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ІНТЕЛЕКТУАЛЬНІ СИСТЕМИ ПРИЙНЯТТЯ РІШЕНЬ І ПРОБЛЕМИ ОБЧИСЛЮВАЛЬНОГО ІНТЕЛЕКТУ

INTELLIGENT SYSTEMS OF DECISION-MAKING AND PROBLEMS OF COMPUTATIONAL INTELLIGENCE

ISDMCI 2024

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UNIVERZITA J. E. PURKYNE V USTI NAD LABEM

National University of Water and Environmental Engineering

June 20-23, 2024
Khmelnitskyi, Ukraine
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І 73 ***Інтелектуальні системи прийняття рішень і проблеми обчислювального інтелекту (ISDMCI'2024)***: матеріали XX Міжнародної наукової інтернет-конференції (20-23 червня 2024 р., м. Хмельницький, м. Усті над Лабем) / за ред. В. І. Литвиненка, С. А. Бабічева. – Херсон: Книжкове видавництво ФОП Вишемирський В. С., 2024. – 49 с.

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У збірнику представлені матеріали наукової конференції «Інтелектуальні системи прийняття рішень і проблеми обчислювального інтелекту», яка відбулася 20-23 червня 2024 р. та була присвячена актуальним питанням сучасних методів прийняття рішень та інформаційних технологій.

Матеріали збірки розраховані на викладачів та студентів вищих навчальних закладів, фахівців науково-дослідних установ та підприємств.

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CONTENT

IMPROVING OF SIMPLIFIED ANALYTHICAL MODEL FOR CALCULATING THE EVACUATION DURATION IN HIGHER EDUCATION INSTITUTIONS WITH INCLUSIVE GROUPS USING MACHINE LEARNING METHODS

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Statistics show that over the past 10 years, the number of students with special educational needs in Ukraine has increased almost 15 times. As of September 1, 2023 more than 12,000 of them study in higher education institutions [1]. The current legislation of Ukraine enshrines state guarantees for the formation of an accessible and safe educational space. Fire protection is an important component of life safety. For each object, one of the criteria for assessing the level of fire safety is the value of individual fire risk. This is a complex indicator, the calculation of which involves taking into account several parameters. One of these parameters is the evacuation duration from the building in case of fire.

The analysis of regulatory documents [2-3] shows that the existing methods do not allow taking into account the presence of students with special educational needs in evacuation flows and their influence on the speed of the flow. This especially applies to evacuation participants, who use wheelchairs and supports (crutches) to move around. According to existing norms their share in the study group can reach 10%.

The use of machine learning methods makes it possible to significantly improve existing calculation models and methods and adapt them for use in higher education institutions with inclusive groups.

The first stage of the work involved conducting experimental studies, the purpose of which was the formation of a dataset, which was later used to train the regression model. During the experiment, the process of an organized evacuation in a higher education institution was reproduced.

Conducting the experiment involved 3 repetitions of 10 different scenarios, in each of which the human flow configuration was different (Table 1).

Table 1

Experimental scenarios

Scenario #	Total number of agents	Number of agents using crutches M3 (%)	Number of agents using wheelchairs M4 (%)	Number of measurements
1	30 (100%)	0 (0%)	0 (0%)	44
2	29 (96,67%)	1 (3,33%)	0 (0%)	46
3	28 (93,33%)	2 (6,67%)	0 (0%)	35
4	27 (90%)	3 (10%)	0 (0%)	37
5	29 (96,67%)	0 (0%)	1 (3,33%)	41
6	28 (93,33%)	0 (0%)	2 (6,67%)	39
7	27 (90%)	0 (0%)	3 (10%)	43
8	27 (90%)	1 (3,33%)	2 (6,67%)	43
9	27 (90%)	2 (6,67%)	1 (3,33%)	47
10	28 (93,33%)	1 (3,33%)	1 (3,33%)	41
Total				**416**

Thus, based on the results of processing the video recordings obtained during the experiment, a dataset of 416 speed measurements was obtained (Fig. 1)

The values of the correlations between the components indicate that the flow density (–0.8) has the strongest influence on the change in the movement speed. An increase in density leads to a decrease in speed. An increase of the percentage of people moving in wheelchairs in the flow also causes a decrease in speed (–0.56). The presence of students using crutches reduces the speed not as significantly as the previous factors (–0.19).

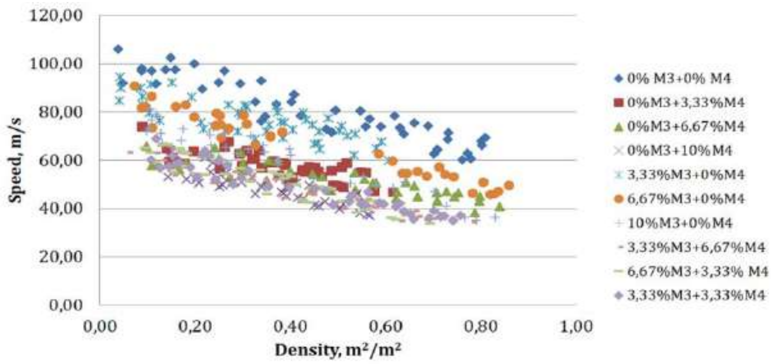

Figure 1. Experimental results

The multicollinearity test showed that the correlations between the predictors are insignificant.

To establish the dependence of V on parameters D, $M3$, $M4$, a linear multivariate regression model was used. The dataset formed at the previous stage of the research was divided into training and test samples in the ratio of 80% to 20%. The results of model training are shown in Table 2.

Table 2

Results of linear multifactor regression

Training data r-squared	0.8199169538612172
Test data r-squared	0.8518523861252831
Intercept	97.03142043670684
Mean absolute error (MAE)	5.304716849646792
Mean squared error (MSE)	39.776420412012506

According to the results of the regression analysis, equation (1) was obtained:

$$V = 97{,}03 - 44{,}68 \cdot D - 1{,}89 \cdot M_3 - 3{,}36 \cdot M_4, \quad (1)$$

where V is the speed of flow, m/s; D – flow density, m²/m²; M_3 – percentage of participants using crutches (%); M_4 is the percentage of participants using wheelchairs (%).

The second method involved the use of a fully connected neural network [17]. Initially, data normalization was performed using the .mean() and .std() methods.

The neural network architecture comprised 2 layers of neurons, with the initial layer comprising 144 neurons activated by the ReLU function. The output layer was a single neuron. A total of 721 parameters were trained. The dataset was split into training and testing sets at an 80:20 ratio. Adam optimizer was utilized, with Mean Square Error (MSE) serving as the performance metric. Additionally, Mean Absolute Error (MAE) was selected as a measure of accuracy. After 80 training epochs, the MSE reached a value of 14,69 on the training and 15,21 on the test samples. MAE reached a value of 3,16 on the training and 3,23 on the test samples.

The comparison of the main metrics shows the better accuracy of the work on the test sample of the neural network in comparison with the linear multiple regression model (Fig. 2).

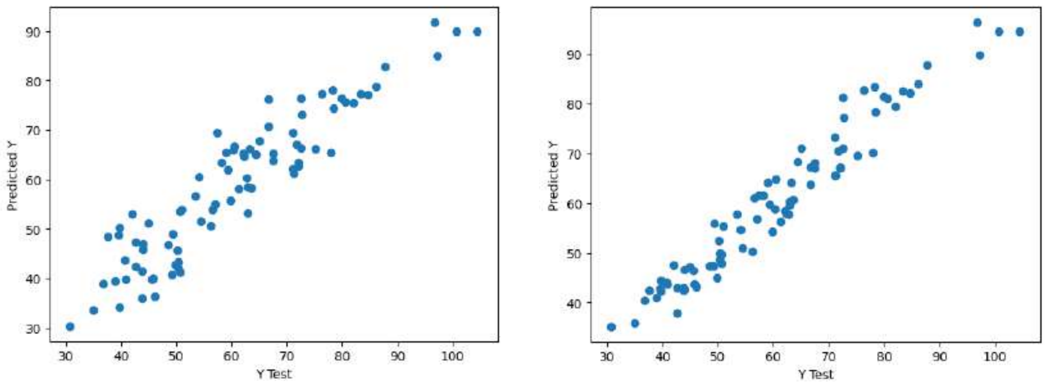

Figure 2. Results of neural network test sample values prediction (a – linear regression model; b – neural network)

The effectiveness of evacuation duration calculations using the obtained models was tested in practice. For this, another series of experiments was conducted with the involvement of other participants. At the same time, on the experimental section of the path with a width of 3 m and a length of 50 m, a section with a length of 5 m was provided, on which the width was narrowed to 1.2 m. This made it possible to achieve different values of the flow density during the movement.

The evacuation duration under each of the scenarios was determined in seconds. After that, the corresponding values were determined by calculation, using a standardized simplified analytical model, the Pathfinder software complex (Fig. 3), as well as improved simplified analytical models supplemented by dependence (1) and a model based on an artificial neural network (NN), respectively.

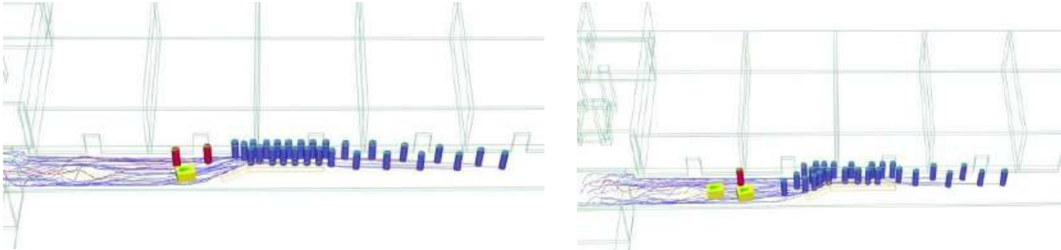

Figure 3. Computer simulation of the evacuation process

The obtained results were summarized in Table 3.

Table 4

Comparison of evacuation duration values (in seconds)

Scenario #	Experiment	Simplified analytical method [2]	Pathfinder software complex	Modified simplified analytical method (Eq. (1))	Modified simplified analytical method (NN)
1	37	30 (–18,92%)	41 (10,81%)	31(–16,22%)	33 (–10,81%)
2	50	42 (–16,00%)	56,3 (12,60%)	44 (–12,00%)	45 (–10,00%)
3	52	42 (–19,23%)	58,2 (11,92%)	47 (–9,62%)	47 (–9,62%)
4	55	42 (–23,64%)	60,3 (9,64%)	48 (–12,73%)	49 (–10,91%)
5	58	50 (–13,79%)	65,9 (13,62%)	54 (–6,90%)	54 (–6,90%)
6	60	50 (–16,67%)	69,3 (15,50%)	55 (–8,33%)	56 (–6,67%)
7	63	50 (–20,73%)	71,1 (12,86%)	56 (–11,11%)	58 (–7,94%)
8	62	50 (–19,35%)	70,3 (13,39%)	56 (–9,68%)	57 (–8,06%)
9	60	50 (–16,67%)	66,7 (11,17%)	55 (–8,33%)	55 (–8,33%)
10	59	50 (–15,25%)	66,2 (12,20%)	54 (–8,47%)	54 (–8,47%)
Average deviation		-18,02%	12,37%	-10,34%	-8,77%

For each of the calculation methods used in the work, the deviation from the experimental results was determined in percent.

The obtained models make it possible to calculate the value of the mixed flow speed, taking into account not only the density, but also the percentage of participants with reduced mobility. Thus, machine learning tools make it possible to improve group models for calculating the evacuation duration and to adapt them for use in institutions of higher education with inclusive groups.

It is worth noting that, in addition to students with musculoskeletal problems, students with visual impairments can study in educational institutions with inclusive education. Visual impairment is a factor that also reduces mobility. Therefore, the goal of further research is to improve the proposed models, which would allow taking into account such an option when calculating the evacuation duration. Also, a promising and important task for further research is the extension of mobility groups standardized in current documents using clustering methods.

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