The MOBIKEY Keystroke Dynamics Password Database: Benchmark Results

Margit Antal and Lehel Nemes

Abstract In this paper we study keystroke dynamics as an authentication mechanism for touchscreen based devices. A data collection application was designed and implemented for Android devices in order to collect several types of password. Besides easy and strong passwords we propose a new type of password—logical strong—which is a strong password, but easy to remember due to the logic behind the password's characters. Three main types of feature were used in the evaluation: time-based, touch-based and accelerometer-based. We propose a novel feature set—secondorder—which is independent of the length of the password. The preliminary results show that the lowest equal error rate (EER) is achieved by the logical strong password, followed by the strong password. The worst performance was achieved by the easy password; suggesting that the strong password is the best choice even in the case of keystroke dynamics based authentication systems.

Keywords Keystroke dynamics · Password difficulty · Mobile authentication · Performance evaluation · Sensors

1 Introduction

The pervasive presence of mobile devices equipped with many powerful sensors has led to new authentication mechanisms. One of them is user-authentication based on keystroke dynamics, an active research topic with remarkable results in the case of computers with hardware keyboards. Keystroke dynamics is a behavioural biometric which adds a second level security to alphanumerical passwords, by modelling the users' typing rhythms. Attempts to access the device by impostors, who have illegally

M. Antal (✉) · L. Nemes
Faculty of Technical and Human Sciences, Sapientia University,
Soseaua Sighisoarei 1C, 540485 Tirgu Mures/Corunca, Romania
e-mail: manyi@ms.sapientia.ro

L. Nemes
e-mail: nemes_lehel@yahoo.com

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obtained the user's password (through smudge-attack or shoulder surfing), can be detected based on the fact that they do not type the password in the same rhythm or that they handle the mobile device differently (device holding position, touchscreen usage).

In this paper we propose to investigate the influence of password difficulty on the authentication system's performance. The analysis is performed on our new dataset collected using mobile devices. This allows investigation not only of the effect of password difficulty, but also the influence of new features provided by the sensors of mobile devices.

Our work makes several contributions. One concerns the collected data, which contain the password typing patterns of three types of password i.e. easy, strong and logical strong. Data was collected using mobile devices therefore; besides time-based raw data we obtained additional data from sensors such as touchscreen and accelerometer. We have already made this data publicly available, hence it can be used by other researchers. Another contribution is the proposed secondorder feature set, independent of the length of the password and with equal error rates close to those obtained from the full feature set. The final contributions concern the evaluation results and the software used for the evaluation. Overall, we hope that our work will help focus attention on the opportunities provided by mobile device sensors in user identity verification.

The remainder of this paper is organised as follows. The next section (Sect. 2) presents related work with an emphasis on studies conducted on touchscreen-based mobile devices. Section 3 addresses research methods such as data collection, feature extraction and the different feature sets used in the evaluation. Section 4 offers evaluation results including two-class classifiers and anomaly detectors. The final section concludes our study and its findings.

2 Related Work

Keystroke dynamics is a well researched area. Several survey papers have been published to date [1, 4, 9, 17]. Most of this research has been carried out on computers or older mobile devices that utilise hardware keyboards. Less work has been carried out on touchscreen equipped mobile devices. However, the influence of key press pressure has been studied before the touchscreen smartphone era [8, 12, 14, 16]. In these studies special pressure-sensitive hardware keyboards were built. All these studies came to the conclusion that using key pressure as an addition feature increased the keystroke dynamic authentication system's performance.

In very recent years a few studies have been conducted on touchscreen-based mobile devices [2, 3, 6, 7, 10, 19, 21]. Except for Draffin et al.'s study [7], the other papers present results related to password-based authentication using keystroke dynamics. The most important aspects for the purpose of comparison are the datasets, the features, the methods and the results. Table 1 presents the characteristics of the datasets used in the aforementioned studies. It is important to note that

Table 1 Characteristics of keystroke datasets collected on touchscreen-based mobile devices

Study	# Users	Password	Raw data	Available	Best result(s) (%)
[19]	152	17-digit	Time	NO	FAR: 6.61
					FRR: 8.03
[21]	80	4–8 digit	Time	NO	EER: 3.75
			Touch		
			Accelerometer		
			Gyroscope		
[10]	20	7q56n5ll44 phrase	Time	NO	EER: 13.6
			Space		
[3]	42	.tie5Roanl	Time	YES	EER: 12.9
			Space		
			Touch		
[6]	28	6–8 character	Time	NO	EER: 13.74
			Space		
			Touch		

not all studies saved the touch related raw data in the same way. Zheng et al. [21] and Buschek et al. [6] saved pressure and size (finger area) both at the moment of touch down and touch up. Conversely Antal et al. [2] saved this raw data only at the moment of key press. There are several differences between spatial raw data too. While Antal et al. saved the x, y coordinates only at the key press moment, Buschek et al. saved both the coordinates of the touch point at the moment of touch down and touch up. The differences between raw data imply different features for the analysed studies. Only Zheng et al. used raw data obtained from the accelerometer and the gyroscope sensors.

We have found only three papers which have studied the influence of password difficulty on the performance of keystroke dynamics system. Bartlow and Cukic [5] conducted the first study in this direction. Besides common short 8-lowercase letter passwords, such as `computer` and `swimming`, they used long 12-character length randomly generated passwords the typing of which required the usage of the Shift key. Example of such passwords include `+AL4lfav8TB=` and `UC8gkum5WH`. In almost every EER performance measurement they observed a notable increase (at least 2 %) from short to long password, indicating that the usage of the shift key in a password plays a significant role. In feature ranking the shift key related features proved to be very discriminating.

Meng et al. [18] questioned the use of keystroke dynamics as biometrics. They built a training interface which allows intruders to train themselves in imitating another person's password typing rhythm. For this study they used two 8-character length passwords, an easy and a difficult one. They concluded that passwords that are easier to type are also easier to imitate.

Mondal et al. [15] introduced complexity measurement related to the typing of a password after which several performance measurements were conducted. In contrast to the previous two studies, they concluded that easier passwords are better choice for keystroke dynamics biometrics.

3 Methods

3.1 Data Collection

An Android application was designed and implemented with the aim of collecting typing data for different passwords. Users had to type in three different fixed passwords. The following passwords were used: easy—`kicsikutyatarka`; logical strong—`Kktsf2!2014`; strong—`.tie5Roanl`. The easy password contained only lowercase letters and was formed by the first three words of a Hungarian saying. Our proposal utilises the logical strong type and is based also on the same Hungarian saying, but in this case we took the first letters of the words and used `sf2!` for `sfsf` (two occurences of sf) followed by the year of data collection. The logic behind the logical strong password was explained to subjects before the data collection experiment. The strong password was used in the keystroke dataset collected by Killourhy [11].

54 volunteers took part in the experiment, 5 women and 49 male, with an average age of 20.61 years (range: 19–26). At the registration stage they stated their experience with touchscreen devices as follows: 2—inexperienced, 6—beginners, 17—intermediate and 29 advanced touchscreen users. Among them 4 users were left handed the others right handed. Data was collected in three sessions one week apart. In each session they typed at least 60 passwords, at least 20 passwords from each type. At the end of data collection each user had provided at least 60 samples from each type of password (easy: 3323 samples, strong: 3303, logical strong: 3308). The data was collected using 13 identical Nexus 7 tablets. Typos were not allowed, instead, the subjects had to retype the password. Each password had to be typed in the same way: the same keys had to be typed in the same order.

3.2 Feature Extraction

The application implemented a custom keyboard in order to store the time, touch and accelerometer related raw data during each user's typing. Raw data was saved at touch events initiated by the user for example, at the point of touch down and touch up. Touch down events were generated by the system when the user touched a key on the software keyboard, and touch up at the point of key release. Table 2 shows the raw data saved during the data collection process.

Table 2 The most important raw data saved during data collection

Data	Explanation
Key	The pressed key
Downtime	The timestamp at touch down event
Uptime	The timestamp at touch up event
Pressure	The pressure exerted on the screen at touch down event
Finger area	Touch area at touch down event
x, y	The x and y coordinate at touch down event
ax, ay, az	Acceleration measured along x, y, z axes

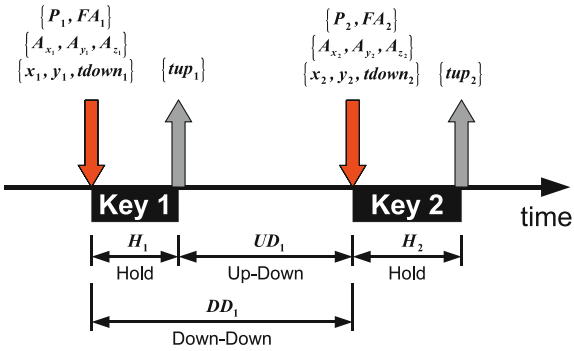

Fig. 1 Data collection. Raw data: *x*, *y*—coordinates; *tdown*, *tup*—timestamps; *Ax, Ay, Az*—directional accelerations; *P*—pressure; *FA*—finger area. Time-based features: *H*—hold time; *UD*—up-down time; *DD*—down-down time

Figure 1 shows the data saved at the moment of touch down and also the time-based features that can be extracted from these data such as hold time—the time between key press and release, down-down time—the time between consecutive key presses, and up-down time—the time between key release and next key press. The Nexus 7 tablet contains an embedded accelerometer with range $-2g$ and $+2g$ and measures the accelerations along three axes (the axes are device related). Its fastest sampling rate on sensor readings is about 50 Hz. During data collection these values were saved at the moment the user touched the screen. Using these directional accelerations we could characterise the device holding preferences of the users.

3.3 Feature Sets

Table 3 shows the full feature sets for each type of password. Because these feature sets contain features related to each key in a password, some feature types contain a different number of features for each password. Mean hold time (MHT) feature represents the average of key hold time values. The other mean values were computed similarly. The total distance feature (TD) was calculated as the sum of the distances (in pixels) between two consecutive buttons on the virtual keyboard. Total time (TT)

Table 3 Full feature sets for each type of password

Mnemonic	Feature type	Easy	Strong	Logical strong
HT	Hold time	15	13	13
DD	Down-down time	14	12	12
UD	Up-down time	14	12	12
P	Pressure	15	13	13
FA	Finger area	15	13	13
MHT	Mean hold time	1	1	1
MP	Mean pressure	1	1	1
MFA	Mean finger area	1	1	1
MAX	Mean X acceleration	1	1	1
MAY	Mean Y acceleration	1	1	1
MAZ	Mean Z acceleration	1	1	1
TD	Total distance	1	1	1
TT	Total time	1	1	1
V	Velocity	1	1	1
Total		82	72	72

represents the time needed to type in the password. Velocity (V) was computed as the quotient of the distance and the total time. Before evaluation data was normalized into the range [0, 1].

Besides the full feature sets presented in Table 3 some evaluations were performed on a so called—secondorder—feature set. This feature set contains 9 features: mean hold time, mean pressure, mean finger area, mean x acceleration, mean y acceleration, mean z acceleration, velocity, total time and total distance. The most important characteristic of this feature set is that the number of features is password-independent. All information related to this research is available at http://www.ms.sapientia.ro/~manyi/mobikey.html.

4 Evaluation and Results

Keystroke dynamics based authentication is a typical outlier detection problem. Given the keystroke data of a typed password the system has to decide whether the data belong to the genuine user. This problem can be formulated as a classification and as an anomaly detection problem. In the case of classification we typically employ a two-class classification algorithm, where the positive samples belong to the genuine user and negatives are selected from the others. Classifiers are more powerful since they yield information about the impostors (negative samples), whereas anomaly detectors can only check the deviation from the genuine

user (positive samples). We should mention that in a real-world authentication system only the anomaly detection method is viable because of the lack of negative samples. However for comparison purposes, we present the evaluation of two-class classifiers too.

4.1 Two-Class Classification

In the case of two-class classification we call the data from the legitimate user positive samples and that from impostors we call negative samples. As our dataset contains data from several users and as each user typed the same password, one can easily select negative data for each user.

The general algorithm used for two-class classification measurements is depicted in Fig. 2. First we select positive and negative samples for a given user (*userData*). As negative samples we used two randomly selected samples from each other user. Then we repeat *nRuns* times the randomization of the data followed by n-fold cross-validation evaluation for the given user. The above two steps were repeated for each user.

Scores for positive and negative test samples were computed so as to form two sets, one for genuine users the other for impostors. Then a user-independent threshold was scanned through the two sets of scores and the False Negative (FN) and False Positive (FP) rates computed for each threshold. Plotted as error curves, these values show the system performance (see Fig. 3).

Besides Random Forests algorithm we chose to evaluate the k-nearest neighbours (kNN) and Bayes Net algorithms. All classification algorithms were used from the Weka Data Mining toolkit [20].

```
1: procedure MEASUREMENT(data, nFolds, nRuns)
2:     for user ← 1, numUsers do
3:         userData ← selectPositiveAndNegativeSamples(data, user)
4:         for run ← 1, nRuns do
5:             userData ← randomize(userData)
6:             for n ← 1, nFolds do
7:                 trainUserData ← trainCV(userData, n)
8:                 testUserData ← testCV(userData, n)
9:                 train two-class classifier for trainUserData
10:                evaluate the trained classifiers using testUserData
11:            end for
12:        end for
13:    end for
14: end procedure
```

Fig. 2 Two-class classification measurement algorithm using n-fold cross-validation

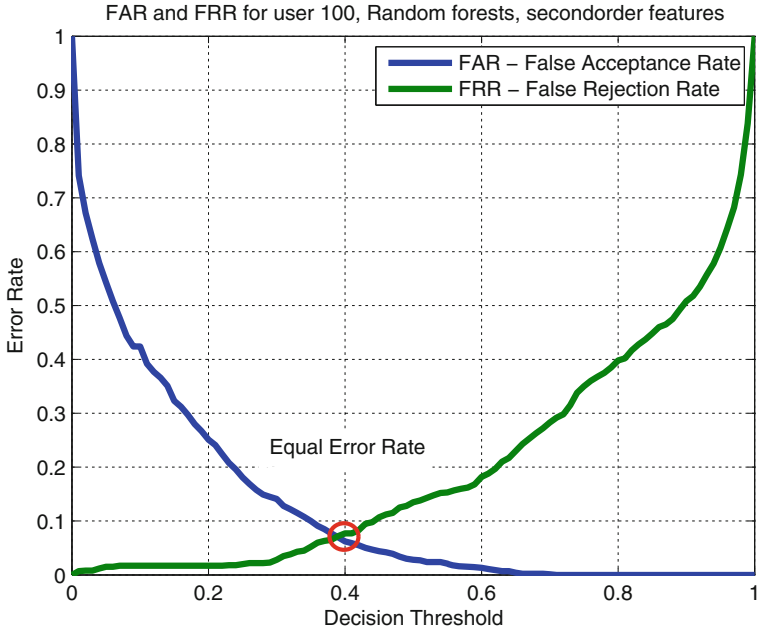

Fig. 3 EER computation for user 100 (Random forests classifier, secondorder features). EER for individual users were estimated as the intersection of FAR (False Acceptance Rate) and FRR (False Rejection Rate) curves

4.2 Anomaly Detection

In the case of anomaly detectors we used five detectors implemented in the R script provided by Killourhy and Maxion [11]. The detectors used were: Euclidean, Manhattan, Mahalanobis, Outlier count and Kmeans. This script works as follows: (i) it splits the data into three equal parts, each containing 20 samples from each user (in our case each part contained data from a single data-collection session) (ii) detectors are trained separately for each user using two-thirds of the data; evaluation was performed on the remaining third positive samples and two negative samples selected from each of the other users (20 positive + 53 * 2 negative); (iii) step (ii) is then repeated three times (threefold cross-validation), and the mean EER and its standard deviation computed.

4.3 Results

Results for classifiers and anomaly detectors are presented in Table 4. EER values were estimated for each user (see Fig. 3), then the mean and standard deviation were computed for each classifier or anomaly detector and each dataset.

Table 4 EER results for different methods and feature sets

Method	Features	Easy	Logical strong	Strong
Bayes net	Secondorder	0.074 (0.046)	0.058 (0.040)	0.067 (0.047)
kNN (k = 1)	Secondorder	0.056 (0.032)	0.048 (0.026)	0.054 (0.036)
Random forests (T = 100)	Secondorder	0.052 (0.029)	**0.045 (0.025)**	0.051 (0.032)
Bayes net	All	0.053 (0.039)	0.046 (0.037)	0.049 (0.038)
kNN (k = 1)	All	0.073 (0.036)	0.068 (0.033)	0.071 (0.043)
Random forests (T = 100)	All	0.032 (0.021)	**0.033 (0.025)**	0.033 (0.022)
Euclidean	Secondorder	0.208 (0.174)	0.149 (0.141)	0.181 (0.145)
Manhattan	Secondorder	0.202 (0.169)	0.144 (0.140)	0.169 (0.146)
Mahalanobis	Secondorder	0.191 (0.182)	0.154 (0.171)	0.159 (0.159)
Outlier count (th = 1.96)	Secondorder	0.208 (0.147)	0.164 (0.140)	0.178 (0.146)
Kmeans (k = 3)	Secondorder	0.177 (0.155)	**0.136 (0.132)**	0.143 (0.137)
Euclidean	All	0.238 (0.186)	0.183 (0.149)	0.195 (0.163)
Manhattan	All	0.203 (0.183)	0.154 (0.140)	0.167 (0.153)
Mahalanobis	All	0.256 (0.140)	0.193 (0.114)	0.210 (0.137)
Outlier count (th = 1.96)	All	0.160 (0.140)	**0.129 (0.126)**	0.143 (0.137)
Kmeans (k = 3)	All	0.173 (0.136)	0.128 (0.097)	0.131 (0.106)

The standard deviations are shown in parenthesis

We used 100 trees for the Random Forests classifier, $k = 1$ for the kNN classifier and the default Weka settings for the Bayes Net classifier. In the case of anomaly detectors the following settings were used: $k = 3$ clusters, at most 20 iterations for the kmeans detector; the *threshold* = 1.96 for the outlier count detector (used to count how many z-scores exceed a threshold) [11].

It can be seen that very low EER values were obtained by the classification algorithms, because these used the negative samples for building the user's model. However in real systems negative samples are not available (in the enrolment stage samples are collected only from the genuine user).

For the error curve we chose the DET error curve (Detection Error Tradeoff) [13], which is the most important error curve for biometric systems. Figure 4a, b show these error curves obtained for the Random Forests classifier (number of trees: 100) and Manhattan detector.

The best equal error rates were obtained by the Random Forests classifier, around 5 % for the secondorder feature set and around 3 % for the full feature set. We mention again that these classifiers use negative samples for building the user's typing model, which is not available in case of real systems. No significant differences were found in this evaluation between different types of password.

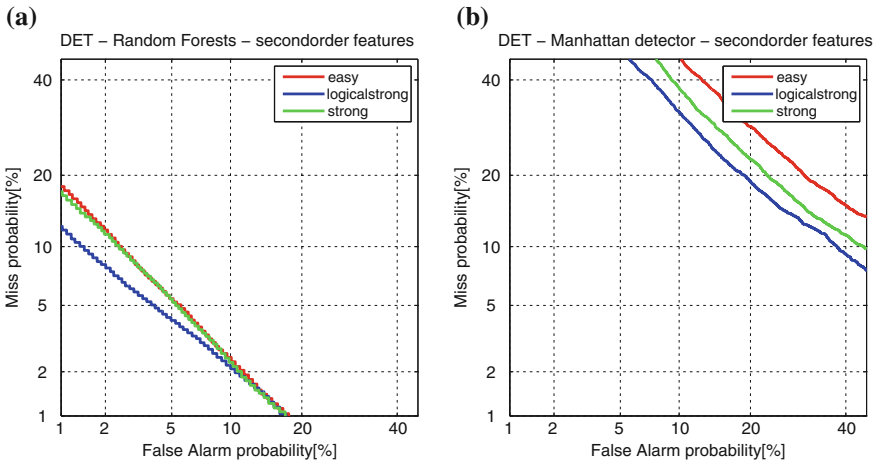

Fig. 4 DET curves—secondorder features. **a** Random Forests (T = 100). **b** Manhattan detector

In the case of anomaly detectors, where the user's model is based only on positive samples (the case of real systems), the equal error rates are always lower for logical strong and strong types of password.

5 Conclusions

Our objective in this work was to collect a dataset on mobile devices containing different types of password and to evaluate the influence of password difficulty on the performance of keystroke dynamics authentication. We provide both the datasets and evaluation methodology to the research community. The main contribution of this paper concerns the datasets, which not only contain three types of password, but contain raw data collected from mobile sensors too. Another contribution is the secondorder feature set which has the same number of features regardless of the password type. Measurements show the effectiveness of this novel feature set as very close to or sometimes better than the results obtained using the full feature set. Evaluations show that in the case of anomaly detectors the lowest equal error rates are obtained for the logical strong password, followed by the strong and the easy one. This is in concordance with the results obtained by Bartlow and Cukic [5] and Meng et al. [18].

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Joint Algorithm for Traffic Normalization and Energy-Efficiency in Cellular Network

P.T. Sowmya Naik and K.N. Narasimha Murthy

Abstract A base station is the core heart of the operation in cellular communication system. Various components e.g. base transceiver station, base station controller, mobile station controller are basically a sophisticated hardware device which require a massive amount of energy just to initiate, manage, and terminate an IP communication over mobile network. Inspite of presence of massive archives of literatures towards addressing energy consumption, there are very few evidence of standard prototype that can be actually adopted in real sense. Therefore, we present an analytical model for jointly addressing traffic normalization problem and energy efficiency problem using simple stochastic geometry. Supported by discussion of algorithms, the presented technique was also compared with one of the most recent study to find its superior performance with respect to energy consumption and processing time.

Keywords Cellular network · Mobile network · Energy consumption · Stochastic geometry

1 Introduction

The area of networking and telecommunication has undergone a significant revolution in past decades. The present scenario of telecommunication is completely different that what used to be there 20 years back. Usage of mobile devices started gaining pace 20 years back, where there are limited mobile phone manufacturer and obviously very limited service providers to obtain network connectivity. But with the increasing pace of technological advancement in semiconductors, the prices of

P.T. Sowmya Naik (✉)
Department of CSE, City Engineering College, Bengaluru, India
e-mail: sowmya.vturesearch@gmail.com

K.N. Narasimha Murthy
Department of CSE, Vemana Institute of Technology, Bengaluru, India

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mobile devices slashed down and more services evolved in Indian consumer market. The present base of users is found to be increasingly using the internet facilities on their mobile devices. Irrespective of economical status and ethnical background of user, mobile communication products and services are quickly establishing itself in every commercial market. Another interesting findings shows that 26 % as majority of user access internet all the 7 days a week. These statistics evidently shows that there are lot of increasing usage of cellular network in recent times which demands a closer look of its scale of effectiveness. Another biggest problem in cellular network is call drop, which even doesn't meet the standard of Telecom Regulatory Authority of India (TRAI). Till date, consumption of energy using services from cellular network is unsolved. A conventional research paper and theory speaks of cellular network in terms of hexagonal topology with essential elements like mobile station and base station. With a massive amount of research manuscript present in digital archives, still a better and benchmarked study towards energy efficiency has not been come across.

Therefore, this paper has introduced a simple framework that focuses jointly on traffic normalization and energy efficiency especially when the traffic is dynamic, uncertain, and unpredictable in nature. Section 2 discusses about prior studies towards energy efficiency followed problem discussion in Sect. 3. Section 4 presents the proposed study followed by research methodology in Sect. 5. Discussion of an algorithm implementation is carried out on Sect. 6 followed by result discussion on Sect. 7. Finally, Sect. 8 summarizes the contribution of the proposed system.

2 Related Work

Hu and Cao [1] have adopted A* search algorithm for minimizing the search space for scheduling offline and online for traffic aggregation for wireless network. Similar study has also been carried out by Gaikwad and Wagh [2] with a difference of focus in LTE network. Giri and Bodhe [3] have presented a technique by signifying importance of multi-agent system that can ensure better QoS in cellular network. The outcomes shows that better performance of call blocking probability can ensure better QoS which can directly contribute to energy conservation. Correa and Fernandes [4] have also emphasized about the QoS factor for better scalability, network efficiency, and Quality of Experience. Study towards QoS enhancement on heterogeneous network was carried out by Kaleem et al. [5], where the authors have aimed for enhancing the throughput for cell-edge user as well as to minimize the interference owing to allocation of dynamic bandwidth. Mtaho and Ishengoma [6] have investigated about various essential parameters that directly influence the QoS considering the case study of cellular data from Tanzania. Memis et al. [7] have carried out the study for allocating network resources for enhancing the QoS factor in cellular network. The outcome of the study shows decrease in power allocation for each link and increase in time allocation for each link. Lorincz and Matijevic [8]

have emphasized on two parameters of energy (energy per unit area and energy per bit unit area) over heterogeneous network. Soh et al. [9] have implemented a probabilistic technique and stochastic approach to understand the energy efficiency in both homo/heterogeneous cellular network. Similar focus on coverage was also emphasized by the work of Zhang et al. [10]. The authors have studied small cells and macro cells for multiple deployment of spectrum. The study conducted by Guo et al. [11] has used involuntary forecasting method on low powered nodes in order to understand the states of power depletion in heaver network load. Wang et al. [12] have presented a study for confirming the energy efficiency towards multimedia delivery considering network interference. Study towards heterogeneous network was also carried out by Sambo et al. [13] where the authors have presented 2-tier deployment of transmission for minimizing the energy depletion. Panahi and Ohtsuki [14] have presented a scheme for cognitive network of heterogeneous type. The recent work carried out by Taranetz [15] has focused on analyzing interference. The authors have also used stochastic geometry for designing the heterogeneous cellular network. Studies conducted by Fan et al. [16] have presented a technique that ensures a sleep scheduling algorithm for heterogeneous cellular network. Tombaz et al. [17] have considered the idle energy as well as backhaul energy into consideration. Yu et al. [18] focused on the macro base station in order to enhance the probability of coverage. Similar problem has also been focused by Esmaeilifard and Rahbar [19], who laid emphasis on complex transmission over cellular traffic. The study has presented an analytical modelling for ensuring maximal energy conservation and efficient network capacity. Study towards energy conservation is also seen in the work of Huang et al. [20] considering the case study of railway communication system. Most recently, the work carried out by Xiang et al. [21] have introduced a topology-based mechanism to conserve energy in cellular network. The prime aim of the study was to minimize the switching frequency of the base station considering the Long-Term Evolution (LTE) network.

3 Problem Identification

Energy is one of the essential factors for successful operation of cellular network. The identified problems of the proposed study are energy consumption due to interface of antenna, energy consumption due to power amplifier, energy consumption die to transceiver, energy consumption due to baseband interface, and energy consumption due to cooling. The conventional study considers evaluating efficiency by dividing output power with input power. For traditional base station in cellular network, the amount of energy depletion is completely dependent on the amount of load due to dynamic traffic. However, due to energy being consumed by the power amplifier, the energy scales down as per the minimizing trend of traffic. The prime reason behind this is reduction of quantity of occupied subcarriers in passive mode of communication with presence of subcarriers without any data to carry. Therefore, such form of scaling over signal essentially depends on type of

base station. The energy consumption by power amplifier for macro base station is 50–60 % while that of low-powered nodes it is around 30 %, which will mean that base station is the prominent victim of the event of energy drainage in cellular network. The operation of base station is also closely associated with other components e.g. BTS, BSC, MSC etc., which equally drags a large amount of power just to initiate, manage, and terminate one active call. Hence, we define out problem as—"It is a challenging task to design a framework that can offer an optimal traffic management along with energy efficient communication over cellular network". The next section discusses about proposed model.

4 Proposed System

The primary motive of the proposed study is to develop an intelligent framework that ensures an effective traffic management as well as cost effective energy conservation in cellular network. The proposed system offers a simple algorithm that is anticipated to be executed over the base station as it is the point of attention for complete traffic and thereby dissipates significant amount of energy. Energy efficiency of one base station will also conserve a significant amount of energy of other base stations too. The scenario of cellular network considered in the proposed system is quite different from existing approaches which uses normally a hexagonal figure. The proposed system considers asymmetric cell area and size with all the base station connected to each other. However, in order to map with real-world set up, we consider that there are base stations which are not connected directly. For an example in the Fig. 1, the base station B3 is not connected with B6 and B4.

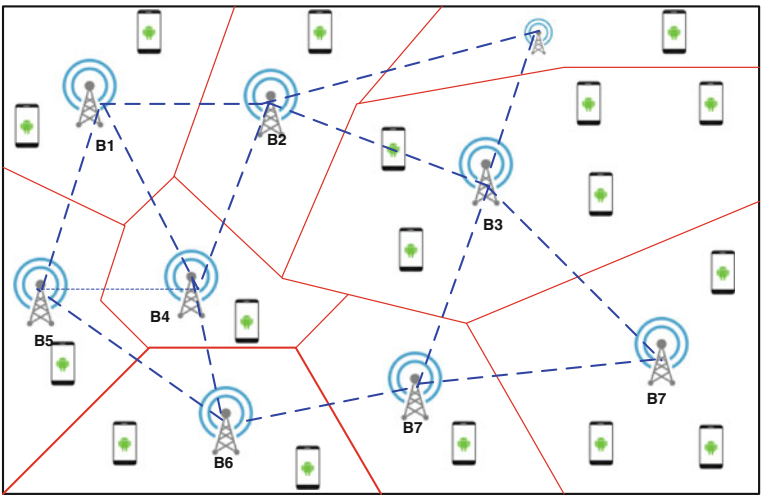

Fig. 1 Topology of cell considered in proposed system

The prime contributions of the proposed system are as follows:

- To gather intelligence by assessing the extent of energy dissipation using stochastic geometry approach of cellular network.
- To evaluate the traffic information of downlink transmission and find the best channel with less traffic.
- To compute the transmission power of the base station of each cells and determines its efficiency.

The proposed system is focused on the power consumption in base station considering both static and non-static power consumption. The static power consumption causes due to baseline power while non-static power consumption causes due to transmission circuits. The uniqueness of the proposed system is the adopted of stochastic geometry considering randomness of base station and mobile stations over the cellular area. The analytical modelling of the proposed system is carried out considering the cumulative interference estimated from interfering base station and mobile station as the core intelligence factor. The system also considers a scenario of natural problems on air e.g. scattering effect, fading effect, path loss, etc. Ultimately, the proposed system offers a joint algorithm that can effectively monitoring uncertain and unpredictable traffic states and offers better resiliency against faster energy drainage of base station.

5 Research Methodology

The proposed study considers the analytical methodology for carrying out the investigation towards energy efficiency in cellular network. The entire planning of the study was done in two phases (i) planning to mitigate traffic load and uncertain by modelling it and (ii) planning to ensure better energy efficiency using stochastic geometry.

The first phase of the planning is done by modelling Poisson's process over the cellular network considering random location of mobile station and base station. The system considers almost all forms of issues e.g. scattering, interference, fading, shadowing etc. The system than computes the cumulative load on traffic on particular cells considering that traffic is originated from the user (mobile station). It also computes the cumulative power on the base station during the transmission process which again depends on interference, rate of traffic, and channel conditions. The density of the traffic density is modelled using Eulerian function. The study in this phase also considers the weight factor for identification of scale of density in the simulation area. We also apply power law to control the traffic density considered in the system. Finally, the system estimates probability distribution of the traffic and after applying power law, we find the links with minimum traffic. Hence, an algorithm is also formulated that can do the similar task and return the best path of communication as output intelligence. The next phase of the study planning takes care of the energy dissipation in cellular network.

The study planning toward controlling energy dissipation initiates by evaluating the power required to perform downlink transmission. A downlink transmission is considered to be taking place between random users in the cells. The extent of interference between two same channels is assumed to be not more than 1. In order to discretely study the interference effect, we evaluate the receiving power for both the interfering mobile stations as well as base station. The study computes the SIR (ignoring noise) considering all the cumulative interference leading to the base station. A relationship between the interference and traffic density is established considering channel capacity assigned for mobile station difference between the channel capacity and the real-time coding as well as the module scheme for reducing rate of bit error. A relative distance between the interfering base station and mobile station is considered in this process.

Therefore, the proposed system finds the best channel and maintains optimal traffic to control unwanted energy consumption of the base station. It then applies energy efficient calculations to monitor any feasibility of outage. The simulation technique uses the concept of iterative random sampling process for developing an analytical model. The framework checks various scenarios of possible traffic density towards downlink transmission and evaluates the effect of weight factor on energy consumption. The outcome of the study is evaluated with respect to time complexity and energy consumption as the performance parameters. The proposed system is also compared with one of the recent on energy optimization, which has adopted optimization principle to enhance network lifetime of the associated base stations in cellular network.

6 Algorithm Implementation

The development of the proposed study was carried out in normal 32 bit machine using Matlab as the programming tool. The development of the proposed system is carried out by two core algorithm related to traffic management and energy efficiency.

6.1 Addressing Peak Traffic Condition

An algorithm is developed for addressing the uncertain and heavy traffic condition in cellular network. The algorithm takes the input of number of nodes to be distributed in random fashion in cellular area (Ca). We apply Eulerian integral (E(x)) to get the random distribution of the uncertain traffic condition in cellular network. The system assumes that traffic condition will be peak and uncertain with the number of mobile stations are more in the cellular network. For analysis of the traffic, we use the relative probability of the random variable using Line-3 of algorithm. The cells and the traffic of the mobile stations are evaluated considering

the traffic density, which is evaluated with the total number of the mobile nodes present in one cell at one active session inside the cellular network. The equation shown in Line-3 consists of the variable a (inverse scale attribute of Eulerian integral function), b is considered as shape attributes, σ is considered as traffic density, and w is considered as weight factor. It is believed that less the weight factor the probability of the downlink traffic is expected to be quite bursty. Using probability logic, if the weight factor is between 0.8 and 1, the traffic density is considered to be quite dense.

Algorithm for traffic management
Input: cell area, nodes,
Output: intelligence of an efficient traffic with less density.
Start
1. Initialize C_a.
2. Define Eulerian integral

$$E(x) = \int_0^{\infty} \frac{t^{x-1}}{e^t} .dt$$

3. Evaluate relative probability of random variable

$$P_{c_a} = \frac{(a)^b}{E(x)} .x^{b-1} . \exp(-ax)$$

4. Evaluate traffic density
5. Evaluate relative probability of traffic density

$$P_{\sigma}(x) = w\sigma_{\min}^{w} . \frac{1}{x^{w+1}} .$$

6. Apply power law of probability distribution

$$Traff = \arg_{\min}(\frac{w_{\sigma_{\min}}}{w-1})$$

End

In order to extract the arbitrariness of the mobile station position as well as density of traffic, the cumulative load of traffic in a particular cell is evaluated. This evaluation is done by considering the specific cell to a point in Poisson distribution process. From the above lines involved in the algorithm, it is clear that the proposed system attempts to assess various active sessions on every cell and then it evaluates the exact size of traffic density. However, the filtering of the traffic is done by extracting only the links with less traffic originated from the base station. The next algorithm is responsible for evaluating and controlling the energy dissipation.

6.2 Addressing Energy Dissipation

The algorithm initially computes the Signal Interference Ratio (SIR) for the downlink transmission of the mobile station (Line-3) ignoring noise. The algorithm than draws a relationship between traffic density and SIR (Line-4) considering δ i.e. difference between bandwidth (C_{cap}) and real time-coding as well as the modulation technique for reducing bit error rate. It than starts evaluating the amount of power dissipation from each cell (Line-5) considering the variables x_i as position of mobile station and y_j as position of base station. It also considers variable R_{pow} as receiving power of the mobile station with n_bs as total number of base station (Line-5). Finally transmission power for all the associated base station is considered (Line-6) considering C_{gain} (channel gain). Finally, energy efficiency of the entire traffic is computed considering output power pout. $Traff_{real}$ is a variable considering the real-time traffic using first algorithm of traffic management.

Algorithm for Energy Efficiency
Input: Cell size, interference (I), γ (flag of interference)
Output: Energy efficiency
Start
1. Evaluate cumulative interference I_{cum} at mobile station (MS)
2. Initialize γ
3. Estimate SIR of MS

$$SIR = \frac{R_{Pow}}{I_{Cum}}$$

4. Construct density & SIR relationship

$$C_{cap}.\log_2(1+SIR/\delta)=\sigma(x)$$

5. Estimate power dissipation in each cell

$$T_{xpow}^{cell} = \sum \frac{||x_i - y_j||^{\alpha}}{n\_bs}.R_{pow}$$

6. Evaluate transmission power of base station

$$T_{xpow} = \left(\frac{R_{pow}}{C_{gain}(||x_i - y_j)}\right)_{n\_bs}$$

7. Evaluate energy efficiency,

$$\eta = Traff_{real}(1-p_{out}) \text{ / mean total power}$$

End

The significant of both the algorithm is considering the entire traffic interference condition, location of base station and mobile station, it calculates the best traffic route (using first algorithm) and calculates energy efficiency (using second algorithm). The best part of the algorithm is its exploration for the best channel with reduced interference level and perform communication and thereby it also reduces

the load of the traffic to and from base station in both uplink and downlink transmission. The next section discusses about the outcomes accomplished after implementing the algorithms.

7 Result Discussion

The outcome of the proposed system is compared with the recent work done by Ho et al. [22]. The reason behind selection of Ho et al. [22] work is similar aim i.e. energy enhancement. The authors have applied an optimization technique using Open StreetMap using non-linear load coupling equalization. The outcomes are studied with respect to energy consumption in Joule and Processing time in second over varying traffic load. For generalizing the outcomes, we consider traffic load in scale of probability 0–1.

Figure 2 shows that proposed system attempts to maintain better uniformity of the energy consumption with increasing load. Although, there is a slight increase in energy consumption but it is likely to happen in any real-time and dynamic traffic condition. On the other hand, Ho et al. [22] have applied a sophisticated optimization technique that is more focused on specific form of network (LTE), which results in increasing of energy consumption as compared to proposed system. Lack of randomness in the topology is another reason for poor outcome of Ho et al. [22] in energy consumption.

Figure 3 shows analysis of the processing time. We felt that processing time is an important performance parameter to judge network delay as well as algorithm complexity. We found that proposed system offers a stable processing time performance. The behavior of curve for proposed system is quite predictable in

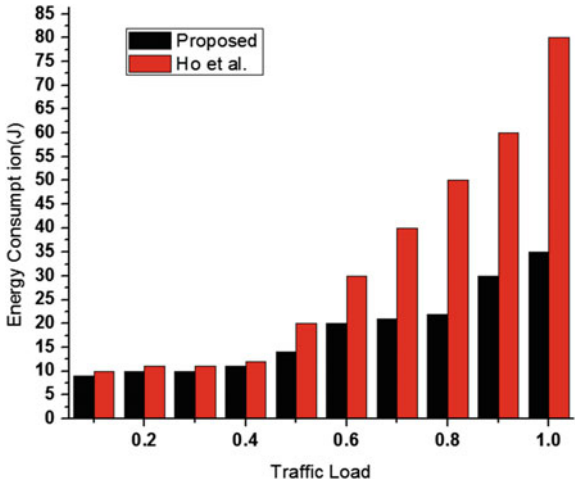

Fig. 2 Analysis of energy consumption

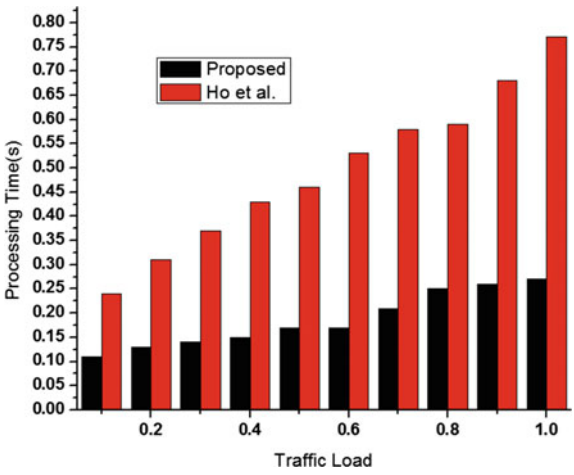

Fig. 3 Analysis of processing time

characteristics hence energy preservation algorithm will find appropriate condition of maintaining uniform performance of energy dissipation. Therefore, superior energy efficiency with lesser cost of resources can be claimed.

8 Conclusion

The presented paper attempts to implement a simple concept in different way. We have implemented a stochastic geometry approach which many researchers have used but implemented it to develop a random topology for positioning of both base station and mobile station in an intelligent manner. The study presents two contributions, where first we attempt to understand the dynamic traffic behavior in the form of preliminary intelligence and develop a simple algorithm to fine the traffic with least density as resultant intelligence. The second contribution of this paper is to develop a simple algorithm to achieve energy efficiency. The algorithm is tested considering the approximated numerical values considered in majority of the current research paper and benchmarking was carried out to find proposed algorithm outperforms existing technique with respect to reduction in energy consumption and well as processing time. Our future work will be to further enhance thus model to develop a novel architecture that can mitigate heavier traffic. Hence, our future work will be also in the direction of developing a further complicated traffic model and to perform more extensive analysis for energy efficiency.

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Architecture and Software Implementation of a Quantum Computer Model

Victor Potapov, Sergei Gushansky, Vyacheslav Guzik and Maxim Polenov

Abstract This paper considers the principles of architecture models of quantum calculators. It describes the existing problems of construction and implementation of their work, as well as ways to overcome these problems. The distinction model of the relevant modules in its composition is achieved. Withdrawal functionality number of three parts modules, their graphics (interface) components, which are produced as a result of differentiation of the model into separate modules included in its composition. We describe the interface of the model and place it in the auxiliary modules and libraries.

Keywords Qubit · Schrödinger equation · Decoherence · Quantum register · Entangled state · Modeling · Quantum computing · Model · Module · Modular structure · Calculator · Model of quantum calculator

1 Introduction

Currently in the world, including Russia, the company is actively working the study and physical implementation of quantum calculator. Prototypes of computers have already been built in various parts of the world at different times, but had not released yet been a full-fledged quantum computer that makes sense to perform

V. Potapov (✉) · S. Gushansky · V. Guzik · M. Polenov
Department of Computer Engineering, Southern Federal University, Taganrog, Russia
e-mail: vitya-potapov@rambler.ru

S. Gushansky
e-mail: smgushanskiy@sfedu.ru

V. Guzik
e-mail: vfguzik@sfedu.ru

M. Polenov
e-mail: mypolenov@sfedu.ru

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simulation of quantum computation on a computer with a classical architecture to explore and further construct quantum calculator. The goals of the construction of models are very different from modeling quantum channel data in cryptography to the simulation of quantum algorithms on the group qubit [1], so the models are constructed in completely different ways and approaches.

Model quantum computer is a kind of quantum calculator model interface, in which one party is represented by a person (user), and the other—by the model itself, which is a set of tools and methods of interaction with the real quantum device.

2 Architecture Calculator

Quantum methods for performing computing operations, as well as the transmission and processing of information, are already beginning to be translated into actual functioning experimental devices that stimulate efforts to implement quantum computers. A quantum computer consists of n qubits and allows one- and two-qubit operations on any of them (or any pair). These operations are performed under the influence of external field pulses controlled by classical computer.

Quantum register [2] is a collection of a number L qubits. Before entering information into the computer all of the qubits of quantum register should be listed in the base states |0>. This operation is called a preparation or initialization. Next, qubits certainly (not all) are subjected to selective external influence (for example, by external electromagnetic field pulses controlled by a classical computer), which changes the value of qubits, i.e., from the state |0> they pass to the state |1> (Fig. 1).

In this state the quantum register just goes into superposition of basic states, i.e. the state of the quantum register initially time will be determined by function:

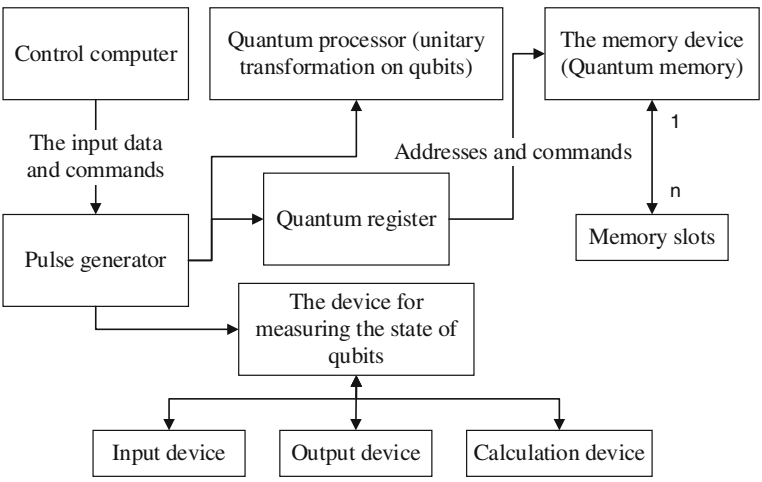


Fig. 1 Schematic structure of a quantum computer

$$|\Psi(0)> = \sum_{n=0}^{2^l-1} c_n |n> \tag{1}$$

In the quantum processor entries are subjected to a sequence of quantum logic operations. As a result, after a number of cycles of the quantum processor operation the initial quantum state of the system becomes a new kind of superposition:

$$|\Psi(1)> = \sum_{n,m=0}^{2^l-1} c_n U'_{mn} |n> \tag{2}$$

After the implementation of reforms in quantum computer, a new feature of superposition is the result of calculations in a quantum processor. We can only assume the values obtained, which are measured values of the quantum system. The final result, a sequence of zeros and ones, and, because of the probabilistic nature of the measurements, it can be any. Thus, quantum computer could have a chance to give any answer. In this scheme quantum computing is considered to be correct, if the correct answer is obtained with a probability sufficiently close to one. After repeating the calculation several times and selecting the answer that occurs most often, you can reduce the possibility of error to an arbitrarily small value.

One of the basic concepts of quantum, as well as classical information theory is the concept of entropy being a measure of the lack of (or uncertainty) information about the actual state of physical system. The description of a quantum system isolated from the environment needs to use the concept of net state, which is characterized by inexact values of coordinates and momenta, and a psi-function ψ [psi] (x, t) (x—a complete set of all continuous and discrete variables that determine the state of a quantum system, for example, it can be coordinate points, the polarization, the spin variables of all the particles, etc.). This complex wave function [3] allows to describe the properties of particles and determine the probability of certain events. The equation in the coordinate representation of Schroedinger [4] or the Heisenberg energy, which is subjected to this function, is a linear differential equation, and in this respect the behavior of the psi-function is perfectly computable and predictable, unlike the behavior described by its quantum objects:

$$|ih\frac{d}{dt}|\Psi(t)> = H'|\Psi(t)> \tag{3}$$

where ħ—Planck's constant, and Ĥ—some special self-adjoint operator, which is called the Hamiltonian operator or Hamiltonian of the system and is defined as the sum of the kinetic energy T and the potential function U:

$$H' = T\wedge + U' \tag{4}$$

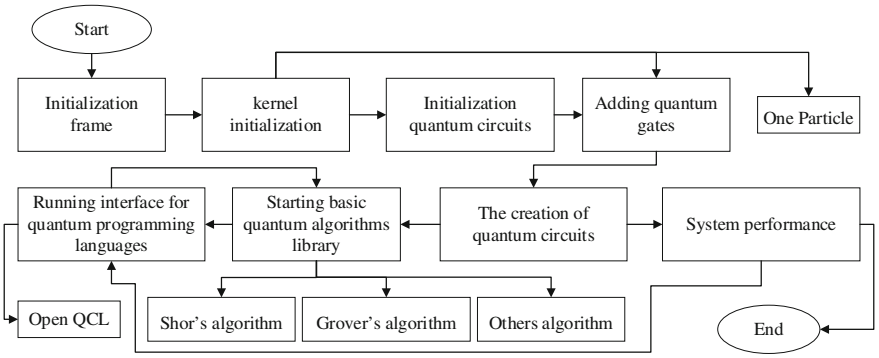


Fig. 2 The initialization of the system

3 The Interface of Model Quantum Calculator

Consider the algorithm of the calculator and the interaction of its various components. The dependence of the components from each other is very high. To begin with, consider the algorithm initialization components and analyze the relationship between the components as shown in Fig. 2.

After frame initialization you should first initialize the modeling kernel that has a default number of qubits in the system. Based on these data the quantum system is initialized, and the modeling of kernel displays the data on the qubits from the nucleus.

3.1 Common Interface Model

Common Interface of developed model [5] is shown in Fig. 3. In left-hand side are control buttons of quantum circuit. This area of the program allows automatic or incremental progress of model forward or backwards, you can also remove the last selected and entered into the scheme member or to completely clean the entire scheme. Above is a menu bar to control and configure the model, the top center is a set of quantum gates, below a state diagram of x-register and y-registers of entangled/not entangled qubits involved directly in the model. Quantum entanglement is a quantum mechanical phenomenon in which the quantum states of two or more qubits are interdependent. The entanglement between the qubits as a prerequisite for any quantum model of the calculator is a key factor responsible for determining the quantum parallelism and quantum advantage over conventional calculator. It is worth noting that the range of objects simulation of developed model is quite wide: gates, quantum algorithms and schemes that we ourselves create by adding the necessary gates, the behavior of particles, not to mention the intricacies of modeling implicitly.

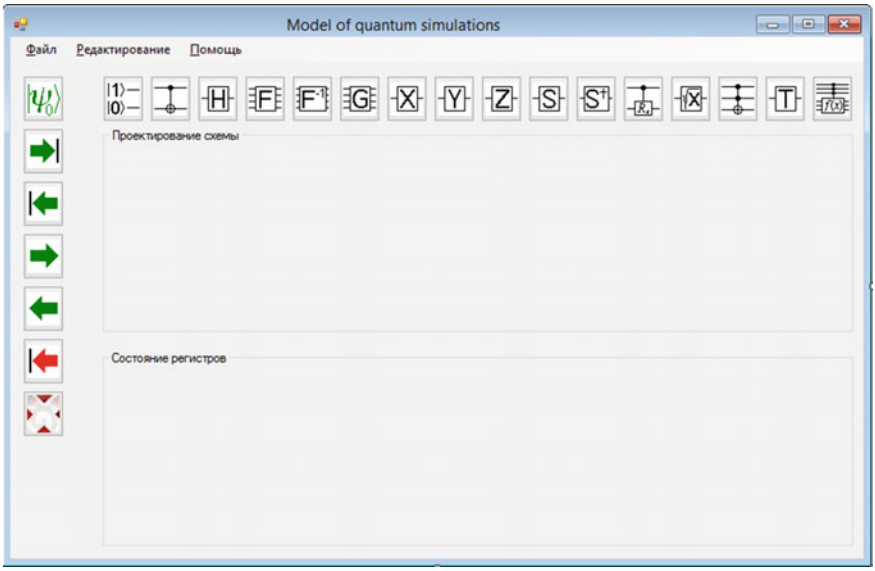


Fig. 3 The interface developed simulation environment

To get started with MQS you should initialize quantum circuit by pressing $|\psi_0\rangle$. This will lead to the conclusion of the window "Dimensions registers". It sets the number of branches of x-register and y-register. The field "design scheme" displays an empty quantum circuit in accordance with the entered values form "Dimensions registers".

Quantum scheme [6] is generated and updated automatically after adding a new gate in the scheme. Figure 4 shows the operation of model, in which intricate interconnected quantum states of the system are presented in different colors (one-color cell, color chart), indicating that the ability of entanglement of states of the developed model. Entangled states can be characterized by the magnitude (extent) of entanglement. The absence of confusion is indicated by y-register (one red cell), with is due to the lack of gates on the branches of the register, in other words, the model in this case has nothing to confuse.

After selecting the qubit, which will be applied to the gate, and agreements with the dialogue in the quantum circuit will add a new gate in the case of pressing the button , which is used to automatically perform quantum circuits, mathematical modeling of the core will perform the corresponding operation. Sometimes it is useful to consider the entire process step by step implementation of quantum circuits. For this purpose, there is a button . This is particularly useful for the study of the intermediate results of a quantum simulator. Each user who logs on to the simulator is given two quantum registers: x-y-register and register. You can use one of them.

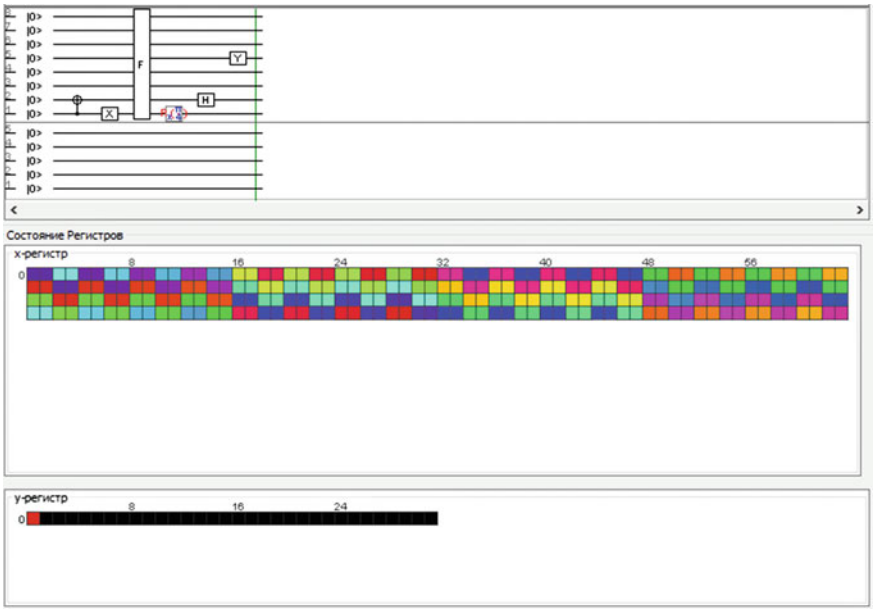


Fig. 4 The quantum circuit simulation environment

State of the quantum register at time t is not exactly the definition and is described by a linear combination with complex coefficients of m-bit states of the form

$$|\Psi> = c_1|0100101110 \quad 0011> + c_2|1100101110 \quad 0011> + \ldots \qquad (5)$$

and the likelihood that the case is in the state $|0100101110\,0011>$ is $|c_1|^2$, the probability of being in state $|11001011100011>$ is $|c_2|^2$, etc.

3.2 *Auxiliary Modules and Libraries in the Model of Quantum Calculator*

One of the most productive methods to increase the functionality of the model is to supplement the model with the subsidiary external libraries and modules. Developed and described earlier model [7] has been supplemented by external functionality, displayed in Fig. 1 in the lower left corner (highlighted in red), and called by pressing the corresponding button on the main form (Fig. 5).

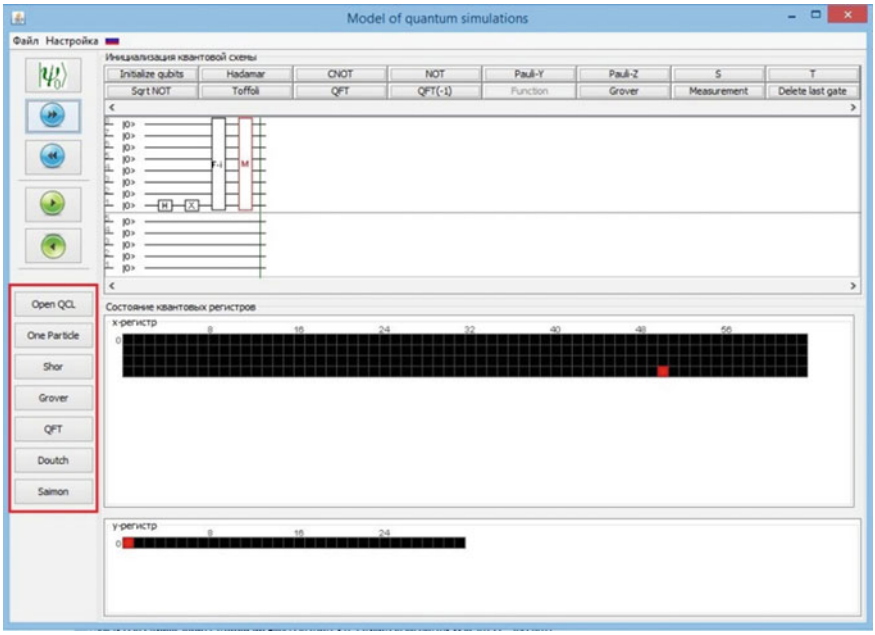


Fig. 5 Main window module (MQS) model of quantum calculator

The structure of plugins includes:

1. Open QCL. By clicking the button «Open QCL» started to write programs form a quantum programming language QCL (Fig. 2). QCL simulates a software environment, providing a classical program structure quantum data types and special functions to perform operations on them (Fig. 6).
2. One Particle. Java-applet simulating quantum mechanics, which describes the behavior of a single particle in bound states in one dimension. It solves the Schrödinger equation and allows visualization solutions.
3. Shor. If you press one of the keys located in the lower left corner, there will be an emulation of the corresponding quantum algorithm [8]: Shore (Fig. 3), Grover, Simon, Deutsch or the quantum Fourier transform (Fig. 7).

The result of the model should be considered:

- quantum circuits to store it in a separate file and load the parties;
- color chart model quantum computer;

The result of the quantum register in Fig. 4 can be interpreted and presented in mathematical (complex) with the help of a color table of probabilities/amplitude states of the qubit, which can then be used to study the degree of entanglement of certain pairs qubit model. Displays information about the state of the qubit system

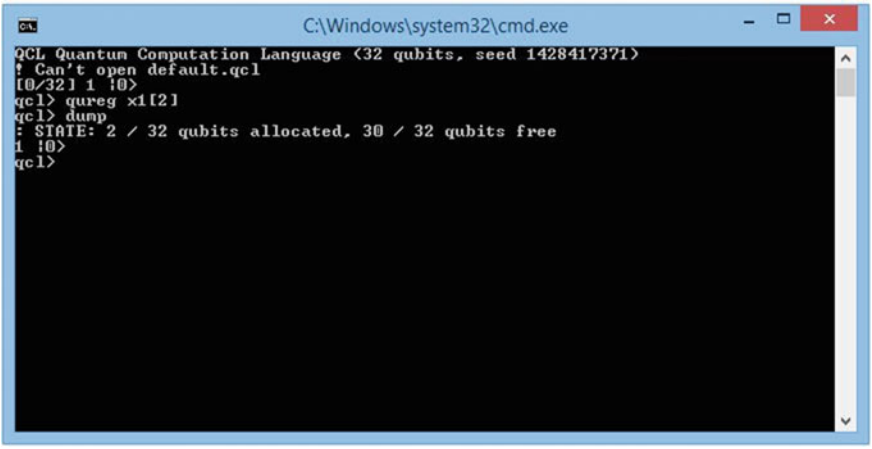
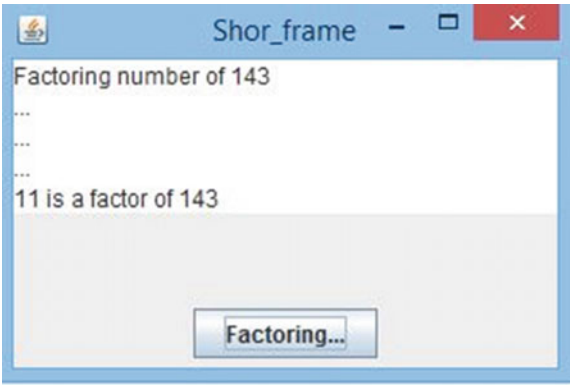


Fig. 6 Interface QCL

Fig. 7 Interface module factorization



using colors provides a more visual data that is easier to take than the numbers, but for the sake of completeness that it is sometimes not enough (Fig. 8).

- The result of the form to write programs on a quantum programming language QCL;

Naturally, that is QCL can be programmed only very small quantum computing. But this is enough to test the basic algorithms of quantum computing and work them before they will be able to use in full-scale quantum device, which is very useful.

- Visualization of the behavior of a single particle in bound states in one dimension;

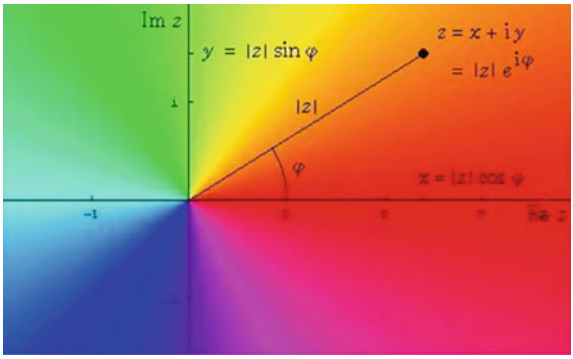


Fig. 8 Decomposition of flowers coloring cells

This external unit is able to visualize and simulate the behavior of a single particle in bound states in one dimension and, as a consequence, analyze and predict its future behavior by varying the available parameters. For example, changing the amplitude.

- The results of calculations of specific quantum algorithms.

The developed model is equipped with a set of specific simulation of quantum algorithms. The article is illustrated by simulation and made a conclusion the results of Shor's algorithm, the factorization of the number 143 (Fig. 7).

4 Conclusion

The interface of the program is no means the last aspect, which should be given to the development of quantum model of the calculator. It is intuitive and visually intuitive user interface simplifies the process of learning and working. The developed model stands out among its peers convenience, features and clarity. The main advantage of the developed modeling tools to the existing analogues is a modular architecture that allows use of mathematical models of several nuclei. Further studies will improve the GUI environment modeling and the possibility of its setting, as well as increase the functionality through the development of the following areas:

- Use other libraries, API, for comparative analysis of the performance and capabilities;
- Increasing the number of operators used;
- Update the graphics editor of quantum circuits new functionality that extends the current editing quantum circuits;

Analyzed and developed a set of features that will be implemented in a computer and described the core of the interface model and place it in the auxiliary modules and libraries. Was launched a series of third-party modules, the functionality of their graphics (interface) components that run as a result of the model in separate modules, included in its composition.

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MEEM: A Novel Middleware for Energy Efficiency in Mobile Adhoc Network

P.G. Sunitha Hiremath and C.V. Guru Rao

Abstract Achieving an enhanced network lifetime is still an open issue in mobile ad hoc network. After years of research and invention, a robust technique to ascertain energy efficiency is yet to be explored especially to overcome an adverse effect of dynamic topology and selection of highly stabilized links during routing. Therefore, we present a very simple and cost-efficient middleware called as MEEM i.e. Middleware for Energy Efficiency in Mobile ad hoc network that offers an effective solution towards this problem. MEEM offers cost effectiveness by enabling the middleware to increase its scope of selection of stabilized routes based on formulating new multiple decision-making parameters e.g. Time for Route Termination, Time for Stable Routing, Frequency of Route Error, Reduction in Signal Attenuation, and Remnant Network Lifetime. The design of MEEM is carried out using quadratic approach thereby retaining parallel processing of an algorithm to enhance the communication performance of the mobile nodes. The outcome of the study was found to excel better results in comparison to frequently used routing protocol e.g. Adhoc On-demand Distance Vector (AODV) and Optimized Link State Routing (OLSR) with respect to energy consumption and algorithm processing time. The algorithm is found to be compliant of time and space complexity thereby results in cost effective solution.

Keywords Energy efficiency · Middleware · Mobile adhoc network · Network lifetime · Route selection · Stabilized links

P.G.S. Hiremath (✉)
Department of Information Science & Engineering, BVBCET, Hubli, India
e-mail: sunitharesearch64@gmail.com; pgshiremath@bvb.edu

C.V.G. Rao
S R Engineering College, Warangal, India

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1 Introduction

A mobile ad hoc network is considered as one of the cost-effective communication technique for emergency [1]. However, owing to the dynamic topology in mobile ad hoc network, it is associated with multiple challenges [2]. A mobile node always dissipates energy whether it is active state, passive state or in sleep state [3]. Because of uncertainty in energy retention scheme among the nodes, there is always a risk of broken links [4], which is highly detrimental to the communication principle. For more than two decades, there has been enough evolution of problems towards energy efficiency in mobile ad hoc network. But till date, there is no evidence of 100 % solution towards energy efficiency owing to over-burdened responsibilities towards resource-constraint nodes [5]. Hence, introducing middleware system can significantly reduce the load of routing and multiple operations that are carried out by mobile nodes in ad hoc network and thereby introduce enough energy efficiency. However, retaining energy efficiency in mobile ad hoc network is not simpler and has multiple challenging factors as an impediment. Till date, there is no substantial study towards encouraging usage of middleware over ad hoc network to enhance network lifetime. The present paper discusses an efficient middleware design that targets to accomplish energy efficiency in the presence of dynamic topology of mobile ad hoc network. Section 2 discusses significant literature towards middleware design in present system followed by brief discussion of problem statement in Sect. 3. Section 4 discusses the proposed model followed by research methodology in Sect. 5. Algorithm implementation is discussed in Sect. 6 followed by a discussion of the accomplished result in Sect. 7. Concluding remarks are discussed in Sect. 8.

2 Related Work

This section discusses the significant work being carried out towards designing middleware applications in mobile ad hoc network most recently.

Most recently, Pasricha et al. [6] have developed a middleware for the purpose of optimizing energy for the mobile devices. The study has considered the case of Android-based smartphones, where the authors have developed a middleware that can optimize the processing and energy utilization to be controlled in the highest degree. The outcome of the study was found to conserve around 29 % of energy. However, the study considers ad hoc network for performing networking and investigation. Another author named as Silva [7] has also dedicated their research towards evolving up with a middleware design exclusively for the mobile system. The focus of the study was into attaining scalability by developing a UDP protocol executed over the mobile nodes for addressing the unstable or broken links. The outcome of the study has also assured enhanced packet delivery ratio for the presented middleware that supports various forms of data delivery too. However, just like the previous study, this study also doesn't emphasize on ad hoc network.

An interesting concept of middleware was formulated by Haschem et al. [8] who presented a system for processing information gathered from mobile internet-of-things. The authors have implemented service-oriented architecture to enhance the usability and scalability of the middleware framework using non-deterministic approach. The outcome of the study was assessed using response time of the system. Mehrotra et al. [9] have developed a middleware system focusing on social networking system. The system also uses contextual data from the social network applications from the information that is sensed from the mobile. It also makes use of a centralized server. The evaluation of the study was hypothetically carried out over multiple databases on server mainly focusing on context awareness. Akingbesote et al. [10] have developed a framework for middleware focusing on the healthcare sector. The authors have incorporated middleware layer in between the multimedia interface and grid infrastructure layer. The outcome of the study was evaluated with respect to waiting time on increasing server utilization. Gherari et al. [11] have introduced another middleware system that using profiling approach over cloud interface. The middleware is designed over a sophisticated architecture using contextual information of both cloud and mobile interface. However, the study doesn't emphasize much on data analysis.

Nikzad et al. [12] have presented a middleware that is responsible for maintaining energy efficiency on the mobile application considering Android operating system. The experimentation was carried out using sensed data from the mobile communication system where the outcome of the study shows 64 % of energy conservation. Similar sort of studies was also presented by Makki et al. [13] by presenting a middleware for android device focusing on the security aspect of mobile devices. Mohapatra et al. [14] have developed a middleware for enhancing the energy conservation for the mobile devices. Similar direction of the study was also carried out by Bajwa [15] by presenting a middleware for maintaining interoperability and integration in e-commerce. Lin et al. [16] have presented a schema of middleware for a mobile application using Bayesian approach using experimental approach. Zhuang et al. [17] have presented a scheme for middleware services for sensing processed information captured from the mobile device. Hence, it can be seen that that there are enough works being carried out in the direction of middleware design. The next section highlights the problem statement of the proposed study.

3 Problem Statement

The existing studies towards middleware are developed mainly focusing on the mobile devices. However, challenges involved in ad hoc network are quite higher in the form of computational complexity. Even if such middleware is design, the next challenge will relate to the selection process of stabilized links. At present, the frequently existing routing protocols e.g. AODV [18] and OLSR [19] are used for routing. Hence, if a middleware will be designed it will have to solely depend on

the effectiveness of such routing protocols, which are associated with both advantages and disadvantages too. A successful and cost-effective design of middleware will call for incorporating a good interface between the middleware components and routing protocols along with energy efficiency. Unfortunately, enough studies have not been carried out in the direction of the mobile ad hoc network. This causes quite an uncertainty, in theory, formulation about how to define a novel middleware technique that can perform an efficient and faster selection of the routing in mobile ad hoc network. Besides, the present routing decision for selection of stabilized link is carried out by residual energy, which is not enough. Hence, there is a need for designing a novel middleware system that can take more information about the stabilized and energy-efficient links considering the problem of spontaneous dissipation of energy among mobile nodes owing to issues of dynamic topology. The problem statement of the study can be stated as *—It is a computationally challenging task to develop an efficient middleware for restoring significant network lifetime of mobile nodes in adhoc network.* The next section presents a discussion about the proposed system that addresses the problems of developing a middleware system for enhancing energy and network lifetime in mobile adhoc network.

4 Proposed System

The prime purpose of the proposed system is to design a novel middleware system that can perform significant conservation of energy among the nodes in mobile ad hoc network. The study introduces a technique called as MEEM (Middleware for Energy Efficiency in Mobile ad hoc network). The present study is an extension of our prior design of middleware system called as MERAM (Message Exchange with Resilient and Adaptive Middleware system) [20]. MERAM was designed for mitigating the replication issues of a message in order to facilitate quick exchange of message for time-critical applications in mobile ad hoc network. The advantages of MERAM are (i) higher resilience to link failures on dynamic topology, (ii) applicable on delay tolerant protocol, (iii) outcomes witnessed with increased delivery probability and reduced message exchanging time. However, MERAM didn't focus on energy efficiency, which may result in minimization of network lifetime. Therefore, in order to accomplish the objective of energy-efficiency over MERAM, the present study performs following contribution:

- To design an ad hoc-based connectivity for wireless access technology that can track and surveil the emergency situation.
- To develop a middleware system that can minimize or control energy drainage from the mobile nodes for data dissemination process in mobile ad hoc network.

5 Research Methodology

The proposed system MEEM considers analytical methodology and intends to design an extended version of the proposed middleware system for incorporating further resiliency against drainage of battery and thereby enhancing the lifetime of hybrid mobile ad hoc network. The proposed system will design a framework on mobile application that is purely on the basis of the MERAM system. The nodes in mobile adhoc network (e.g. Smartphone, laptops, tablets etc.) can always have multiple radio interfaces, although the conventional research-based study only consider single radio interface. Therefore, the proposed system considers multiple radio interfaces for connecting various mobile nodes and to increase data rates. In order to minimize any forms of radio frequency interference, the proposed MEEM considers smaller transmission range. The design of this part of the system will be based on message-oriented middleware system as well as to provide an asynchronous communication system between the communication mobile nodes. The prime focus of this part of the study is to develop an analytical modeling of energy dissipation during the communication between the two mobile nodes. The intention is being to understand the cost involved in the transmission in ad hoc nature and give a proper solution to it and thereby present a robust middleware system. The proposed MEEM is a technique that will run over the mobile nodes to perform a certain operation which is mainly associated with communication control for ensuring energy efficiency. MEEM will be responsible for reviewing the amount of various resources being used during routing and it will offer an empirical means of evaluating the following:

- **Time for Route Termination (TRT)**: This is the time witnessed after an established route expires.
- **Time for Stable Routing (TSR)**: This factor calculates the time between two nodes with sufficient residual energy. We say stable routing to be only formulated between two nodes of sufficient level of remnant energy.
- **Frequency of Route Error (FRE)**: This variable calculates the total number of the occurrences of error witnessed in a particular route.
- **Reduction in Signal Attenuation (RSA)**: This parameter checks for the level of drop of signal attenuation as a quality signal to be evaluated.
- **Remnant Network Lifetime (RNL)**: It is the approximated residual power of all the nodes in the simulation network.

The system architecture used in MEEM is highlighted in Fig. 1, which shows that MEEM performs aggregation of the information for TRT, TSR, FRE, RSA, and RNL on every routing cycle. All these metrics are used for finalization of one probable route to be established, hence, MEEM is an algorithm of the first kind in MANET where the establishment of stabilized link depends on multiple parameters. All these parameters can be taken from the novel design of a control message

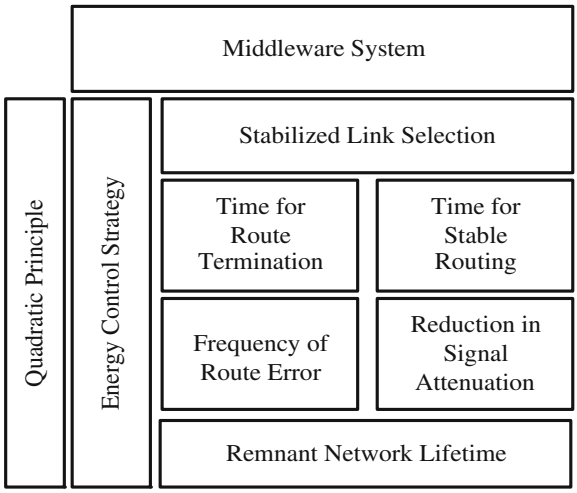

Fig. 1 Architectural Schema Adopted by MEEM

shown in Fig. 1. Therefore, as a consequence MEEM minimizes the probability of broken links as now the routing technique have more decision parameters, which are not found in conventional energy efficient routing protocols in MANET [21]. The mobile nodes are considered to follow the multi-path propagation of the message for faster message delivery in proposed schema.

The next section discusses the algorithms that are designed for proposed middleware for energy efficiency in mobile ad hoc network.

6 Algorithm Implementation

This section discusses the implementation of the proposed MEEM. The proposed system considers n number of mobile nodes that are positioned in simulation area using random mobility model. The design of the algorithm mainly emphasized on accomplishing following novel components of middleware system in ad hoc network as Time for Route Termination (TRT), Time for Stable Routing (TSR), Frequency of Route Error (FRE), Reduction in Signal Attenuation (RSA), Remnant Network Lifetime (RNL). The brief discussion of the algorithms is as follows:

Algorithm for Time for Route Termination (TRT)
Input: n (number of nodes), r (transmission range), u_1/u_2 (node speed), φ_1/φ_2 (orientation of two nodes), $\alpha\ \beta\ \gamma, \delta$ (orientation-based route termination parameters),
Output: Time for Route Termination.
Start

1. Init n, r
2. Init node speed u_1 and u_2.

3. Init direction φ_1 and φ_2.
4. Apply Random Waypoint
5. Applying quadratic principle
6. $E_1 = (\alpha\beta + \beta\gamma)$
7. $E_2 = |\sqrt{(\alpha^2 + \gamma^2) \cdot \arg_{\max} r^2 - (\alpha\delta - \gamma\beta)^2}|$
8. $E_3 = 1/(\alpha^2 + \gamma^2)$
9. $E = E_1 \cdot E_2 \cdot E_3$
10. $TRT = \arg_{\min}|E|$

End

Normally, the termination of the route takes place owing to two reasons e.g. (i) dynamic topology, (ii) sudden node death. Hence, MEEM addresses both the problems by TRT algorithm. After suitable initialization of nodes (n), transmission range (r), speed and orientation of two communicating nodes (u_1/u_2 and φ_1/φ_1), we apply random waypoint as the mobility model and quadratic approach is considered for algorithm formulations. The prime reason behind the adoption of quadratic approach is to incorporate optimization in the information for better middleware design. The system formulates three entities E_1, E_2, and E_3 corresponding with the standard variables (a, b, c) in any quadratic approach. The parameter α computes the cosine difference of first node speed ($u_1 \cdot \cos \varphi_1$) with second node speed ($u_2 \cdot \cos \varphi_2$). Similarly, The parameter δ computes the sinusoidal difference of first node speed ($u_1 \cdot \sin \varphi_1$) with second node speed ($u_2 \cdot \sin \varphi_2$).The parameter β and δ are the positional difference between two nodes and corresponds to $x_1 - x_2$ and $y_1 - y_2$ respectively. Finally, the time is computed that assist proposed middleware to decide about the selection process of a route during the route discovery process in mobile ad hoc network.

Algorithm for Time for Stable Routing (TSR)
Input: C_E (Cut-off energy of a node), n_s/n_d (nodes), E_{sd} (remnant energy of source-destination)
Output: Time for Stable Routing
Start

1. init C_E
2. If $E_{sd} > C_E$
3. $n_s \rightarrow n_d$
4. or else,
5. reject (n_d)
6. search_next(n_d);
7. Evaluated time $(n_s \rightarrow n_d)$

End

The TSR algorithm is responsible for exploring the total time found with the higher probability of stabilized link. An algorithm is designed with a cut-off energy level of a node, which is a permissible battery level till which the node functions properly. It can be different for different applications. If the sender node finds the remnant energy of its neighbor node to be less than cut-off energy, it is believed that such link formation will not be reliable to carry forward the data and hence rejected. Hence, link formation is only supported by proposed middleware of the remnant energy is more than cut-off.

Algorithm for Frequency of Route Error (FRE)
Input: *rec_msg* (RREQ), C_{err} (Cut-Off Error)
Output:
Start

1. Capture *rec_msg* (n_d) & Calculate BER
2. if (BER>C_{err})
3. remove those nodes
4. or else
5. Consider those nodes for communication

End

The above algorithm is responsible for the selection of route based on the error rate. In order to do so, our middleware system captures the control message from the communicating nodes and keeps on computing bit error rates. A cut-off error rate can be defined based on different applications which will be compared with accomplished BER. In the case of permissible limit, proposed middleware will give positive feedback for selection of such communicating nodes to establish a link.

The next part of the implementation will focus on capturing the signal attenuation (in dB) (RSA) while the MEEM can keep on collecting the remnant energy information of the entire node in the simulation for analysis purpose (RNL). The prime performance will be observed from the extent of energy consumption in mobile ad hoc network.

7 Results and Discussion

The outcome of the proposed system is evaluated with respect to energy consumption per node in Joule and algorithm processing time in second. The proposed MEEM is compared with the frequently used AODV and OLSR routing algorithm by using uniform simulation parameters. The simulation study considers 500–1000 mobile nodes with a variation of 100–550 m of transmission range. With omni-antenna considered on each node, the initialized power is 0.5 J considering MAC protocol for IEEE 802.11 standard.

Figure 2 shows the comparative analysis fo proposed middleware-based communication system on mobile ad hoc network with AODV and OLSR. The sequence number of AODV is higher but definitely not the latest, for which purpose each intermediate node has to allocate an extra energy in case of broken links. Owing to a periodic delivery of control message, OLSR keeps more updated route entries compared to AODV, but it requires an extra processing power to do so. However, proposed MEEM undertakes this decision of routing based on Time for Route Termination (TRT), Time for Stable Routing (TSR), and Frequency of Route Error (FRE). Hence, the amount of information required to avoid re-routing as well as reliable communication is quite high enough compared to AODV and OLSR and hence can take decision faster thereby requiring less processing power. In increasing iterations, the middleware becomes less dependent on routing information and hence processing power increases in a very slower pace thereby restoring sufficient amount of energy (Fig. 3).

Algorithm processing time is one of the significant parameter for scaling the effectiveness of the proposed middleware system. The outcome shows that processing time of MEEM is considerably less than existing routing mechanism e.g. AODV and OLSR. Although delay for establishing the connection is less in AODV but it requires a massive channel capacity to process the message for 500-1000

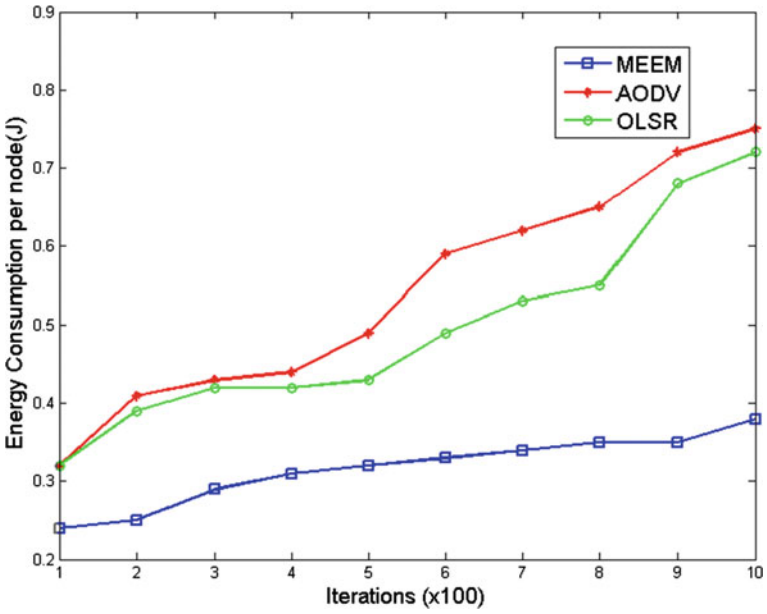

Fig. 2 Comparative Analysis of MEEM, AODV and OLSR (Energy)

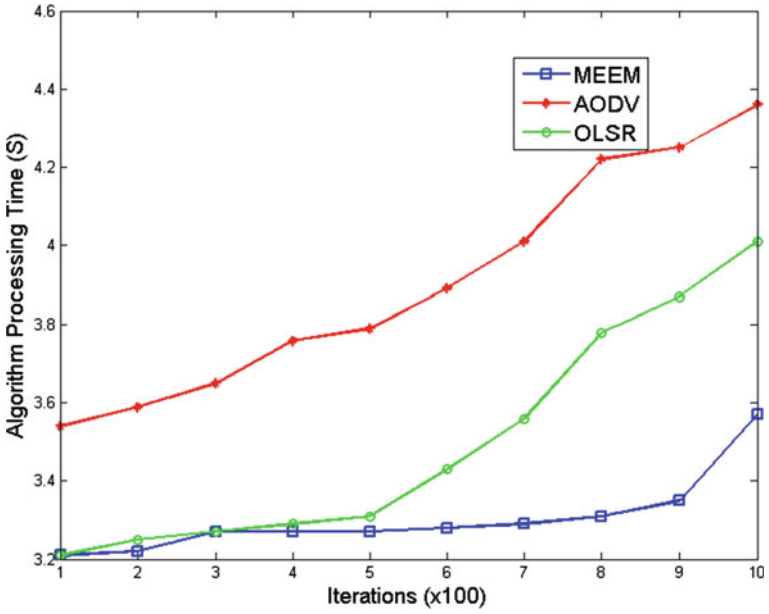

Fig. 3 Comparative Analysis of MEEM, AODV and OLSR (Algorithm Processing Time)

mobile nodes. This increases the time of construction of routes. On the other hand, OLSR is not at all dependent on such control message to ascertain the link stability. Unfortunately, OLSR consumes more processing time to find out the unstable routes as well as any broken links. We address this problem in MEEM by using cut-off level of remnant energy which avoids the routing decision to be made on less stabilized nodes. Similarly, the system performs continuous monitoring of Time for Route Termination (TRT) and Time for Stable Routing (TSR) that significantly accumulates up with relevant routing data thereby requiring fewer algorithms processing time. Moreover, the cut-off values are completely dependent on the application which means MEEM can be customized for any futuristic applications of MANET.

From storage complexity viewpoint, the algorithm doesn't require more than 20–30 Kb of space for 5000 iterations. This fact will mean that proposed MEEM can be used for any low-powered embedded mobile device in ad hoc network. Therefore, the proposed middleware is found with higher energy preservation, lower algorithm processing time and it is highly compliant of time and storage complexity from the performance of the MEEM viewpoint.

8 Conclusion

There are various adverse effect of dynamic topology where the prominent one is on energy efficiency and routing. For more than a decade there has been an enough evolution of various energy efficient technique as well as the routing protocol for delivering better communication standards. However, till date, there is no such existence of energy efficient routing that can overcome the adverse effect of dynamic topology in mobile ad hoc network. This paper appraises that there is an adoption of middleware and has been quite a common in mobile devices; however, there was a less attempt towards investigation of middleware towards energy efficiency. This paper has introduced a technique called as MEEM that formulates multiple parameters e.g. Time for Route Termination (TRT), Time for Stable Routing (TSR), Frequency of Route Error (FRE), Reduction in Signal Attenuation (RSA), and Remnant Network Lifetime (RNL) for selection of stable routes. The outcome of the simulation study was compared with frequently used AODV and OLSR routing protocols to see superior performance in energy conservation and lowered processing time.

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A 3D Visualization Design and Realization of Otrokovice in the Nineteen-thirties

Pavel Pokorný and Markéta Mazáčová

Abstract This paper briefly describes a visualization method of the Otrokovice Municipality in the Nineteen-thirties. The rapid growth of this town began at the beginning of the 20th century, and in 1938, Otrokovice had around 8000 inhabitants. Many building plans, cadastral maps and historical photographs are preserved from this period. This is the reason why a rendering set in these years was created. All of the collected information was chronologically sorted, and on this basis, a 3D visualization of the Otrokovice town center was created. To begin with, a terrain model of Otrokovice was created, based on the altitude values published on the Internet. All buildings and accessories were separately modeled (the standard polygonal representation was used) and textured by the UV mapping technique. Then, a more complex 3D scene from the individual models and accessories was created. The visualization output is performed by rendered images and animations in these years.

Keywords Computer graphics · 3D visualization · Modeling · Texturing · Animation · Rendering

1 Introduction

Data visualization is a hot topic. A simple definition of data visualization says: It's the study of how to represent data by using a visual or artistic approach rather than the traditional reporting method [1]. Represented data are most often displayed through texts, images, diagrams or animations in order to communicate a message.

P. Pokorný (✉) · M. Mazáčová
Faculty of Applied Informatics, Department of Computer and Communication Systems, Tomas Bata University in Zlín, Nad Stráněmi 4511, 760 05 Zlín, Czech Republic
e-mail: pokorny@fai.utb.cz

M. Mazáčová
e-mail: mazacova.marketa@gmail.com

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Visualization today has ever-expanding applications in education, science, engineering (e.g. product visualization), interactive multimedia, medicine, etc. Typical example of a visualization application is the field of computer graphics. The invention of computer graphics may be the most important development in visualization since the invention of central perspective in the Renaissance period. The development of animation also helped the advance of visualization [2].

With the development and performance of computer technology, the possibilities and limits of computer graphics are still increasing. The consequences of this are 3D visualizations, which are used more frequently, image outputs get better quality [3] and the number of configurable parameters is rising [4]. As mentioned above, these visualizations are used in many scientific and other areas of human interest [5].

One of the fields is visualizations of history. Based on historical documents, drawings, maps, plans and photographs, it is possible to create 3D models of objects that exist no more—things, products, buildings or extinct animals. If we assign suitable materials and the corresponding textures to these models, we can get a very credible appearance of these historic objects. From these individual objects, we can create very large and complex scenes that can be very beneficial tool for all people interested in history.

This paper describes a 3D visualization method of Otrkovice in the Nineteen-thirties.

1.1 The History of Otrokovice

Otrokovice is a town in the Zlín Region, Czech Republic. It is located in a hilly area centrally located in the region called Moravia and is located on the Morava River.

The first written record of Otrokovice's existence dates back to 1141, when the Bishop, Henry Zídka, mentioned this village in his documents—where the ownership of the Olomouc Diocese was calculated. In the first half of the 14th Century, Otrokovice still remained in the Church's ownership and it subsequently passed into secular hands and formed the joint property of the Tečovice Estate. This estate was purchased by William Tetour of Tetovo in 1492, who was the owner of the nearby Zlín Estate and a Black Company commander in the service of Matthias Corvinus (King of Hungary) [6]. During this time, the whole estate developed into a successful economy [7].

In the early 18th Century, a total of 305 people lived in Otrokovice, 198 of them were peasants. The village recorded growth over the next few years, and in 1805, its own school was built. The rural character of the village began to diminish in the early 20th Century. In 1929, the Bata Company purchased a large parcel of ground in an area on the right bank of the Morava River, which was used as a suitable place for building houses and a new factory area. Construction took place along the main road and, among many other buildings, the Sokol Building was built in 1925

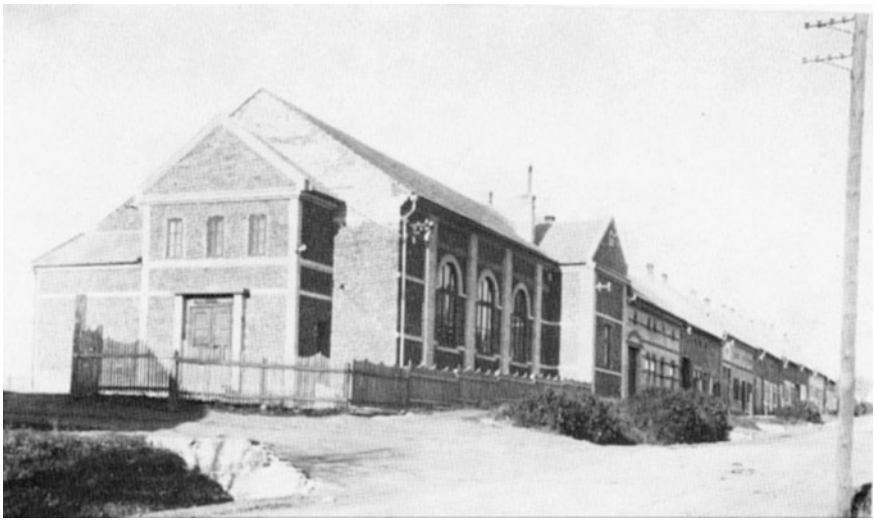

Fig. 1 The Sokol Building after 1925 [7]

Table 1 Number of inhabitants and houses in Otrokovice in 1930–1938 [7]

Year	1930	1932	1933	1934	1935	1937	1938
Inhabitants	2009	3300	3654	4788	5567	6571	8002
Houses	339	406	585	655	761	821	901

(Fig. 1). These various constructions significantly contributed to the expansion of the city boundaries. A few years later, Otrokovice was fully electrified [8].

Otrokovice became the most important offshoot of the Bata Company's Zlín factories during the Nineteens-thirties and grew into the second most important place in the Zlín District. The significant growth of the population was hardly experienced or equaled by any other community throughout Czechoslovakia at this time. Its growth during the 1930–1938 period, is described in Table 1 [7].

The 3D visualization, designed and created for this purpose, shows the town of Otrokovice at this time.

2 Resources and Software

The first phases that needed to be done were to collect all available historical materials relating to Otrokovice and to select appropriate programs for visualization creation purposes.

2.1 Acquiring Resources

The overall progress of this work was initiated by the collation of available historic materials and information about the town of Otrokovice in the Nineteen-thirties. The main resources were the Moravian Land Archive in Brno [9], the State District Archive in Zlín – Klečůvka [10], books and the Internet. Attention was mainly focused on building plans, cadastral maps and historical photos.

The cadastral maps of that period are a very important part of the visualization process. In the Moravian Land Archive in Brno, there are two of these maps of Otrokovice available—from 1877, and 1926. Both maps were acquired and, because they were divided into several parts, they were loaded and combined in the GIMP software [11] in order to obtain the entire maps. These maps are colorized and in them, it is easy to distinguish wooden or brick buildings, gardens, roads, rivers, fields, etc. A part of the cadastral map of the center of Otrokovice, dating from 1877, is shown in Fig. 2. We used these maps for the creation of the model's terrain (e.g. the proper placement of edges and faces), terrain texture drawings, ground plans of buildings and the correct placements and orientations of the 3D models of buildings and accessories in the final scene.

Period photographs are the next important resources. We used two historical books [8, 12] that were published by the town of Otrokovice. In addition, in these books, the period photographs are supplemented by textual information, which complements the former conditions. The other suitable historical resources were

Fig. 2 A part of the cadastral map of the Otrokovice Center from 1877 [9]

found in the Zlín – Klečůvka Archive, where many historical archival materials are stored. The Internet was the last resource used. Some historical photographs were found on various www pages, mainly of the Otrokovice town center.

Approximately 150 photographs were obtained from the above-mentioned resources, which captured the appearance of the town between the years 1830–1960.

2.2 Used Programs

Where possible, "free to use" software was preferred. For 3D modeling, texturing and rendering, the Blender software suite was therefore used [13]. Textures were drawn in GIMP [11]. Microdem [14] was the last software package that was used.

Blender is a fully integrated creation suite, offering a broad range of essential tools for the creation of 3D content, including modeling, uv mapping, texturing, rigging, skinning, animation, particle and other simulation, scripting, rendering, compositing, post-production, and game creation [15, 16]. Blender is cross-platform, based on the OpenGL technology, and is available under GNU GPL license.

GIMP is an acronym for GNU Image Manipulation Program. It is a freely distributed program under the GNU General Public License. It is mainly a digital image editor and a drawing tool. It allows one to retouch photos by fixing problems affecting the whole image—or parts of the image, adjust colors in photographs to bring back the natural look, image compositing or image authoring [17].

Microdem is a freeware microcomputer mapping program, designed for displaying and merging digital elevation models, satellite imagery, scanned maps, vector map data or GIS databases [14]. This software was used in order to convert landscape elevation map data into a bitmap image (i.e. a heightmap).

3 A Landscape Model of Otrokovice

Data files which contained text information about the earth elevations were used in order to create the landscape model of Otrokovice and its vicinity.

The Digital Elevation Model data (i.e. DEM) was used, which was provided by the NASA Shuttle Radar Topographic Mission (SRTM) in 2007. The data for over 80 % of the globe is stored on [18] and can be freely downloaded for noncommercial use.

So the data of the Otrokovice region was downloaded, and then opened with the Microdem freeware program, which was described above. This software is able to convert the obtained data into a bitmap image. Microdem can clip and convert these images into grayscale (e.g. into a heightmap) that was applied to the Otrokovice region. Specifically, a heightmap area of 17.5 km^2 (a rectangle with 3.5 km width and 5 km height, centered on the center of Otrokovice—Fig. 3) was created.

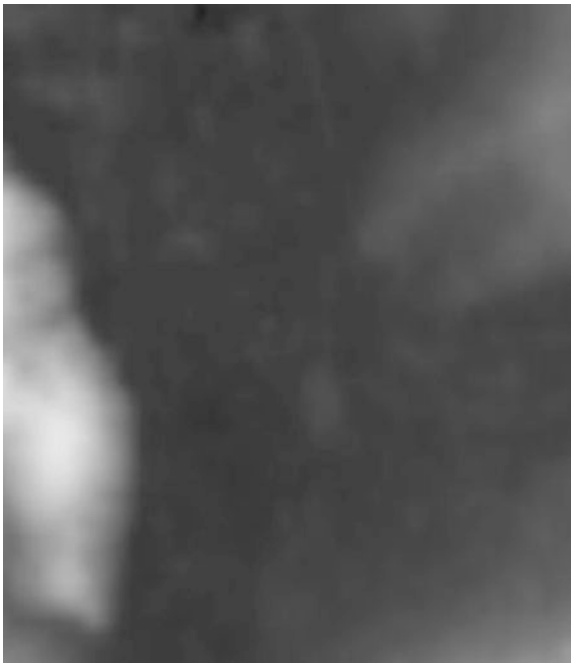

Fig. 3 The heightmap of the Otrokovice's Region

This heightmap in PNG format was saved (it is very important to use lossless compression). In Blender, a square was inserted (the Plane object) in the new scene and its edges were scaled to the ratio 3.5:5. After that, it was divided several times with the Subdivide tool in order to get a grid with a density of several thousand vertices. Then, the Displace modifier was used, to which a texture was assigned (for the obtained heightmap). The Displace modifier deforms an object, based on the texture and setting parameters (Fig. 4). The model of Otrokovice's landscape was

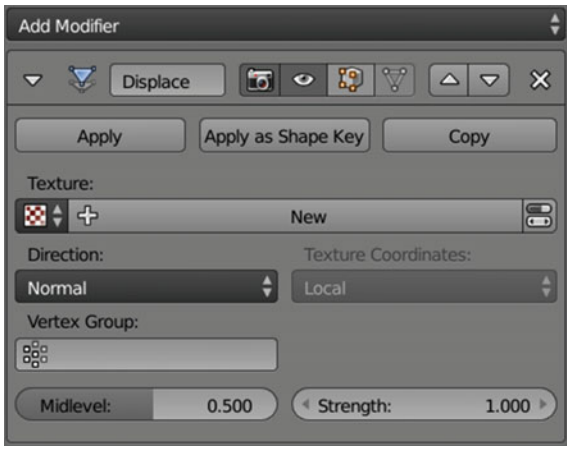

Fig. 4 Settings for the displace modifier in the Bender environment

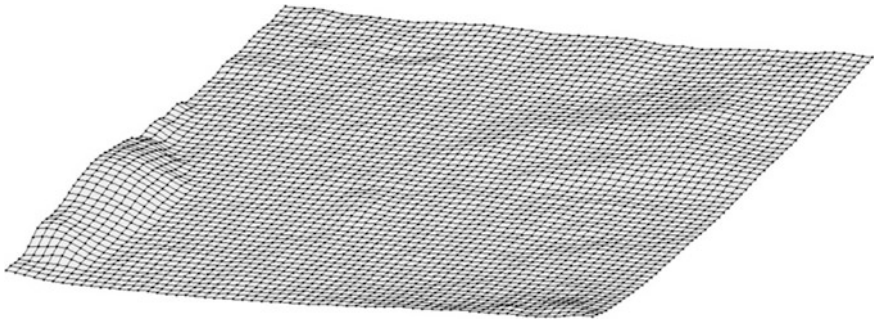

Fig. 5 The final mesh model of the Otrokovice Region's landscape

obtained by using this method in this way. This is shown in Fig. 5. Although this model is not entirely accurate—but given the scale, the whole scene, and the quality of the Otrokovice model buildings, it is sufficient.

4 Modeling Buildings and Accessories

The modeling of the buildings was always performed in the Blender program, and according to the same scenario. Before the modeling phase, the appropriate part of the cadastral map with the selected building described in Sect. 2.1 was incorporated into the background screen in Blender. After that—the Plane object was inserted and then its profile (i.e. the size and shape) was modified according to the floor plan of the building in the 3D scene. Mainly, two tools were used to shape this object. The Extrude tool allows one to alter the selected face in a specifically chosen direction; and then the Subdivide tool—which breaks down the selected face into an even greater number of smaller parts [16].

When the floor shape was finished, this profile was extruded to a height corresponding to the existing photographs. In cases where the photographs were missing, the building height and its accessories were improvised according to the neighboring buildings—whose photographs did still exist.

The next step was the necessity to model the building's roof. Buildings in Otrokovice at that time had only one type of roof—a pitched roof, whose shape was always adapted to the building's floor plan. The pitched roof was created by dividing the top face into two parts, and the newly created edge was subsequently moved to the required height.

To make the windows and doors embedded in the buildings, the Subdivide tool was used again on the relevant faces. After this, these new sub-faces were deleted to model holes. Additionally, the border edges of these holes were extruded to the depth of embedment of windows and doors. Chimneys were created from the Cube objects with changed scales in selected axes.

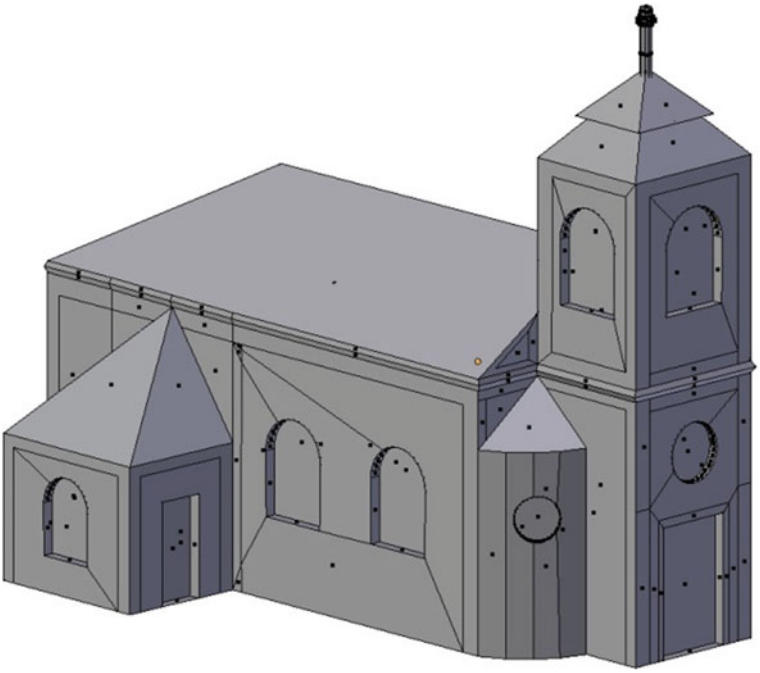

Fig. 6 A 3D model of the Otrokovice Church

An example of one modelled building is shown in Fig. 6. Here is for example, the Otrokovice church model from the Nineteen-thirties in the Blender environment.

3D models of trees and shrubs were created by the help of Blender's internal script called Sapling. This script allows one to create different trees, based on set initial parameters. The tree objects used in this project were simplified as much as possible so that the scene was not too complicated for the rendering process.

In order to make the whole rendered scene look more realistic, models of grasses were added. These models were based on Plane objects, on which the grass textures with transparency were mapped later. Groups of these objects created tufts of grasses that have good visibility from different viewpoints. Later, these groups were inserted as multiples into the scene and thereby large lawns were generated.

5 Texturing

The UV mapping technique was used for texturing objects. This process starts by the decomposition of each object into 2D sub-surfaces (a UV map). At the beginning of the decomposition process, it is necessary to mark the edges, which

should be ripped from one another. In Blender, this process is performed by the Mark Seam command. After that, it is possible to finish decomposing by using the Unwrap tool. The UV map created in this way is saved into the .png raster graphic format (it is also possible to save it into another raster graphic format, but it is necessary to use a lossless compression algorithm). The resolutions 512 × 512 or 1024 × 1024 pixels for the UV maps were used, because the rendering process usually needs the power of two texture resolution.

All textures were drawn in the GIMP software environment. Therefore, all of the UV maps created in this way were also opened in GIMP. In these pictures, the location of each part of the 3D object is visible. With this information, a user can fill each individual sub-surface as necessary. Most of these textures were drawn by hand, and in some cases, pre-created textures from the CGTextures website were used [19]—these textures were edited and modified in order to use them on the models so created. For texture creation and editing purposes, standard GIMP

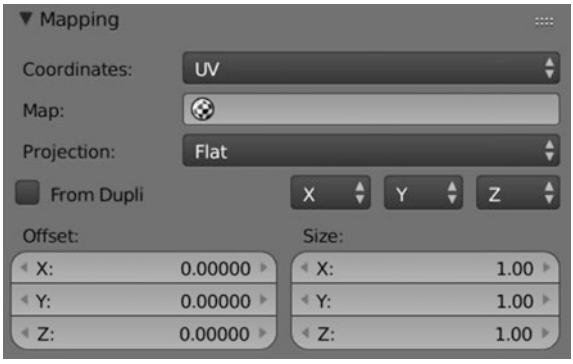

Fig. 7 The user environment for the UV mapping settings in Blender

Fig. 8 Textured 3D model of the Otrokovice Church

drawing, coloring and transforming tools were used [17]. Once this process was finished, they were saved in .jpg format. In this case, the graphic format with a lossy compression algorithm can be used in order to save computer memory—and the .jpg format is ideal for that. The next step was to re-load these created textures in Blender and to correctly map them into 3D objects. This process is performed by correcting the set parameters in the Texture Mapping panel (Fig. 7).

All 3D sub-models of Otrokovice center in the Nineteen-thirties were also created and textured in this way. An example of the Otrokovice Church model with textures is shown in Fig. 8.

6 Rendering and Animation

After the completion of the modeling phase of separate buildings and accessories with textures, they were inserted into a single complex 3D scene of the landscape model. In addition, here, it was necessary to set the other suitable parameters—like the surroundings, lighting and cameras. The surrounding area setting parameters are performed by the World window in Blender. It is possible to set simple colors for the horizon and zenith and to blend them, or to use the internal (i.e. procedural) or external texture (any bitmap file). In this project, the Clouds procedural texture was used, which looks close to reality in the scene.

Lighting of the scenes can be realized in several ways in Blender. It is possible to use light objects (called Lamps in Blender) for local lighting or global influences (i.e. Ambient Light, Ambient Occlusion, Environment Lighting and Indirect Lighting). The Environment Lighting technique combined with the Emit material settings of selected objects was used in this 3D scene.

The last step before the rendering process was to select a suitable position for the cameras. In order to capture the scene from different positions and prepare for the virtual tour output in the future, 8 camera objects were inserted in the scene and placed in suitable positions. After that, these cameras were correctly oriented in order to capture the most graphic images of the whole scene.

The Render command performs the rendering calculation process in the Blender environment. Additionally, the user can set many of the accompanying parameters. The basic parameters are the choice of a rendering algorithm, image or animation resolution, type of output file format, antialiasing, motion blur, enable/disable ray-tracing and shadows. In this project, the decision was made to use Blender's internal renderer with image resolutions of 1920×1080 pixels, 25 frames per second and the MPEG-2 output format to render animations. Figure 9 shows one rendered image of the Otrokovice Center in the Nineteen-thirties.

Fig. 9 The rendered image of the Otrokovice Center model in the Nineteen-thirties

7 Conclusion

This paper has presented a visualization method for the Otrokovice town in the Nineteen-thirties. Based on the historical materials, a more complex 3D scene was created that contains 3D models of terrains, houses and buildings, trees, shrubs, grasses and even more accessories in order to achieve the best possible authenticity. The output of this work includes two different ways of doing so. The rendered images are the first output. They captured the scene in the places where the most photographs of that time were created in order to provide a comparison. The second output consists of an animation. This animation is performed by the Curve object, which links through the whole scene and the camera is connected to it and follows the curve's shape during the defined time.

The next goal, in the future, is to expand and improve the whole scene in order to make it even more realistic. This process will include the creation of more models of houses and buildings—mainly on the edge of town, and the modeling of more types of accessories, like other constructions, fences, benches, etc. The authenticity mainly depends on obtaining other historical materials.

A further extension could be the rendering of a virtual tour. This output requires panoramic rendered images, which are possible to create in the Blender environment by the appropriate camera parameter settings. After that, the panoramic images have to be joined, corrected and exported to another application that can process them and generate the virtual tour from them.

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