of disadvantages, the main of which is a high level of error that affects accuracy of the calculation.

One of the most popular solutions in this direction is the development of "e-ticket" systems. The equipment in such systems operates on the basis of the NFC (NearField Communication) modules, validators and smart cards [16]. The shortcoming of such systems is the fact that they imply existence of the NFC modules, embedded in a passenger's mobile phone (in most cases it is missing); if there is no phone, then a passenger may use a smart card, which must be purchased at special points, which must be equipped accordingly. This system does not exclude the case of passing cash from a passenger to the driver if there is no travel card [17].

The solutions based on the use of video cameras and applications on the basis of computer vision [18] and photogrammetry [19] are also under development. The process of development or purchase of such software is fairly resource intensive while accuracy of the calculation usually does not exceed 85–95 %.

An analysis of existing technical solutions that we conducted demonstrates that the disadvantages of systems of accounting passenger flow of city public transport include high price of equipment, insufficient functionality taking into account specifics and peculiarities of passenger traffic turnover in Ukraine and low accuracy of calculation of passengers.

Accordingly, the purpose of the study is the development and implementation of a physical model of a controller for registering passenger flow of public transport of a "smart" city, which would guarantee functionality, high accuracy of calculating passengers, transparent cash flow from a passenger to the driver and a reasonable price of equipment.

3. The aim and tasks of the study

The aim of this work is the development of a controller for registering passenger flow of public transport, which is characterized by wide functional capacities and low price.

To achieve the set goal, it is necessary to solve the following tasks:

– to develop a structure of a client-server system for accounting passenger flow of city public transport and a structure of the controller for registering passenger flow of public transport, which are based on the modular principle;

– to build up an algorithm for functioning of a controller and a model for the analysis of work of the controller for registering passenger flow of public transport based on the Petri network theory, which will allow us to explore the dynamics of work of the designed device;

– to develop specialized software of the controller for registering passenger flow of public transport, which implements all of the aforementioned functions of the device;

– to build a physical model of a controller for registering passenger flow of public transport, which is based on the modular principle, uses a single board computer Raspberry Pi and ensures low cost of technical solution.

4. Development of a client-server system of accounting passenger flow of city public transport

This work highlights the client part of the system of registering passengers flow and the motion of public transport. The system operates on the basis of the client-server interaction. The client (controller) is responsible for the collection, initial processing and sending data to the server (web, ftp). The server part deals with processing, storing and analyzing data from all clients, their presentation in a format convenient for the user, and building up of analytics. A simplified diagram of a client-server system for registering passenger flow and the motion of public transport is represented in Fig. 1. It includes drivers and the modules that interact with customers, as well as operators who interact with the server.

4. 1. Development of structure of controller for registering passenger flow

The structure of the device for registering passenger flow that we built includes a controller, which has the following constituent elements: the single board computer Raspberry Pi [20]; GSM module; GPS module; controller of battery power supply of the device (CBPD); controller of emergency restart of the device (CERD); button for registering passengers enjoying privileges (PEP); camera for registering passengers enjoying privileges and cameras for registering passenger flow in the vehicle. An example of the designed structure is shown in Fig. 2.

The developed structure is characterized by the modular organization that allows quickly upgrading the designed device.

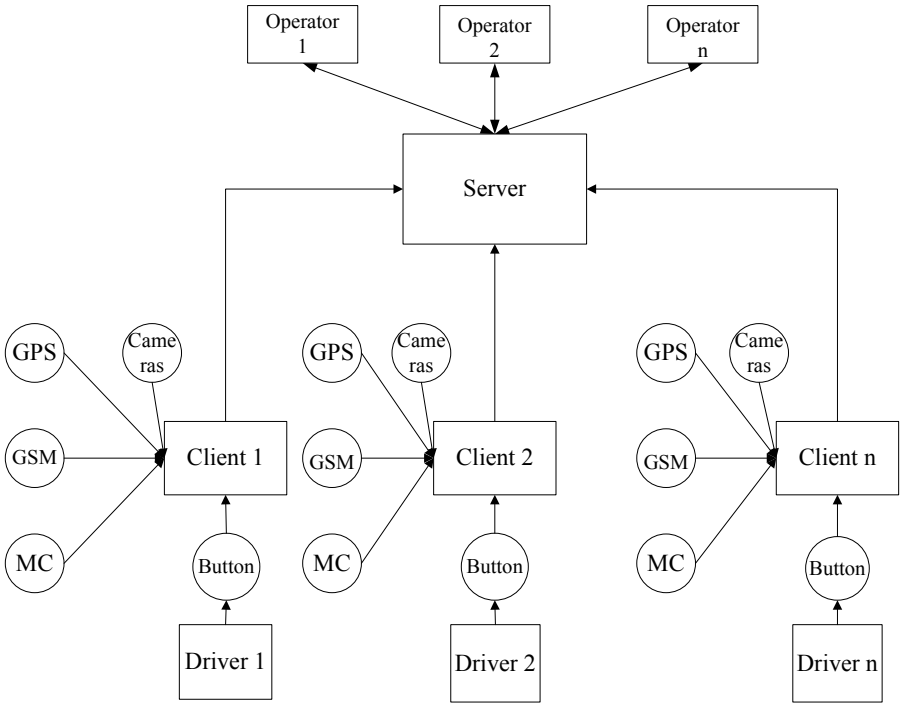

Fig. 1. Scheme of client-server system of passenger flow of city public transport

4. 2. Algorithm of the device performance

The operation of the device is organized in such a way that when one opens front or rear passenger doors of a transportation vehicle, video capturing of passengers getting on and off starts automatically (Fig. 3).

As soon as a signal of doors closing is received, the video fixation stops, the video files are stored in the memory of the controller and are prepared to be sent to the server. Corresponding operations are implemented using components of the controller, which are shown in Fig. 2.

If a passenger who enjoys privileges gets on a bus at a bus stop, the driver has to ask him to show appropriate document and then use the button of registering passengers who enjoy privileges, which activates the photo camera.

During these actions (doors opening, pressing the button of registering passengers who enjoy privileges), the POST/GET requests with the date, coordinates and names of files that are sent to the server for processing, are automatically formed on the controller.

If there is no connection with the remote server, all data are stored in the memory of the controller as archives and are sent to the server as soon as the connection resumes.

In a case of power cut off in a vehicle, the system proceeds to the offline power mode, registers this situation, sends the information about it to the server and in a certain time correctly completes its work by self turn-off.

If the device freezes under certain circumstances, in particular the operating system Raspbian Wheezy, the controller of emergency restart will perform its function and make a forced restart of the entire system to ensure improved reliability and stability.

The constructed algorithm allows meeting the requirements for registering parameters of the passenger flow and archiving the data. The block diagram of the designed algorithm is shown in Fig. 3.

4. 3. Device software

The Raspberry Pi 2 Model B in this configuration is operated by the Raspbian Wheezy system [21] that was developed on the basis of Debian. The Raspbian is a project to create the port Debian Wheezy (7.x) armhf with support of mathematical coprocessor for Raspberry Pi. It is designed to provide users of Raspberry Pi with an access to more than 10000 binary Debian packages, optimized for the best compatibility with Raspberry Pi. The project is still under development, the compilation of all the packages was completed in June 2012. Currently, all efforts are aimed at making Raspbian the easiest, the most stable and most optimal distributive of Linux for Raspberry Pi.

Programming of microcontrollers was carried out in the language C, and programming of the controller based on the Raspberry Pi 2 Model B was performed using Python.

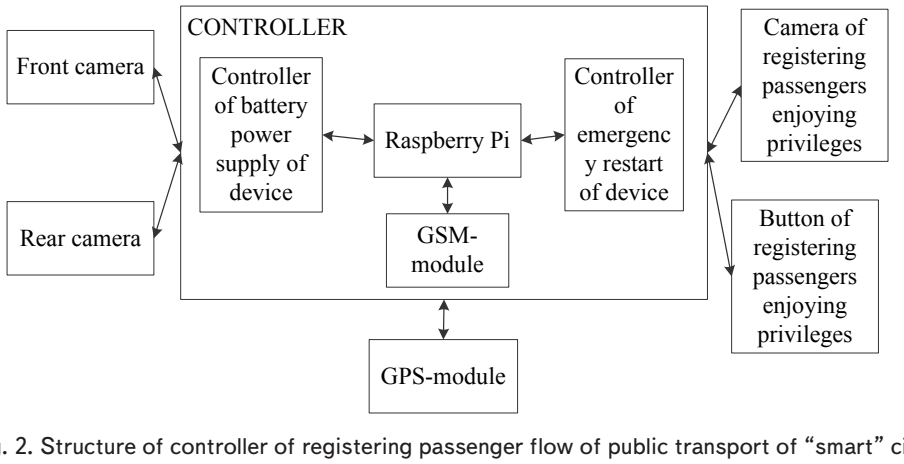

Fig. 2. Structure of controller of registering passenger flow of public transport of "smart" city

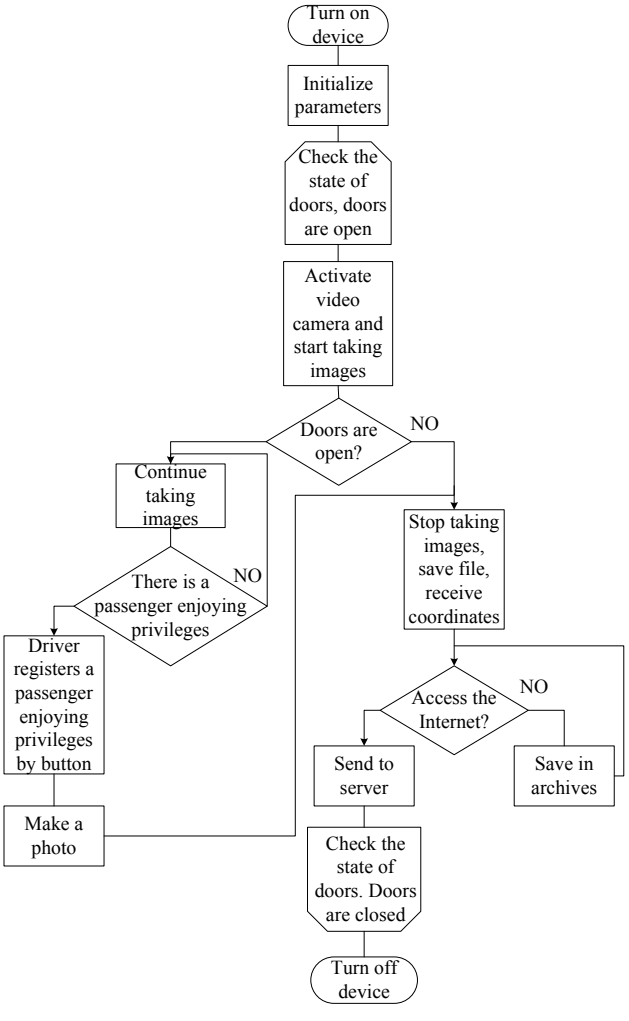

Fig. 3. Block diagram of operating algorithm of designed device

The base of the controller software is the modules, developed in the Python language. They include scripts that are responsible for data exchange between Raspberry Pi and GPS module, GSM module, cameras, microcontrollers, primary processing of the received data and sending them to the server.

Most of the third-party programs were installed from the packages of the standard repository Raspbian Wheezy.

4. 4. Model of controller based on the Petri networks

A structural model of the controller was built using apparatus of simulating complex discrete systems of the Petri networks [22]. In a general case, model based on the Petri networks can be described by the following expression:

$$N = \{S, T, F, M_0\},$$

where

$$P = \{S_1, S_2, ..., S_n\}$$

is the set of positions (states);

$$T = \{t_1, t_2, ..., t_m\}$$

is the set of transitions; F is the set of arcs, which includes two subsets of input and output arcs in relation to transition; M_0 is the set that specifies initial markings of the Petri networks.

This model reproduces the course of processing by the controller of the input data from peripheral devices (IP cameras, USB cameras, buttons, GPS module, GSM module) with sending the processed data to the server [23, 24]. A structural model of the controller based on the Petri networks is presented in Fig. 4.

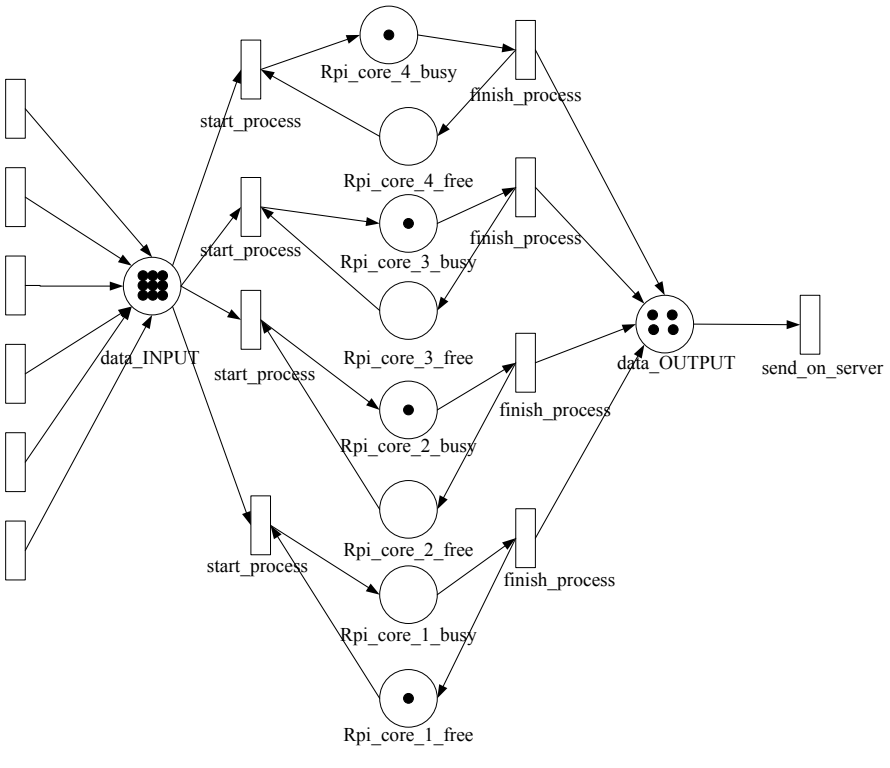

Fig. 4. Structural model of controller with the use of the Petri networks

It was found in the process of simulation that all states of the network are available, there are no dead-ends, and the Petri network is active and attainable.

5. Discussion of results: physical implementation of the controller for registering passenger flow of public transport

In the work we developed a physical model of the controller for registering passenger flow in public transport. The base of the controller is the well-known single board computer Raspberry Pi 2 Model B. The choice is explained by full functionality of this mini-computer, as well as the relative cheapness and its wide use, the main characteristics of which are given in Table 1.

Table 1

Basic technical characteristics of the computer Raspberry Pi 2

Processor type	ARM Cortex-A7
Frequency, GHz	0,9
Number of cores	4
Volume of RAM, GB	1
Graphic chipset	integrated VideoCore IV 3D
Sound controller	integrated
External ports	4x USB, HDMI, 1xAudio Jack (Mic in/Headphone out)
Card reader	microSD
Network adaptor	Ethernet
Additional interfaces	Camera interface (CSI), Display interface (DSI), 40 GPIO pins

Module L20 of Quectel company was selected as the GPS module. The GPS module L20 operates on the base of SiRF StarIV chip. 48 PRN channels will allow L20 to discover and capture satellites in the shortest time, even with an extremely low signal. This module is configured to work with the controller by the UART interface. GSM module is presented by a 3G modem by ATEL, which is configured to work with Raspberry Pi Model B 2. This model is connected to the controller via USB connector.

A certificate button is a usual closer of contacts to activate the camera. A camera for registering certificates of the passengers enjoying privileges is a Web camera that performs registration of people enjoying privileges by taking photos when a driver presses the certificate button, is connected to the controller also via USB connector. This model uses the USB web-camera by Trust.

Cameras above the doors of a transportation vehicle are presented by the IP-cameras made by Intellinet. Video cameras and the network's controller card through the network switch make up a local computer network.

A controller of the battery power supply of the device is a board with a microcontroller and a rechargeable battery. This subsystem provides backup power supply and correct shutdown of the system.

A controller of emergency restart of the device is a microcontroller, which performs the function of the forced restart of the whole system in case of emergency, when it has stopped working and cannot restart by itself.

An example of the implemented physical model of the controller for registering passenger flow of public transport of a "smart" city and positive results of testing allow us to draw a conclusion about correctness and conformity with the requirements of its operation. In particular, the casing of the controller is presented in Fig. 5–7. An example of a plafond with the embedded camera and LED lighting is presented in Fig. 5. Small dimensions are the design features of the microcontroller.

Fig. 5. Controller's exterior view

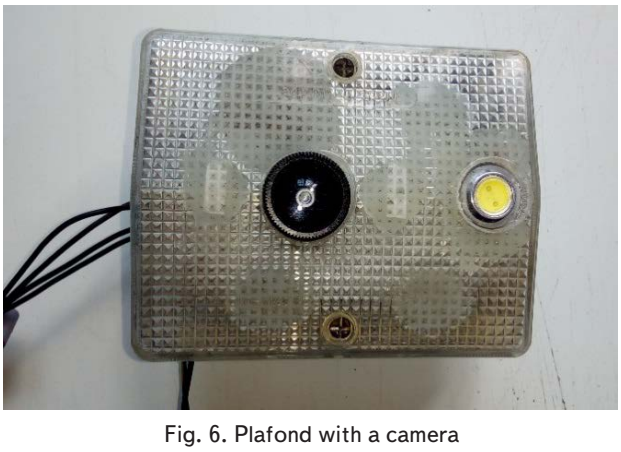

Fig. 6. Plafond with a camera

Thus, a developed physical model of the controller for registering passenger flow of public transport performs all necessary functions, makes it possible to calculate parameters of passenger flow with high accuracy and is characterized by low price.

Fig. 7. Main components of the designed device (1 — plafond with front camera, 2 — plafond with rear camera, 3 — certificate camera, 4 — 3G modem, 5 — GPS module, 6 — certificate button)

Using the single board computer Raspberry Pi with a fully fledged operating system and the Python programming language provides for an effective and rapid implementation of the functional at the program level, which is an important element under conditions of changing the rules of carrying passengers and adding additional features. Since upgrading the device and changing functions of the system are performed through the software modification rather than technical modification, which is an expensive and time-consuming process. Moreover, the programs written in Python are cross-platform, which ensures operation of the developed software with various operating systems and hardware platforms and allows cutting down the costs of program development.

A developed and implemented controller for registering passenger flow of public transport is used at the auto transportation enterprises (ATE) "Mens-Auto" and "Etalon" in the city of Ternopil (Ukraine).

However, from the view of enhancing reliability and accuracy of the system, it is planned to use in future microcontrollers of the Cortex M3 family, STM32F103VE, which will work with TTL cameras with the serial interface in plafonds and communicate with the main controller (Raspberry Pi) by SPI.

6. Conclusions

1. We developed a structure of the client-server system for accounting passenger turnover of city public transport and the controller for registering passenger flow using a modular principle, which ensures effective modification and improvement of the designed system in the process of its development. The proposed structures ensure meeting all requirements for the designed system and easy scaling of the system in future.

2. To study all possible states in the process of functioning of the controller, a model based on the Petri theory of networks was developed. Constructed model made it possible to explore the dynamics of operation of the designed system. In the process of modeling, it was found that all states of network are available and attainable, there are no dead-ends and the Petri network is operating.

3. Specialized software based on the object-oriented approach was developed, which allows rapid expanding and improving functionality of the system. A combination of the high level programming languages Python and C provides for flexibility in the process of considering the peculiarities of hardware platform based on the single board computer Raspberry Pi and allows achieving necessary performance speed and functionality.

4. A physical model of the controller for registering passenger flow of public transport was developed and implemented. To ensure low cost of the project solution, the single board computer Raspberry Pi was used. A combination of the developed technical and software provision of the controller for registering passenger flow of public transport allows achieving high accuracy of determining passenger flow parameters. Designed and implemented controller for registering passenger flow of public transport was tested at ATE "Mens-Auto" and "Etalon" in Ternopil (Ukraine). Obtained results make it possible to state that the system is working properly and correctly and the device performs all its functions in full.

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За результатами експериментальних досліджень проаналізована на однорідність стохастична структура вибірок волокон льону олійного української та польської селекції. Визначені закони розподілу волокон як сумішей нормального та логарифмічно нормального законів розподілу. Показана адекватність побудованих нелінійних моделей законів розподілу. Доведена суттєва розбіжність ймовірнісних розподілів довжин волокон льону олійного різної селекції на основі статистичного критерію Колмогорова-Смирнова

Ключові слова: льон олійний, показники якості, суміш законів розподілу, адекватність нелінійних моделей, критерій Колмогорова-Смирнова

По результатам экспериментальных исследований проанализирована на однородность стохастическая структура выборок волокон льна масличного украинской и польской селекции. Определены законы распределения волокон как смесей нормального и логарифмически нормального законов распределения. Показана адекватность построенных нелинейных моделей законов распределения. Доказано существенное расхождение вероятностных распределений длин волокон льна масличного различной селекции на основе статистического критерия Колмогорова-Смирнова

Ключевые слова: лен масличный, показатели качества, смесь законов распределения, адекватность нелинейных моделей, критерий Колмогорова-Смирнова

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HOMOGENEITY INVESTIGATION OF OIL FLAX PROCESSING PRODUCTS BY QUALITY INDEXES

N. Tuluchenko
Postgraduate student*
E-mail: nadya.tuluchenko@mail.ru
L. Chursina
Doctor of Technical Sciences, Professor*
E-mail: chursina_la@mail.ru
D. Krugliy
PhD, Associate Professor*
E-mail: natali270869@ukr.net
*Department of commodity, standardization and certification
Kherson National Technical University
Berislav highway, 24,
Kherson, Ukraine, 73008

1. Introduction

In the conditions of development of innovative technologies, the index of successful work of industrial enterprises is the quality of products. One of the factors of products quality management is a reliable forecast of quantitative and quality descriptions of the properties of these products on the stage of planning. Despite the considerable number of standards and specifications that regulate methodologies of testing of raw materials, finished products and estima-