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Michael E. Auer
Thrasyvoulos Tsiatsos *Editors*

Internet of Things, Infrastructures and Mobile Applications

Proceedings of the 13th IMCL Conference

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Editors
Michael E. Auer
Carinthia University of Applied Sciences
Villach, Austria

Thrasyvoulos Tsiatsos
Department of Informatics
Aristotle University of Thessaloniki
Thessaloniki, Greece

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Preface

IMCL2019 was the 13th edition of the International Conference on Interactive Mobile Communication, Technologies and Learning.

This interdisciplinary conference is part of an international initiative to promote technology-enhanced learning and online engineering worldwide. The IMCL2019 covered all aspects of mobile learning as well as the emergence of mobile communication technologies, infrastructures and services and their implications for education, business, governments and society.

The IMCL conference series actually aims to promote the development of mobile learning to provide a forum for education and knowledge transfer, to expose students to latest ICT technologies and encourage the study and implementation of mobile applications in teaching and learning. The conference was also the platform for critical debates on theories, approaches, principles and applications of mobile learning among educators, developers, researchers, practitioners and policy-makers.

IMCL2019 has been organized by Aristotle University of Thessaloniki, Greece, from 31 October to 01 November 2019.

This year's theme of the conference was "Internet of Things, Infrastructures and Mobile Applications".

Again, outstanding scientists from around the world accepted the invitation for keynote speeches:

- Olga Viberg, KTH Royal Institute of Technology, Sweden: **Supporting Self-Regulated Learning with Mobile Learning Analytics.**
- Ralf Klamma, RWTH Aachen University, Germany: **The Future of Learning and Teaching Augmented Reality – A European Perspective**.
- In addition, two invited speeches have been given by
- Ioannis Kompatsiaris, Centre of Research and Technology Hellas—Information Technologies Institute (CERTH-ITI), Greece: **Integrating Sensors, Multimedia and Semantic Analysis for Health and Security IoT Applications**.
- Petros Nicopolitidis, Aristotle University of Thessaloniki, Thessaloniki, Greece: **Security issues in Mobile Communications**.

Furthermore, one very interesting workshop and one tutorial have been organized:

- Tutorial titled "A Gameful Approach Towards Tutors' Professional Development on Mobile Learning and Interactive Blended Learning" by Anna Mavroudi (Norwegian University of Science and Technology, Norway) & Olga Viberg (KTH Royal Institute of Technology, Sweden).
- Workshop titled "5G Networks: Technologies, Challenges, Deployments and Demo" by Thrasyvoulos Spyropoulos (EURECOM, France), Kostas Tsagkaris (Incelligent/Wings ICT Solutions, Greece), Markos Anastasopoulos (University of Bristol, UK) & Evangelos Pikasis (Eulambia Advanced Technologies Ltd, Greece).

Since its the beginning, this conference is devoted to new approaches in learning with a focus to mobile learning, mobile communication, mobile technologies and engineering education.

We are currently witnessing a significant transformation in the development of working and learning environments with a focus on mobile online communication.

Therefore, the following main topics have been discussed during the conference in detail:

- Mobile Learning Issues:
  - Dynamic learning experiences
  - Large-scale adoption of mobile learning
  - Performance support in the workplace
  - Ethical and legal issues
  - Assessment, evaluation and research methods in mobile learning
  - Mobile learning models, theory and pedagogy
  - Lifelong and informal learning using mobile devices
  - Open and distance mobile learning
  - Social implications of mobile learning
  - Design of adaptive mobile learning environments
  - Cost-effective management of mobile learning processes
  - Quality in mobile learning
  - Case studies in mobile learning
  - Interactive Communication Technologies and Infrastructures:
  - Wearables & Internet of Things (IoT)
  - Tangible, embedded and embodied interaction
  - Location-based integration
  - Cloud computing and future Internet research and experimentation (fire) environments
  - Emerging mobile technologies and standards

  - Interactive and collaborative mobile learning environments
  - Crowd sensing
  - 5G network Infrastructure

- Mobile Applications:
  - Smart cities
  - Online laboratories
  - Game-based learning
  - Mobile health care and training
  - Learning analytics
  - Mobile learning in cultural institutions and open spaces
  - Mobile systems and services for opening up education
  - Social networking applications
  - Mobile Learning Management Systems (mLMS)

The following special sessions have been organized:

- Designing and Developing Mobile Serious Games for Augmenting Arts and STEM Competencies, Capabilities and Skills (DG-STEAM)
- University–Industry–Cooperation in Mobile Technologies (UIC-MT)
- Mixed Reality Applications for Industry and Education (MIRINDE)
- Digital Technology in Sports Program Committee (DiTeS)
- 5G Wireless and Optical Technologies for Mobile Communication Systems (5G Fi-Wi for MC)
- Social Networks and Mobile Applications for Health (SNMAH)
- Interactive Learning Interfaces for Music Education (iLIME'2019)

Also, the "3rd IMCL International Student Competition for Mobile Apps" has been organized in the context of IMCL2019. The winning team of the competition presented "Magic-Matt, An Interface To Transform Video Games To A Sports Experience" and were composed by Nikolaos Politopoulos, Agisilaos Chaldogeridis, Hippokratis Apostolidis, Panagiotis Stylianidis, Angeliki Mavropoulou by Aristotle University of Thessaloniki, Greece, presenting the

As submission types have been accepted:

- Full paper, short paper, distant/pre-recorded presentation
- Work in progress, poster
- Special sessions
- Round-table discussions, workshops, tutorials and students' competition

All contributions were subject to a double-blind review. The review process was very competitive. We had to review about 250 submissions. A team of about 160 reviewers did this terrific job. Our special thanks go to all of them.

Due to the time and conference schedule restrictions, we could finally accept only the best 105 submissions for presentation.

Our conference had again more than 175 participants from 31 countries.

IMCL2021 will be held again at Aristotle University of Thessaloniki, Greece.

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3rd IMCL Student International Competition for Mobile Apps

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George Palaigeorgiou	University of Western Macedonia, Greece

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Predictive Modeling Concerning Mobile Learning Advance

Malinka Ivanova(✉)

College of Energy and Electronics, Technical University of Sofia, Sofia, Bulgaria
m_ivanova@tu-sofia.bg

Abstract. The paper treats an application of predictive modeling in the field of mobile learning. A methodology to facilitate the realization of a model predicting the most utilized research topics that are close to the term mobile learning is developed. The constructed model is based on machine learning technique and fuzzy logic method and it predicts the implementation of mobile learning in different educational context. The results point out the found dependency and tendency for future advance of mobile learning.

Keywords: Mobile learning · eLearning informatics · Machine learning · Linear regression · Fuzzy logic

1 Introduction

One brunch of eLearning Informatics as a scientific field explores the possibility of Informatics statements and theories how to be applied in the context of eLearning. Informatics attainments propose a huge pool of knowledge in different topics, including in modeling of concepts, events and processes in eLearning. Modeling algorithms and techniques contribute to better understanding the static and dynamic features of a system, preparing views from different perspectives. For the purposes of modeling a wide variety of machine learning approaches are utilized to automate identification of patterns and trends in the domain of teaching and learning [1]. Predictive modeling with machine learning algorithms allows complex systems to be explored and studied with opportunity of algorithms for self-learning and self-evolving. Predictive analysis facilitates understanding the challenging issues, assumptions permission and decision making based on precise data processing and training.

Mobile learning (mLearning) is seen as the future of eLearning proposing new virtual learning environment that stimulates students to learn from any geographical location and at suitable for them time [2, 3]. Mobile technology is also a driving force for open teaching achieving extreme flexibility and efficacy. eLearning imperceptibly converts to mLearning uncovering multiple advantages of mobile technologies like: devices portability and integration of smart functions, wearability and networking as well as its applications in different learning context. The state of mobile learning in Europe is summarized in [4], giving its main characteristics related to: bridging formal and informal learning, improving collaborative and conversational learning, stimulating self-directed and personalized learning.

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Predictive modeling based on machine learning techniques in mobile learning is well accepted approach for predicting the students' performance and effectiveness, for identifying the students' at-risk and their drop-out rate, to improve retention and engagement.

This work presents a methodology for forecasting the directions for evolvement of mobile learning and its relationships with contextual learning, based on extracted terms from abstract and citation database Scopus and construction and visualization the bibliographic networks as well as applying linear regression and fuzzy logic techniques. A model based on the proposed methodology is created to predict the future state of *mLearning* and its further implementation in a wide variety of scenarios and situations.

2 Methodology

This methodology is developed to facilitate the implementation of a predictive model concerning the mLearning evolvement in order to point out the well explored topics and topics that need more attention by researchers. The methodology consists of the following procedures: I. Data extraction from abstract and citation database Scopus and construction of bibliometric networks through usage of VOSviewer software for scientific visualizations.; II. Creation of preparatory matrixes with extracted terms containing information about terms' *occurrences* in the used set of documents and the terms' *total link strengths* as well as the dependences between *occurrences* and *year* of publication.; III. Applying linear regression algorithm to forecast the effect of changes in the term's *occurrences* and the term's *total link strengths* during eleven consecutive years – from 2008 year to 2018 year as well as to predict the trends trough utilization of Octave software for numerical computations.; IV. Constructing a fuzzy inference system (FIS) through usage of software VisPro for predicting the connection of the term *mobile technology* to the terms *teaching* and *learning*.

I Procedure: Data extraction and bibliometric networks construction.

1. *Gathering data about the term mLearning*. The starting point is query construction in Scopus search engine regarding the keyword *mobile learning* (and its equivalents keywords *mLearning* and *m-learning*) and performance of results limitation according to documents relevance, year of publication – consecutive eleven years – from 2008 to 2018 year, document type – conference paper, article and review, source type - conference papers and journals, language – English. The query is applied to search in Article title, Abstract and Keywords of documents. The obtained bibliographic results (citation information, bibliographical information and abstract and keywords) separately for each year are exported in csv format.
2. *Construction of bibliometric networks.* To find the connections among the term *mLearning* and other extracted terms the bibliometric networks over the selected years separately are constructed. For this purpose the exported .csv file from Scopus is imported in VOSviewer [5]. Several settings are adjusted like: type of analysis is chosen to *co-occurrence* and unit of analysis is selected to *all keywords*. The applied method is *full counting* and minimal numbers of occurrences of a keyword

is limited to *5*. A *co-occurrence link* between two terms shows the number of documents that at the same time include these both terms. Just one link connects two terms. Each link characterizes with a *strength* that is defined with a positive number. The *strength* is greater when the number of *co-occurrences* is higher. *Full counting* method takes into account the assigned number of occurrences of a keyword in documents. Then the software calculated the *total strength* of the co-occurrence links from one term to other terms through text-mining method and linguistic filtering. The result is a list with terms and assigned weights related to frequency of *occurrences* and *total links strength*. The final set with terms is used for creation of bibliometric network that presents the terms, links and distance among them.

II Procedure: Creation of preparatory matrixes.
The preparatory matrices for each year and for every extracted term with values of occurrences and total links strength are prepared for machine learning analysis in Octave software. Two types of data files are created. The first type of data files contains measurements of *occurrences* and *total links strength*. The y-values are *occurrences* of a keyword in documents and x-values are *total links strength* corresponding to the *occurrences*. The second type of data files points out the x-values which are the *years* and y-values show the corresponding *occurrences*.

III Procedure: Building a predictive model forecasting the effect of changes in the terms regarding the values of *occurrences* and *total link strengths* and dependences between *years* and *occurrences*.

Applying Supervised Learning. The sets with the preparatory matrices are used for input data to Octave software. The linear regression algorithm with gradient descent is applied to the training sets according to the equations [6]:

$$y = \beta_0 + \beta_1 x + \epsilon, \qquad (1)$$

where β_0 is a coefficient that represent the intercept and β_1 is the coefficient showing the slope, ϵ is the error.

The prediction of the future y value is based on x value:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x, \qquad (2)$$

where $\hat{\beta}_0$ and $\hat{\beta}_1$ are estimated coefficients for the model.

The residual sum of squares RSS is:

$$\begin{aligned} RSS &= e_1^2 + e_2^2 + \cdots + e_n^2 \\ &= \left(y_1 - \hat{\beta}_0 + \hat{\beta}_1 x_1\right)^2 + \left(y_2 - \hat{\beta}_0 + \hat{\beta}_1 x_2\right)^2 + \cdots + \left(y_n - \hat{\beta}_0 + \hat{\beta}_1 x_n\right)^2, \end{aligned} \qquad (3)$$

where $e_i = y_i - \widehat{y_i}$ is the ith residual.

To minimize the residual sum of squares *RSS*, the coefficients $\hat{\beta}_0$ and $\hat{\beta}_1$ are chosen to be: $\hat{\beta}_1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x}_i)(y_i - \bar{y}_i)}{\sum_{i=1}^{n}(x_i - \bar{x}_i)^2}$ and $\hat{\beta}_0 = \bar{y} - \hat{\beta}_1\ \bar{x}$, where $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ and $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ are samples.

IV Procedure: Construction of a fuzzy inference system for predicting the context of *mobile learning* usage.

The FIS is created for predicting the context of mobile technology usage: for teaching, learning or for both. It is an important issue describing the most common exploitation of mobile technology – whether mobile technology mainly supports teachers or mainly facilitates learners or the applied scenarios are balanced, assisting at equal level the teachers and learners. The numerical data of the extracted terms during the whole examined period with VOSviewer software are used as input for FisPro software. The last one is utilized for FIS construction with three input values: *mobile technology*, *teaching* and *learning* and one output value: *context*. All values (input and output) are defined using standardized fuzzy partitioning approach that is described through the following equation: $\sum_j \mu_{A_j^i}(x) = 1$ for every $x \in X_i$, where x is a point from a fuzzy set A with a membership degree $0 \le \mu_A(x) \le 1$, A_j are fuzzy sets formed after partitioning, μ_A is the membership function [7]. The created fuzzy standardized partitions are characterized with linguistic variables that are chosen to be: very low, low, average, high and very high. The Mamdani conjunctive fuzzy rules are applied in the following form:

$$IF\, x_1\ is\, A_1^i\ AND\, x_2\ is\, A_2^i\ AND\ldots AND\, x_n\ is\, A_n^i\ THEN\, y_1\ is\, B_1^i, \tag{4}$$

where $A_1^i, A_2^i, \ldots A_n^i$ and B_1^i are fuzzy sets that present the input and output space partitioning.

The utilized rule aggregation concerns disjunction of defined conjunctive rules and it is described through the *max* operation:

$$W^j = \{\max(w_r(x)) | C^r = j\} \tag{5}$$

for $\forall j = 1, 2, \ldots, m$ and where r is the number of rules, m is the number of labels of the partitioned space.

3 Creating a Predictive Model

For identification of the key terms connected to the main explored term *mLearning* (mobile learning, m-learning) the software for scientific visualizations VOSviewer is exploited. The extracted terms with their corresponding values of *occurrences* and *total link strengths* are classified in tables for each year. Table 1 is just one example showing the selected terms with non-zero values of *occurrences (O)* and *total link strengths*

(TLS) for 2018 year. The Table 2 includes the values of *occurrences* and *total link strengths* of the term *mLearning* during the explored years – from 2008 to 2018 year. Similar tables to Table 2 containing data for the extracted terms are used as data sources for performance of linear regression algorithm. The constructed bibliometric network for the term *mLearning*, pointing out its connection to the other terms and the strength of each connective link, is presented on Fig. 1.

Table 1. Connected terms to the term *mLearning* in 2018 year

mLearning in context	O	TLS	mLearning in context	O	TLS
mLearning	506	1886	Collaborative/ Cooperative learning	12	49
eLearning	252	1394	Experimental learning	5	34
Engineering education	43	290	Adaptive learning	7	33
Higher education	34	165	Online learning	7	35
Learning through augmented reality	34	164	Ubiquitous learning	21	92
Game-based learning	28	154	Interactive learning	7	43
Personalized learning	7	39	Secondary schools	5	32
Learning in virtual reality	18	112	Distance education	5	23
Language learning	15	63	Informal learning	9	38
Technology enhanced learning	14	84	Flipped classroom	5	12
Problem-based learning	5	25	MOOC	13	77
Blended learning	12	66			

Table 2. *Occurences* and *total link strengths* for the term *mLearning* during the examined period

2018		2017		2016		2015	
O	TLS	O	TLS	O	TLS	O	TLS
506	1886	433	1985	452	2279	441	2344
2014		2013		2012		2011	
442	1902	383	1580	543	2821	419	1886
2010		2009		2008			
463	2423	326	1779	253	728		

The results after applying the algorithm for linear regression for selected terms are summarized through graphics on Fig. 2. The created patterns with trained data express the usage of the terms and show the future trends. The constructed approximate lines are characterized with *intersect* and *slope* which parameters talk about the usage state of a given term at the examined period and about the frequency of the term usage during the years. For example, if a comparison related to the usage of mobile learning in context of learning through augmented reality and learning through games is

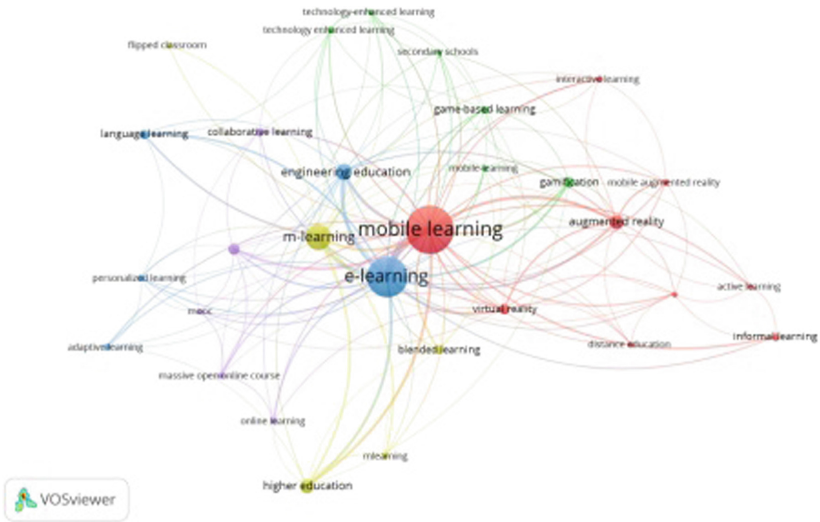
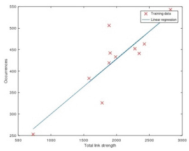


Fig. 1. Bibliometric network for the term *mLearning* for 2018 year

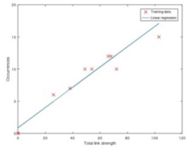
performed, then the analysis shows very close *intersect* and *slope* coefficients that reflect on the similar line steepness. It leads to the conclusion that the topics related to mobile learning through augmented reality and games take the similar attention of researchers, including these terms in their publications. Also, the lines steepness is positive that outlines an increasing tendency for utilization of these terms in the scientific production.

The summarized results after applying linear regression method to the extracted terms indicate one positive tendency of the research topics concerning mobile learning.

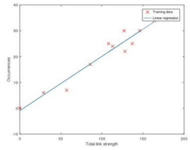
The detailed analysis of the gathered data for 2018 year outlines that the mobile learning is explored in different context and multiple learning scenarios. The highest interest addresses the connection between mLearning and eLearning. Then the explorations are focused on applications of mLearning in engineering education, Higher education, learning through augmented reality, game-based learning, ubiquitous learning, learning in virtual reality, language learning, technology enhanced learning, MOOC, blended learning, collaborative/cooperative learning, informal learning, adaptive learning, online learning, personalized learning, interactive learning. The small number of research papers connects mLearning to problem-based learning, flipped classroom, experimental learning, distance education and learning in secondary schools. With zero values of *occurrences* for 2018 year are the terms: elementary schools, learning through web 2.0 technologies, seamless learning, life-long learning, inquiry-based learning, situated learning, authentic learning, outdoor learning, workplace learning, self-regulated learning/self-directed, pervasive learning, intelligent tutoring, micro-learning.



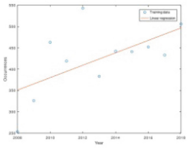
a) O/TLS for the term mLearning



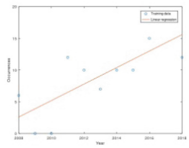
b) O/TLS for the term blended learning



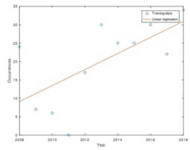
c) O/TLS for the term learning with augmented reality



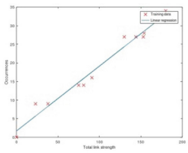
d) O/Year for the term mlearning



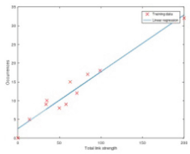
e) O/Year for the term blended learning



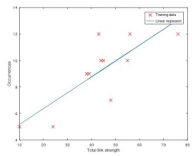
f) O/Year for the term learning with augmented reality



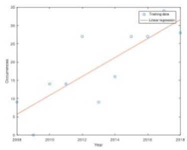
g) O/TLS for the term game-based learning



h) O/TLS for the term language learning



i) O/TLS for the term in-formal learning



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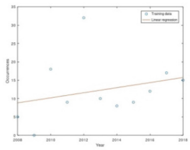

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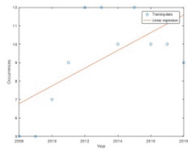

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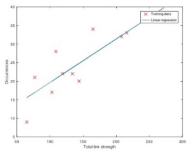
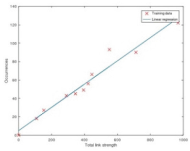
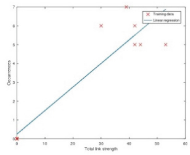


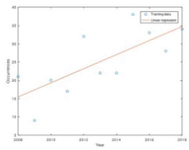
m) O/TLS for the term High-er education



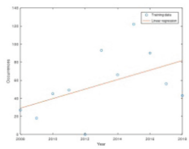
n) O/TLS for the term engineering education



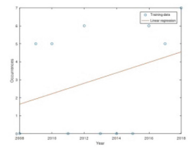
o) O/TLS for the term personalized learning



p) O/Year for the term Higher education



q) O/Year for the term engineering education



r) O/Year for the term personalized learning

Fig. 2. Results from linear regression

In order to understand the future utilization of mobile technology for teaching and learning a FIS is constructed with 125 rules and the part of the inference is shown on Fig. 3. The terms *mobile technology*, *learning* and *teaching* are examined for the period of eleven years – from 2008 to 2018 year. The final result shows different usage of the terms *teaching* and *learning* in the context of mobile learning during the examined years. The extracted tendency is that the term *mobile technology* will be closer to the term *learning* than to the term *teaching*. Also, according to the selected values of the terms *teaching* and *learning* in the constructed FIS could be found a solution that is closer to teaching or to learning as well as an approach for balanced utilization of mobile technology in teaching and learning.

The surface view regarding the FIS response at two input variables *mtechnology* and *learning* is presented on Fig. 4. The red color indicates the minimum of the output value corresponding to the input values.

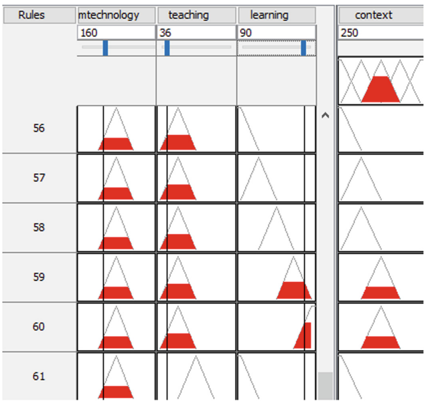


Fig. 3. The constructed fuzzy inference system

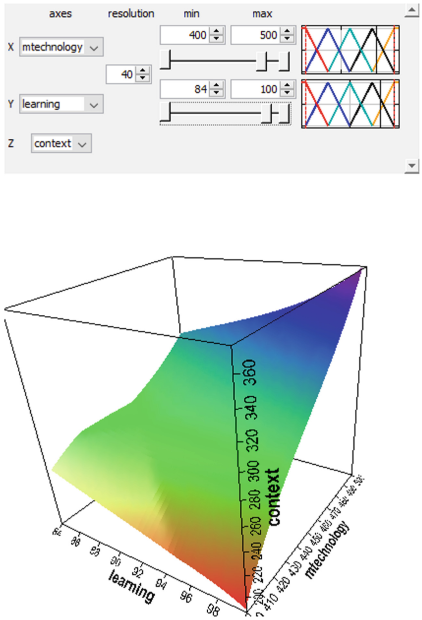


Fig. 4. The FIS response with surface view

4 Conclusion

The current research uses extracted terms from Scopus bibliographic data to describe the current state regarding the connection between the term *mobile learning* and other examined terms as well as to find the tendency concerning the future of mobile learning implementation. For these purposes the machine learning algorithm of linear regression and fuzzy logic method are utilized. Also, a research methodology and a predictive model are developed. The finding point out that the term *mobile learning* is closer to the terms *eLearning*, *engineering education*, *higher education*, *learning through augmented reality*, *game-based learning*, *ubiquitous learning* and with big distance from the term *mobile learning* are the terms: *cooperative learning*, *environmental education*, *elementary education*, *secondary education*, *experimental learning*, *location-based learning*. The found tendency about the usage of the term *mLearning* in scientific publications is characterized with an increasing line. Also, the term *mobile learning* is better connected to the term *learning* that to the term *teaching*.

The proposed methodology and created predictive model are useful for: (1) gathering results about challenging issues and its further understanding, (2) for hypothesis construction and its acceptance/rejection and (3) for decision making taking account the found tendency. In the context of this work, the reached findings outline the more explored topics by researchers and the tendency of their examination during the years. Such findings can give orientation to teachers and researchers about the current state and can indicate the future directions for research.

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