Sukkur IBA Journal of Computing and Mathematical Sciences

Recognized by HEC Pakistan in "Y" Category

E-ISSN: 2522-3003

P-ISSN: 2520-0755

Volume: 4 | No: 2 | Jul - Dec | 2020

Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS) is the bi-annual research journal published by **Sukkur IBA University**, Sukkur Pakistan. **SJCMS** is dedicated to serve as a key resource to provide practical information for the researchers associated with computing and mathematical sciences at global scale.

Disclaimer: The opinions expressed in **Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS)** are those of the authors and contributors, and do not necessarily reflect those of the journal management, advisory board, the editorial board, Sukkur IBA University press or the organization to which the authors are affiliated. Papers published in **SJCMS** are processed through double blind peer-review by subject specialists and language experts. Neither the **Sukkur IBA University** nor the editors of **SJCMS** can be held responsible for errors or any consequences arising from the use of information contained in this journal, instead errors should be reported directly to corresponding authors of articles.

Publisher: **Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS)**
Office of Research Innovation & Commercialization – ORIC
Sukkur IBA University – Airport Road Sukkur-65200, Sindh Pakistan
Tel: (092 71) 5644429 Fax: (092 71) 5804425 Email: sjcms@iba-suk.edu.pk URL: sjcms.iba-suk.edu.pk

Mission Statement

The mission of **Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS)** is to provide a premier interdisciplinary platform to researchers, scientists and practitioners from the field of computing and mathematical sciences for dissemination of their findings and to contribute in the knowledge domain.

Aims & Objectives

Sukkur IBA Journal of Computing and Mathematical Sciences aims to publish cutting edge research in the field of computing and mathematical sciences.

The objectives of **SJCMS** are:

1. to provide a platform for researchers for dissemination of new knowledge.
2. to connect researchers at global scale.
3. to fill the gap between academician and industrial research community.

Research Themes

The research focused on but not limited to following core thematic areas:

Computing:

- Software Engineering
- Formal Methods
- Human Computer Interaction
- Information Privacy and Security
- Computer Networks
- High Speed Networks
- Data Communication
- Mobile Computing
- Wireless Multimedia Systems
- Social Networks
- Data Science
- Big data Analysis
- Contextual Social Network Analysis and Mining
- Crowdsource Management
- Ubiquitous Computing
- Distributed Computing
- Cloud Computing
- Intelligent devices
- Security, Privacy and Trust in Computing and Communication
- Wearable Computing Technologies
- Soft Computing
- Genetic Algorithms
- Robotics
- Evolutionary Computing
- Machine Learning

Mathematics:

- Applied Mathematical Analysis
- Mathematical Finance
- Applied Algebra
- Stochastic Processes

Publisher: **Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS)**
Office of Research Innovation & Commercialization – ORIC
Sukkur IBA University – Airport Road Sukkur-65200, Sindh Pakistan
Tel: (092 71) 5644429 Fax: (092 71) 5804425 Email: sjcms@iba-suk.edu.pk URL: sjcms.iba-suk.edu.pk

Patron's Message

Sukkur IBA University has been imparting education with its core values merit, quality, and excellence since its inception. Sukkur IBA University has achieved numerous milestones in a very short span of time that hardly any other institution has achieved in the history of Pakistan. The university is continuously being ranked as one of the best university in Pakistan by Higher Education Commission (HEC). The distinct service of Sukkur IBA University is to serve the rural areas of Sindh and also underprivileged areas of other provinces of Pakistan. Sukkur IBA University is committed to serve targeted youth of Pakistan who is suffering from poverty and deprived of equal opportunity to seek quality education. Sukkur IBA University is successfully undertaking its mission and objectives that lead Pakistan towards socio-economic prosperity.

In continuation of endeavors to touch new horizons in the field of computing and mathematical sciences, Sukkur IBA University publishes an international referred journal. Sukkur IBA University believes that research is an integral part of modern learnings and development. Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS) is the modest effort to contribute and promote the research environment within the university and Pakistan as a whole. SJCMS is a peer-reviewed and multidisciplinary research journal to publish findings and results of the latest and innovative research in the fields, but not limited to Computing and Mathematical Sciences. Following the tradition of Sukkur IBA University, SJCMS is also aimed at achieving international recognition and high impact research publication in the near future.

Prof. Dr. Mir Muhammad Shah
Vice Chancellor, Sukkur IBA University
Patron SJCMS

Publisher: **Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS)**
Office of Research Innovation & Commercialization – ORIC
Sukkur IBA University – Airport Road Sukkur-65200, Sindh Pakistan
Tel: (092 71) 5644429 Fax: (092 71) 5804425 Email: sjcms@iba-suk.edu.pk URL: sjcms.iba-suk.edu.pk

Editorial

Dear Readers,

It is a pleasure to present to you the eight issue of (volume 4, issue 2) of Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS). The Higher Education Commission Pakistan recognized SJCMS in **Y-Category**. I congratulate all the stakeholders for this achievement.

During the past few months, lifestyle of the people has been changed due to COVID-19. Advances in science and technology enables the survival in all areas including businesses, medical, education, health, agriculture, communication, transportation, and defense etc. This has been driven by an ever-growing volume of exciting discoveries, largely emanating from research community. In order to highlight the future technology challenges, the SJCMS aims to publish cutting-edge research in the field of computing and mathematical sciences for dissemination to the largest stakeholders. SJCMS has achieved milestones in very short span of time and is indexed in renowned databases such as DOAJ, Google Scholar, DRJI, BASE, ROAD, CrossRef and many others.

This issue contains the double-blind peer-reviewed articles that address the key research problems in the specified domain The SJCMS adopts all standards that are a prerequisite for publishing high-quality research work. The Editorial Board and the Reviewers Board of the Journal is comprised of renowned researchers from technologically advanced countries. The Journal has adopted the Open Access Policy without charging any publication fees that will certainly increase the readership by providing free access to a wider audience.

On behalf of the SJCMS, I welcome the submissions for upcoming issue (Volume-5, Issue-1, January-June 2021) and looking forward to receiving your valuable feedback.

Sincerely,

Ahmad Waqas, PhD
Chief Editor

Publisher: **Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS)**
Office of Research Innovation & Commercialization – ORIC
Sukkur IBA University – Airport Road Sukkur-65200, Sindh Pakistan
Tel: (092 71) 5644429 Fax: (092 71) 5804425 Email: sjcms@iba-suk.edu.pk URL: sjcms.iba-suk.edu.pk

Publisher: **Sukkur IBA Journal of Computing and Mathematical Sciences (SJCMS)**
Office of Research Innovation & Commercialization – ORIC
Sukkur IBA University – Airport Road Sukkur-65200, Sindh Pakistan
Tel: (092 71) 5644429 Fax: (092 71) 5804425 Email: sjcms@iba-suk.edu.pk URL: sjcms.iba-suk.edu.pk

Contents

Vol. 4, No. 2 | Jul – Dec 2020

Yeh's Satisfaction Index Modelling of Tenants in Rental Appartments: A Case Study of Latifabad, Hyderabad

Rabia[1], Saima Kalwar[1], Irfan Ahmed Memon[1], Imtiaz Ahmed Chandio[1]

Abstract:

The population of urban areas has been rapidly growing over the last few decades. This has increased the housing demand including rental apartments in Pakistan. Although the satisfaction of tenant accommodated in an apartment is a big challenge. There are also many problems like income and affordability, lack of building bylaws for those tenants. This study finds the satisfaction level of the tenant living in apartments. A standardized closed-ended questionnaire survey was used to collect the data. The analysis was done in two parts: (1) analysis of frequency ranking of all amenities, services, and facility types, (2) Yeh's satisfaction index model to find the satisfaction level of tenants toward particular amenity, service, or facility. Findings revealed issues like; water supply, ventilation, sunlight, age of apartment, electricity, improper cleaning, insufficient parking, minimum play area, isolation, over rent, price of services, maintenance, and management, suffocation, congestion, etc. This result implies that rents are more likely to base be on provided amenities rather than on unit size which reconfirms that rent is driven by provided amenities.

Keywords: *Yeh's satisfaction index; amenities; services; rent.*

1. Introduction

The population of urban areas has been growing at a rapid scale from the last few decades, and it is expected that about 60% world population will live in cities by 2050 so that the housing demand increasing including rental apartments [1]**.** Public rental accommodation is viewed as an important aspect of the overheated real estate industry in addressing housing issues. At the end of 2016, the initiative has helped a total of 11.3 million households with housing problems, and their housing conditions had changed dramatically [2]. In developing nations, typical central areas of urban centers are notorious for low housing standards and a declining community climate. There is however a lack of observational research on the degree to which inhabitants of such regions are satisfied with their housing conditions [3]. The prevalence of inadequate housing conditions not only impacts the quality of life of people but also threatens the pursuit of the aim of "sufficient housing for all" [4]. The events of recent years have made renter apartments more critical because of observing that rental is a big deal, this is because many households that were foreclosed upon have been forced to move into rental apartments. For mobile people that don't wish up-to-date the fixed prices of owning and busy people that don't want up-to-date the management price of owning, a rental apartment is a fundamental choice [5]**.** A

[1] Mehran University of Engineering & Technology, Jamshoro, Pakistan.
Corresponding Author: saima.kalwar@faculty.muet.edu.pk

people satisfaction survey helped measure the quality of housing according to its technological and practical criteria, as well as the degree of partnership between consumers and contractors/builders [6]. Investors widely use rental yields, central bankers, researchers, and policymakers to assess and detect disorders in apartment markets [7]**.** Also, external factors such as traffic congestion, proximity to work, and access to public transportation may have significant impacts on rent [8, 9]. Research measuring the effect of these factors on apartment rent should have essential implications for anyone setting rents, controlling vacancies, marketing apartment projects, and designing and planning new apartment housing [8]**.** Therefore, the identification of determinants of this satisfaction has become an important consideration for service assessment in recent years for managers and practitioners in their studies [10, 11]**.** Satisfaction with the level of service quality offered by the service providers is expected This is determined by the combined knowledge of a tenant in all points of communication with the business [12]**.** According to R. Negi**,** service providers must understand which added value and satisfaction attributes of the service can only meet minimal requirements and mitigate dissatisfaction [13].

A field survey is conducted to find ethnic discrimination in a rental apartment. Such a field survey has made use of personal approaches. Generally, two testers are matched and trained so that they make equivalent inquiries when speaking to renters in their apartments [14]. This method is used by researchers in this research to conduct the survey related to measuring apartment rent, services, and amenities such as utilities, maid services, and location facilities. Susilawati's research in 2002 highlighted the need to identify satisfaction for tenants to match the success of the organization [15-20]. Leader happiness conceptualizes human perception of a certain service meeting as an interactional means. Tenant depends on the awareness of service providers and the performance of the service equally [21, 22]. Furthermore, fulfillment on the part of the occupant by finishing a commercial tenancy value or cost and benefits review [23]. According to Amérigo and J. I. Aragones find the satisfaction behavior of tenants toward particular amenity or services by using the satisfaction index method given by Yeh's with the help of a questionnaire within the study area [21, 24-27].

2. Methodology

2.1. Study Area

Hyderabad city is comprised of three Talukas. For this study, the researcher has selected Latifabad Taluka as a case study area. As per the 2017 population census, the population of Hyderabad is 1,732,693 in which Latifabad Taluka contains 672,504. The Latifabad Taluka is distributed in 12 zones, which are commonly called Units. The study had collected data from the tenants residing in 6 and 7 Units (zones) of Latifabad Taluka. The purpose of selecting these two units was that half of the population of 6 and 7 Units are living in the apartments.

2.2. Methods for Data Collection

Researchers used the primary data collection method where they conducted the questionnaire survey from the tenants of Latifabad Unit 6 and Unit 7. The sample consists of 384 individuals/Apartments by using cluster sampling techniques from various parts of Latifabad using different focus groups. The sample is selected about the existing situation of tenants residing over different areas of Latifabad. The purpose of the study is to know the satisfaction level of tenants in a rental apartment for this researcher has taken 15% of all samples 384, which is 58 to know the satisfaction level of tenants from different areas, through the Cluster sampling technique [28-30].

2.3 Methods for Data Analysis

The collected data was analyzed through Microsoft Excel and Yeh's satisfaction index Model. Microsoft Excel helps to obtain the frequencies that determine the number of responses on the given variables based on the existing condition of apartments in Latifabad Unit 6 and 7 that show either respondents were satisfied with the existing condition or not. Whereas Yeh's Satisfaction index is also a very helpful tool that is used to highlight the level of satisfaction and dissatisfaction.

2.3.1 Satisfaction Index Method

In this research work, researchers used the satisfaction index model of Kyle and Baird (1995) to analyze the satisfaction level of respondents regarding rent payment, amenities, and services while living in rental apartments by using the satisfaction index method given by Yeh's [17] with the help of a questionnaire within the study area.

YSI= Satisfied- Dissatisfied/ total respondents x 100
YSI = Yeh's satisfaction Index

Through this formula, the researcher is come to know about the satisfaction level of tenants regarding apartment rent, amenities, and services

By using this Index researcher obtained numerical values which may be positive or negative or zero, these positive and negative or zero values may show that there is no satisfaction if the answer comes under 0 or it may show minimum, moderate, or strong satisfaction if the answer comes under 25% or 50% or 75%. Similarly, if the answers come under negative values such as – 25%, -50%, or -75% then it will come under minimum dissatisfaction, moderate dissatisfaction or strong dissatisfaction and so on that will help the researcher to decide that how much response is satisfying or dissatisfying based on following criteria as mentioned in Table I:

TABLE I. Shows the criteria for the satisfaction and dissatisfaction level of tenants

S. No.	Criteria for Satisfaction and Dissatisfaction level of tenants	
	Percentages	***Level of satisfaction and dissatisfaction***
01	0	No satisfaction/dissatisfaction
02	0.25 or 25%	Minimum satisfaction
03	0.50 or 50%	Moderate satisfaction
04	0.75 or 75%	Strong satisfaction
05	0.90> or 90% and above	Highly strong satisfaction
06	0	No satisfaction/dissatisfaction
07	-0.25 or -25%	Minimum dissatisfaction
08	-0.50 or -50%	Moderate dissatisfaction
09	-0.75 or -75%	Strong dissatisfaction
10	-0.90> or -90% and above	Highly strong dissatisfaction

3 Results

All the responses obtained from Latifabad Unit 6 and 7 are based on various research variables that are combined and presented in the form of tables and graphs.

Fig 1 shows that tenants who are residing in Latifabad Unit 6 are satisfied to some extent with the availability of basic services and amenities available to them but these tenants are not highly satisfied even they are paying rent and utility bills for the services available to them. Most of the responses related to the availability of hygienic services and ventilation the apartment shows that 45 respondents are satisfied and 15 are dissatisfied out 58, the question related to the condition of electricity shows that 48

respondents are satisfied and 10 are dissatisfied and services charges indicate that 48 responses are dissatisfied whereas 10 respondents are satisfied, satisfaction with the location of plaza shows that 11 respondents are dissatisfied and 47 are satisfied, and current rent payment shows that 37 respondents are not satisfied with the amount of rent whereas 21 responses showed there satisfaction.

Fig 2 shows the responses obtained from Latifabad Unit 7. Most of the responses indicate that tenants who are residing in Latifabad Unit 7 are not satisfied with the existing living condition and services and amenities available to them, they are paying more than they consume. Collected responses were based on the variables such as sufficient apartment area, availability of hygienic services, ventilation in the apartment, proper cleaning system, condition of electricity, availability of sufficient drinking water, satisfaction with the location plaza, sufficient parking space within the plaza, sufficient play area, overall beneficial area for the tenants, feeling of isolation in the apartment, available facilities in the apartment, services charges, hygienic services, quality of basic services, the safety of tenants in the apartment, benefits of the area and current rent payment. The responses related to these variables indicate that related to sufficient apartment area 50 respondents are satisfied and 8 respondents are dissatisfied, however, for the availability of hygienic services and ventilation in the apartment 45 respondents are dissatisfied and 15 are satisfied, condition of electricity and services charges shows 47 respondents are dissatisfied and 11 responses are satisfied out of 58.similiarly all the other responses on variables indicates that majority of tenants are not satisfied with their existing condition.

TABLE II shows the results in the form of percentages obtained from the tenants of Latifabad Unit 6. The showed results are calculated through Yeh's Satisfaction Index which brings positive and negative values. With the help of these positive and negative values researchers come to know the satisfaction and dissatisfaction levels of tenants according to the criteria mentioned in Table 1. However, the calculations show that tenants are highly strong satisfaction with the apartment area, response related to the availability of hygienic services and ventilation in the apartment shows that tenants are moderately satisfied, related to proper cleaning system, availability of sufficient drinking water, sufficient parking space within the plaza, sufficient play area and quality of basic services shows that tenants are minimum satisfied. Tenants are strongly satisfied with the condition of electricity, satisfaction with the location of the plaza, overall beneficial area for the tenants, and services charges.

TABLE III shows the results in the form of percentages obtained from the tenants of Latifabad Unit 7. The showed results are calculated through Yeh's Satisfaction Index which brings positive and negative values. With the help of these positive and negative values researchers come to know the satisfaction and dissatisfaction levels of tenants according to the criteria mentioned in Table 1. However, the calculations show that tenants are highly strongly satisfied with the apartment area, response related to the availability of hygienic services and ventilation in the apartment shows that tenants are moderately dissatisfied, related to proper cleaning system, availability of sufficient drinking water, sufficient parking space within the plaza, sufficient play area and quality of basic services, shows that tenants have minimum dissatisfaction.

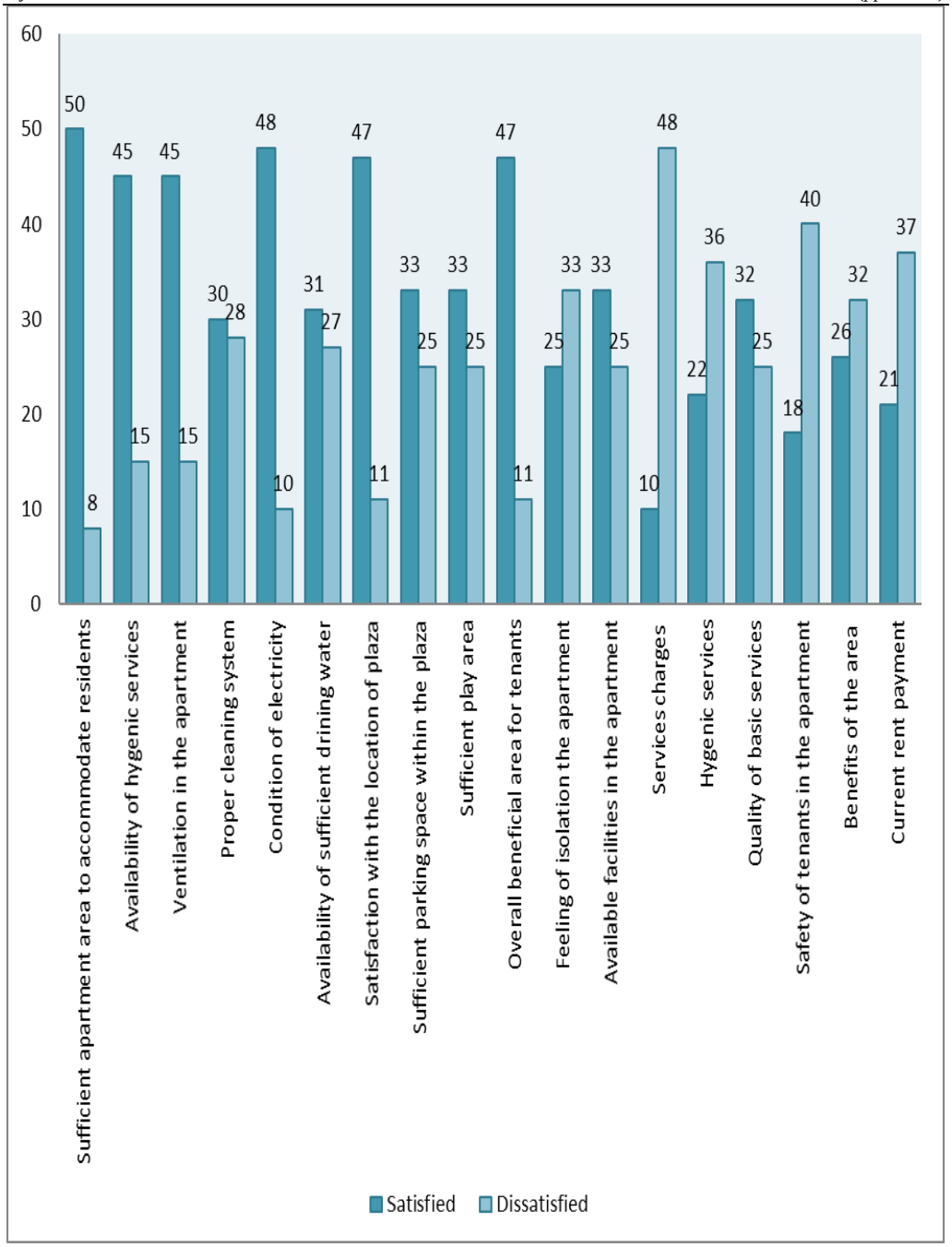


Fig. 1. Shows the satisfaction and dissatisfaction level of tenants residing in Latifabad Unit # 6

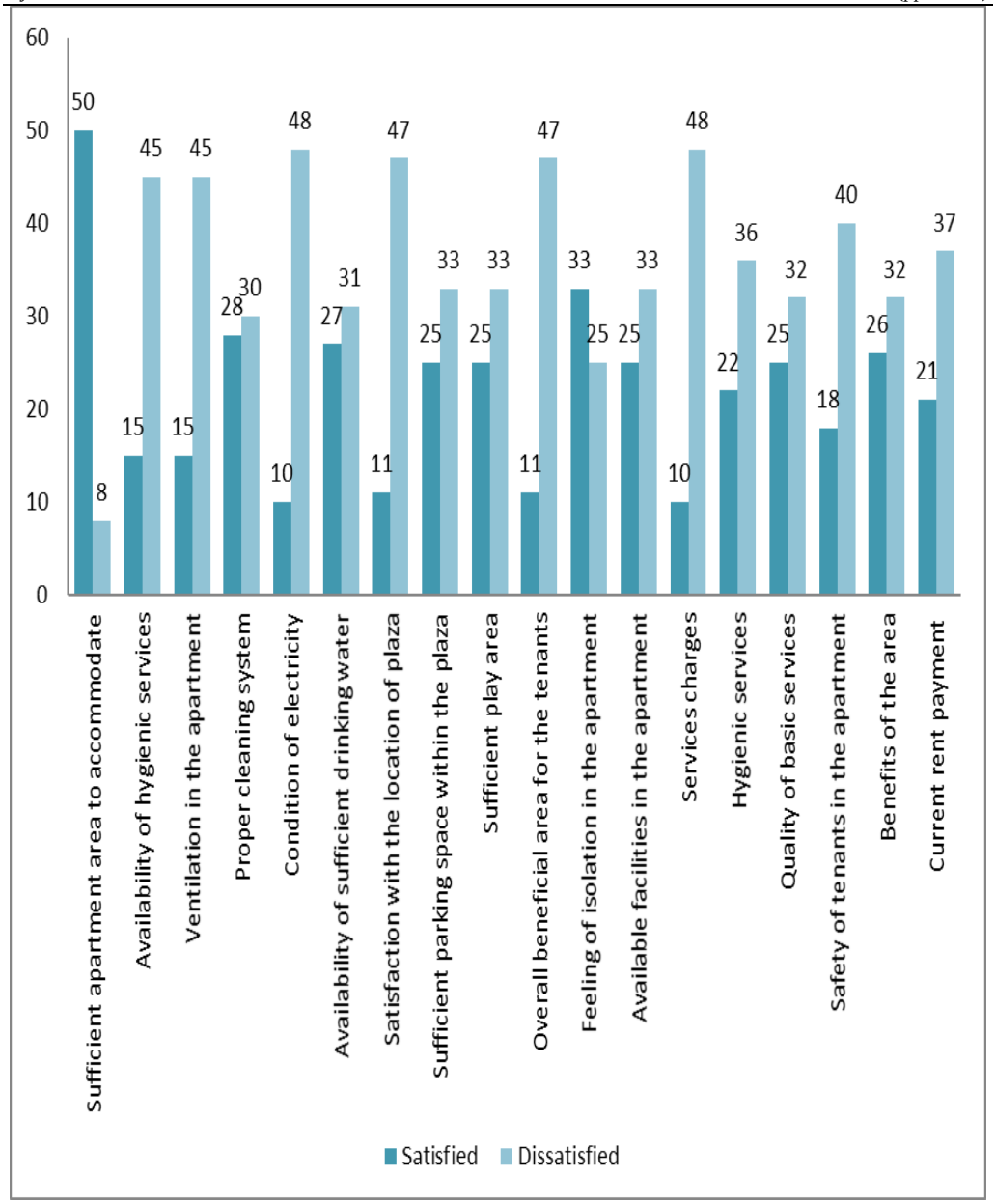


Fig. 2 Shows the satisfaction and dissatisfaction level of tenants residing in Latifabad Unit 7

TABLE III shows the results in the form of percentages obtained from the tenants of Latifabad Unit 7. The showed results are calculated through Yeh's Satisfaction Index which brings positive and negative values. With the help of these positive and negative values researchers come to know the satisfaction and dissatisfaction levels of tenants according to the criteria mentioned in Table 1.

TABLE II. Shows the Satisfaction and Dissatisfaction level of tenants residing in Latifabad Unit 6

Variables	**Satisfaction and Dissatisfaction level determined through Yeh's Satisfaction Index**	
	Satisfy	***Dissatisfy***
Sufficient apartment area to accommodate	72%	
Availability of hygienic services	51.72%	
Ventilation in the apartment	51.72%	
Proper cleaning system	3.44%	
Condition of electricity	65.5%	
Availability of sufficient drinking water	6.9%	
Satisfaction with the location of the plaza	62%	
Sufficient parking space within the plaza	13.79%	
Sufficient play area	13.79%	
Overall beneficial area for the tenants	62%	
The feeling of isolation in the apartment		-13.79%
Available facilities in the apartment		-13.79%
Services charges	65.5%	
Hygienic services		-24.14%
Quality of basic services	12.6%	
Safety of tenants in the apartment		-37.9%
Benefits of the area	10.34%	
Current rent payment		-27.58%

TABLE III. Shows the Satisfaction and Dissatisfaction level of tenants in Latifabad Unit 7

Variables	**Satisfaction and Dissatisfaction level determined through Yeh's Satisfaction Index**	
	Satisfy	***Dissatisfy***
Sufficient apartment area to accommodate	72%	
Availability of hygienic services		-51.72%
Ventilation in the apartment		51.72%
Proper cleaning system		-3.44%
Condition of electricity		-65.5%
Availability of sufficient drinking water		-6.89%
Satisfaction with the location of the plaza		-62.06%
Sufficient parking space within the plaza		-13.79%
Sufficient play area		-13.79%
Overall beneficial area for the tenants		-62.06%
The feeling of isolation in the apartment	13.79%	
Available facilities in the apartment		-13.79%
Services charges		-65.51%
Hygienic services		-24.13%
Quality of basic services		-13.79%
Safety of tenants in the apartment		-37.9%
Benefits of the area		-10.34%
Current rent payment		-27.58%

Table 1. However, the calculations show that tenants are highly strongly satisfied with the apartment area, response related to the availability of hygienic services and ventilation in the apartment shows that tenants are moderately dissatisfied, related to proper cleaning system, availability of sufficient drinking water, sufficient parking space within the plaza, sufficient play area and quality of basic services, shows that tenants have minimum dissatisfaction. Tenants are strongly dissatisfied with the condition of electricity, satisfaction with the location of the plaza, overall beneficial area for the tenants, and services charges. The results are calculated through Yeh's Satisfaction Index which indicates that most of the tenants are dissatisfied with the existing condition which is determined through the positive and negative values obtained through Yeh's Satisfaction Index and mentioned below in Table III.

4 Conclusion

This research aims to determine the satisfaction level of tenants in rental apartments based on data collected through the questionnaire on the selected site Latifabad unit 6 and 7 Hyderabad. Through which it has been derived that people who are living in rental apartments are mostly low and middle income that is migrated from rural areas for employment and education purposes. Due to their medium and low-income factor, they are not able to buy a home or get rented well-conditioned apartments through this factor they also did not have access to amenities and services. With the help of Yeh's satisfaction index, it has been concluded that people are not satisfied with the apartment rent and available basic services and amenities. Whereas the collected data also indicates that the satisfaction level of tenants living in Latifabad Unit 6 is much better than those who are living in the unit.

References

[1]UN, *World Urbanization Prospects: The 2014 Revision-Highlights*. UN, 2014.

[2] J. Li, M. Stehlík, and Y. Wang, "Assessment of barriers to public rental housing exits: Evidence from tenants in Beijing, China," *Cities*, vol. 87, pp. 153-165, 2019/04/01/ 2019, doi: https://doi.org/10.1016/j.cities.2018.09.019.

[3] B. A. Adewale, E. O. Ibem, B. Amole, and A. B. Adeboye, "Assessment of residential satisfaction in the core area of Ibadan Metropolis, Nigeria," *Journal of Human Behavior in the Social Environment*, vol. 29, no. 2, pp. 206-233, 2019/02/17 2019, doi: 10.1080/10911359.2018.1502116.

[4] N. Lepkova, E. Butkiene, and M. Belej, "Study of Customer Satisfaction with Living Conditions in New Apartment Buildings," *Real Estate Management and Valuation*, vol. 24, pp. 52-70, 10/12 2016, doi: 10.1515/remav-2016-0021.

[5] R. K. Green, "Thoughts on rental housing and rental housing assistance," *Cityscape*, pp. 39-55, 2011.

[6] J. Li, D. Li, X. Ning, J. Sun, and H. Du, "Residential satisfaction among resettled tenants in public rental housing in Wuhan, China," *Journal of Housing and the Built Environment*, vol. 34, no. 4, pp. 1125-1148, 2019/12/01 2019, doi: 10.1007/s10901-019-09667-x.

[7] R. J. Hill, M. Steurer, and S. R. Waltl, "Owner Occupied Housing in the CPI and Its Impact on Monetary Policy During Housing Booms and Busts," 2018.

[8] V. Dökmeci and A. Yavas, "External factors, housing values and rents: Evidence from survey data," 2000.

[9] J. Zietz, E. N. Zietz, and G. S. Sirmans, "Determinants of house prices: a quantile regression approach," *The Journal of Real Estate Finance and Economics*, vol. 37, no. 4, pp. 317-333, 2008.

[10] A. Shaikh, U. Amjad, R. Khan, and N. Ur, "IMPACT OF SERVICE QUALITY ON CUSTOMER SATISFACTION:

EVIDENCES FROM THE RESTAURANT INDUSTRY IN PAKISTAN," *Management & Marketing Journal,* vol. 9, no. 2, 2011.

[11] R. Saravanan and K. Rao, "Measurement of service quality from the customer's perspective–an empirical study," *Total Quality Management and Business Excellence,* vol. 18, no. 4, pp. 435-449, 2007.

[12] A. Eshghi, S. K. Roy, and S. Ganguli, "SERVICE QUALITY AND CUSTOMER SATISFACTION: AN EMPIRICAL INVESTIGATION IN INDIAN MOBILE TELECOMMUNICATIONS SERVICES," *Marketing Management Journal,* vol. 18, no. 2, 2008.

[13] R. Negi, "DETERMINING CUSTOMER SATISFACTION THROUGH PERCEIVED SERVICE QUALITY: A STUDY OF ETHIOPIAN MOBILE USERS," *International Journal of Mobile Marketing,* vol. 4, no. 1, 2009.

[14]A. M. Ahmed and M. Hammarstedt, "Discrimination in the rental housing market: A field experiment on the Internet," *Journal of Urban Economics,* vol. 64, no. 2, pp. 362-372, 2008.

[15] C. Susilawati, "Customer satisfaction survey of the facilities provided by office building "X" in Surabaya," in *Proceedings of The 8th Pacific Rim Real Estate Society Annual Conference,* 2002.

[16] M. A. Almomani, S. Basri, and A. R. Gilal, "Empirical study of software process improvement in Malaysian small and medium enterprises: The human aspects," *Journal of Software: Evolution and Process,* vol. 30, no. 10, p. e1953, 2018.

[17] A. R. Gilal, J. Jaafar, S. Basri, M. Omar, and A. Abro, "Impact of software team composition methodology on the personality preferences of Malaysian students," in *2016 3rd International Conference on Computer and Information Sciences (ICCOINS)*, 2016: IEEE, pp. 454-458.

[18] A. R. Gilal, J. Jaafar, M. Omar, S. Basri, and A. Waqas, "A rule-based model for software development team composition: Team leader role with personality types and gender classification," *Information and Software Technology,* vol. 74, pp. 105-113, 2016.

[19] A. R. Gilal, M. Omar, J. Jaafar, K. I. Sharif, A. Mahesar, and S. Basri, "Software development team composition: personality types of programmer and complex networks," in *6th International Conference on Computing and Informatics (ICOCI-2017)*, 2017, pp. 153-159.

[20] M. Z. Tunio, H. Luo, C. Wang, F. Zhao, A. R. Gilal, and W. Shao, "Task Assignment Model for Crowdsourcing Software Development: TAM," *Journal of Information Processing Systems,* vol. 14, no. 3, 2018.

[21] S. A. Taylor and T. L. Baker, "An assessment of the relationship between service quality and customer satisfaction," *Journal of retailing,* vol. 70, no. 2, pp. 163-178, 1994.

[22] M. A. Jones and J. Suh, "Transaction-specific satisfaction and overall satisfaction: an empirical analysis," *Journal of services Marketing,* vol. 14, no. 2, pp. 147-159, 2000.

[23] N. Brackertz and R. Kenley, "Evaluating community facilities in local government: Managing for service enablement," *Journal of Facilities Management,* vol. 1, no. 3, pp. 283-299, 2002.

[24] M. a. Amérigo and J. I. Aragones, "A theoretical and methodological approach to the study of residential satisfaction," *Journal of environmental psychology,* vol. 17, no. 1, pp. 47-57, 1997.

[25] A. Batool, N. Naz, and G. A. Anjum, "Socio-cultural value of public open spaces with hamchas in dera ghazi khan City, Pakistan," *Mehran University Research Journal Of Engineering & Technology,* vol. 35, no. 2, p. 181, 2016.

[26] I. A. Memon, N. Madzlan, M. A. H. Talpur, M. R. Hakro, and I. A. Chandio, "A

Review on the Factors Influencing the Park-and-Ride Traffic Management Method," in *Applied Mechanics and Materials*, 2014, vol. 567: Trans Tech Publ, pp. 663-668.

[27] I. A. Memon, M. Napiah, M. A. Hussain, and M. R. Hakro, "Influence of factors to shift private transport users to Park-and-Ride service in Putrajaya," in *In Engineering Challenges for Sustainable Future: Proceedings of the 3rd International Conference on Civil, Offshore and Environmental Engineering (ICCOEE 2016, Malaysia, 15-17 Aug 2016)*, 2016, p. 385.

[28] I. A. Memon, S. Kalwar, N. Sahito, S. Qureshi, and N. Memon, "Average Index Modelling of Campus Safety and Walkability: The Case Study of University of Sindh," *Sukkur IBA Journal of Computing and Mathematical Sciences*, vol. 4, no. 1, pp. 37-44, 2020.

[29] I. A. Memon, M. Napiah, M. A. H. Talpur, and M. R. Hakro, "Mode choice modelling method to shift car travelers towards Park and Ride service," 2016.

[30] K. Shaikh, A. Memon, I. A. Memon, Z. A. Laghari, and A. M. Memon, "Awareness regarding Coronavirus pandemic among the population of Sindh, Pakistan: A cross-sectional study," *Sukkur IBA Journal of Computing and Mathematical Sciences,* vol. 4, no. 1, pp. 28-36, 2020.

Vol. 4, No. 2 | Jul – Dec 2020

Optimization of Central Pattern Generator based Quadruped Animation using Time Series with Genetic Algorithm

Zeeshan Bhatti[1], Shahneela Pitafi[1], Naila Shabbir[1]

Abstract:

Generating believable quadruped motion is a challenging task for an application like Games, Virtual Reality, and Augmented Reality, where runtime user interaction is needed. In order to successfully generate the believable motion, the runtime or dynamic adjustment to motion gaits is essential. As the use of the Central Pattern Generator (CPG) is vital in generating a range of dynamic quadruped motions, the optimization is crucial for smooth motion curves. We use the Genetic Algorithm (GA) based tuning technique to optimize the motion curves generated through CPG. The quadruped motion generated through CPG is applied on Skeletal joints and then optimized through fitting the artificial motion parameters tuned using a genetic algorithm. The results generated show much smooth and stable quadruped motion with believable gait patterns.

Keywords: Central Pattern Generator, Quadruped Animation, Time Series, Genetic Algorithm

1. Introduction

Animation means giving motion to virtual objects created and manipulated using computers. The use of animation tools and techniques in modern times has immensely increased from application areas including TV, Movies, CGI, Games, Cartoons, VFX, Virtual and Augmented reality. With demand comes to the great responsibility of producing realistic or believable motions of virtual objects. The Quadruped animation has always posed a great challenge due to the increased number of articulated legs and a wide range of motion gait patterns[1][2].

The neurological analysis of quadruped motions has given the concept of the Central Pattern Generator (CPG) system, responsible for generating multiple locomotions and their transitions within each gait. The central pattern generator is a system that consists of a network of neurons residing inside the nervous system of multilegged animals. Along with many responsibilities, it is primarily responsible for maintaining accurate coordination between multiple legs during cyclic motion of multiple gaits and patterns [3]. The use of CPG to generate an animation of quadrupeds in a virtual environment is a very tricky task. In this research work, the motion generated from CPG is optimized to produce accurate believable motion curves using a Genetic Algorithm. The genetic algorithm is a very popular and common algorithm used commonly for heuristic search and optimization purposes in various fields.

A. Central Pattern Generator for Motion

Central Pattern Generator is a neurological circuit that is responsible for generating cyclic rhythmic motion patterns through neural activity. These neural circuits behave like a distributed system that consists of nonlinear coupled oscillators. The rhythmic motion signals are produced using the phase coupled oscillator principle

[1]Institute of Information and Communication Technology, University of Sindh, Jamshoro
Corresponding Author: Zeeshan.bhatti@usindh.edu.pk

having different phase shifts for varying gait patterns. The change in gait patterns is achieved using altering the phase of coupling methods of oscillators[3].

In this research, the Phase oscillator is used as modelled by Kuramoto's [4]. The oscillator model consists of N coupled phase oscillators, where the phase difference of sine function is used to couple the phase oscillators. This principle is model mathematically as [5][6].

$$\dot{\theta}_i = w_i + \sum_{j=1}^{N} \lambda_{ij} \sin(\theta_j - \theta_i - \Delta\phi_{ij}) \quad (1)$$

$$\ddot{r}_i = \mu_i^2 (R_i - r_i) - \frac{3}{2}\mu_i \dot{r}_i \quad (2)$$

$$x_i = r_i[1 + \sin(\theta_i)] \quad (3)$$

Where phase of the i^{th} oscillator is denoted by Î,$_i$ and frequency by Ï‰$_i$. with its own frequency, the oscillator runs independently, while Î»$_{ij}$ is synchronizes it with all other oscillators. The phase shift parameter is Δâ^…$_{ij}$ between the two oscillators *i* and *j*. This type of CPG system consists of behaviors based on a stable limit cycle, due to which their output is modified by explicit parameters [7]. Figure 1, shows the frequency and amplitude modulated based on the above principle.

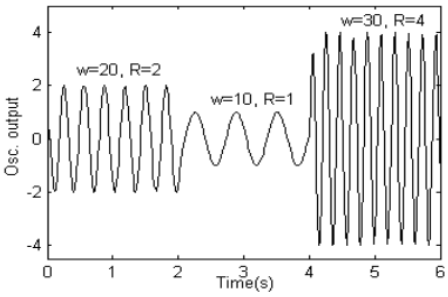


Fig 1: Change in frequency and amplitude of the oscillator (Source: [6])

B. Genetic Algorithm

Genetic algorithm is an optimization technique, belonging to a progressive class of artificial intelligence. The genetic algorithm randomly generates an initial population, then selects among the whole population the fittest by using the fitness function crossover between selected chromosomes and finally performs mutation and repeat cycle till the condition of the stop is true, as shown in generation cycle figure 2. A genetic algorithm consists of biological ideas like the population of chromosomes child production with cross over and mutation.

A Genetic algorithm is comparatively different than other commonly used optimization methods, as it is based on selecting the fittest from a given population. Genetic Algorithm does not use decision variables, it uses codes instead. For this type of optimization technique, binary or symbolic coding is necessary moreover genetic algorithm is a random process [8].

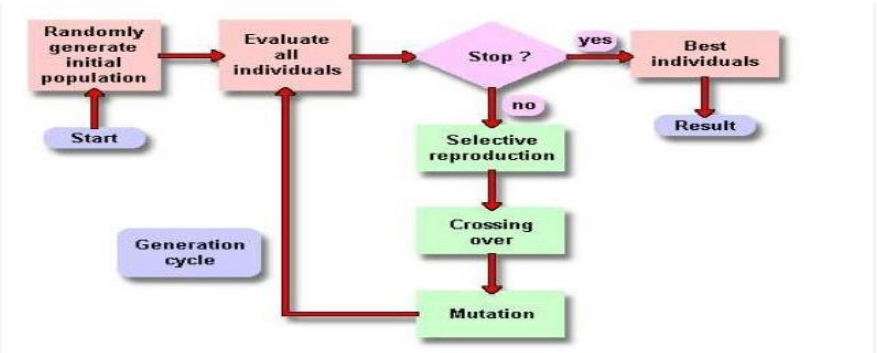


Fig 2: Genetic Algorithm presenting generation cycle (source: https://becominghuman.ai)

2. Literature Review

A.P. Gerdelan et all in 2009 [9] proposed a Genetic-Fuzzy System (GFS) which is used for the optimization of animated character motion authors worked on a new thing that is an optimization of motion during running, this Genetic- Fuzzy system is ideal for gaming and simulation based on the real-time environment. Author has given a study to solve one of the drawbacks of fuzzy systems which is for every new type of character time-intensive manual calibration of system parameter is required. Similarly, Zühtü Hakan Akpolat et all in 2017 [10] used the Lagrange method and simulation of the robotic fish model in MATLAB/SimMechanics environment to produce the dynamic model of one active joint robotic fish. Langrange energy equation is used to drive the mathematical model of the system for the robotic fish inspired from a real carangiform fish and solidWorks is used to design the computer-aided design (CAD) model of the robotic fish which is then transferred to simMechanics environment, results found for joint angles from SimMechanics and dynamic models are compared and proved with animation video of the robotic fish

Hiroshi Kimura et. al in [11] proposed a quadruped walk in a robot using a neural system model based on Central Pattern Generator (CPG) derived reflexes and responses. Response regulates the CPG phase, and reflex produces joint torque. Whereas, Katsuyoshi Tsujita et all in [12] proposed a control system for the four-legged robot using nonlinear oscillators. The control system is based on a gait pattern that encompasses a nonlinear oscillator and a leg motion controller uses a local feedback control that initiates the actuators of the four legs. Similarly, Chengju LIU et. al in [13] also proposed a Central Pattern Generator (CPG) for a quadruped robot with reflex vestibular to produce a rhythmic motion. They used a function called knee-to-hip mapping and oscillator network to understand the elementary animal-like walking gait. Moreover, Chengju Liu et. al in (2009) [6] also generated different gaits and gait transitions by using CPG control system for monitoring the locomotion of a 4-legged robot.

Primarily, four basic quadruped gaits were produced using phase-locked oscillation shapes with mutually coupled phase oscillators built a body CPG network.

Abdalftah Elbori et all in (2018) [6] uses a couple of CPGs such as unidirectional, uncoupled, bidirectional. Abdalftah Elbori tries to apply hybrid function in genetic algorithms and debates on the stability analysis of CPGs moreover utilized the bidirectional two CPGs to familiarizes the CPGs to robotic systems that accomplish one-leg movement the results show that CPGs rheostat locomotion without any sensory feedback and increase movement as well.

Whereas, Shivendra Shivani et all in [14] discussed the genetic algorithm with animation of the physical body to hit a target intelligently within an obstructed path. The genetic algorithm was used to train the objects and physical animation of the body for finding the accurate path and to be able to respond to the obstacles as the body collides with them.

L. GRITZ et. al proposed an AI-based Genetic Programming (GP) technique for achieving the goals of automatically derive the control program agents, his work [15]. It is a kind of motion prerequisite which is an alternative to key framing that permits a knowledge-based technique for highly automated generation of motion. L. GRITZ suggested that this method is a generalized approach as it can successfully generate the motion which is aesthetically tempting, specific to nature, and physically plausible.

J. J. Collins et all present in his work [17] a CPG model which is hard wired with non-linear oscillators to generate numerous 3 specific gaits for quadruped including walk, trot & bound motions, using oscillation patterns that are phase-locked. This was achieved by altering the oscillator

parameters of the network's driving signal that yielded transitions between the different gaits are generated. Similarly, Bhatti, Zeeshan (2019) [18] discussed and developed a procedural animation framework that uses the same Central Pattern Generator (CPG) model to generate a coupled oscillation pattern for various quadruped characters, that produced oscillating in-phase and out-phase motion curves driven through kinematic joint chains and procedural programming techniques.

Bruno Floriano et all [19] proposed the use of a multi-objective Genetic Algorithm for generating optimized quadruped walk gait patterns with a balanced control using kinematics technique and empirical methodology. In order to maintain the stability of a quadruped robot with a consistent response, a balance control mechanism is developed proportionally with speed achieved through measurements of the embedded accelerometer. Whereas, R. Singh ET all proposed [16] a model for locomotion of quadruped robot with the application of obstacle avoidance based on the fuzzy logic controller. This controller detects and implements the obstacle avoidance mechanism using three main Ultrasonic sensors (HC-SR04) mounted at the front of the robot. Results show the obstacle avoidance fuzzy controller and navigation work successfully.

3. Quadruped Model:

The quadruped model and skeletal structure used in this work are of a Lion and Horse character [20]. Each leg consists of 6 joints with joints near hips and front shoulders having a ball joint with 2 degrees of freedom, whereas, the knee and ankle joints consist of ball joints with 1 degree of freedom [21], as shown in Figure 3(a) and (b). In this research, the motion of the spine and neck have not been considered and calculated to limit the focus work and so are not discussed further.

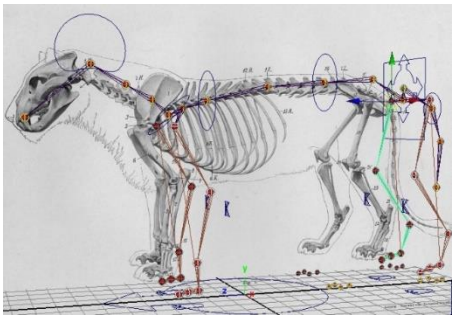


Fig 3(a): Skeletal joint structure of Lion

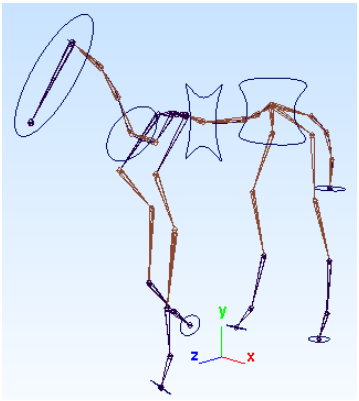


Fig 3(b): Skeletal Joint structure of Horse

4. Central Pattern Generator (CPG) for Quadruped

The animal gaits possess a type of permutation symmetry which is grouped and characterized according to its type. Based on this, each leg of a multi-legged animal is assumed to possess a subnetwork of neurons driven through individual and separate CPG for each leg. Most of the CPGs work on this principle, with inter-limb synchronization and coordination achieved through coupling these multiple CPG networks together. According to this, the system implements multiple units of CPG's based on the coupled oscillator principle.

This system then directly controls each leg's motion and generate a coupled pattern of symmetrical rhythmic oscillation. By using these multiple units of CPGs on each leg, the coupling of leg In-a-Phase, leg Out-of-Phase, and variable phases are done, generating different rhythmic behaviors.

These varying rhythmic behaviors include gait patterns of a different family of animals, i.e, Lion tiger, Horse, with walking, trotting, galloping, and others [22][18].

A. Systems of Two Coupled Oscillators

A coupled phase oscillator model is used in our quadruped CPG system to modulate the sinusoidal patterns of leg motion as discussed in [23]. The model of coupled phase oscillator allows us to synchronize the various periodic gait patterns of quadrupeds, generated through the CPG. In a typical system, by coupling two identical oscillators, two oscillation patterns are obtained as a result [24] [3]

The In-Phase pattern: in this technique the waveforms generated is the same from both the oscillators

The Out-of-Phase pattern: in this technique the waveforms generated are the same, however, there is a difference of half a period between each wave obtained from both the oscillators.

The motion analysis study shows that the gaits of quadruped animals move with a periodic cyclic pattern in a symmetrical rhythm, as the four legs are already located in symmetry [25].

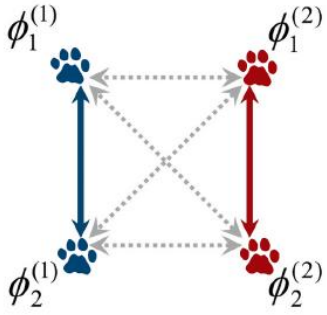


Fig 4: The Lateral and Diagonal couplings are represented by the solid and dotted lines, respectively for a quadruped gait.

The symmetrical coupling of the four legs is represented in Figure (3), where solid bars show the lateral and dotted lines show the diagonal synchronization. A cycle is represented by the interval between successive foot strikes of the same foot, from where the sequence is repeated [3]. The foot strike factor, determined by impact phase (dip), is the fraction of a cycle when the foot is in contact with the ground. The motion of quadruped phenotypes produces two variants of gait phases, where the legs are out-of-phase (walking or running) or in-phase (jumping or hopping), with some gaits having a more complex behavior of the relative phase [26][3][21].

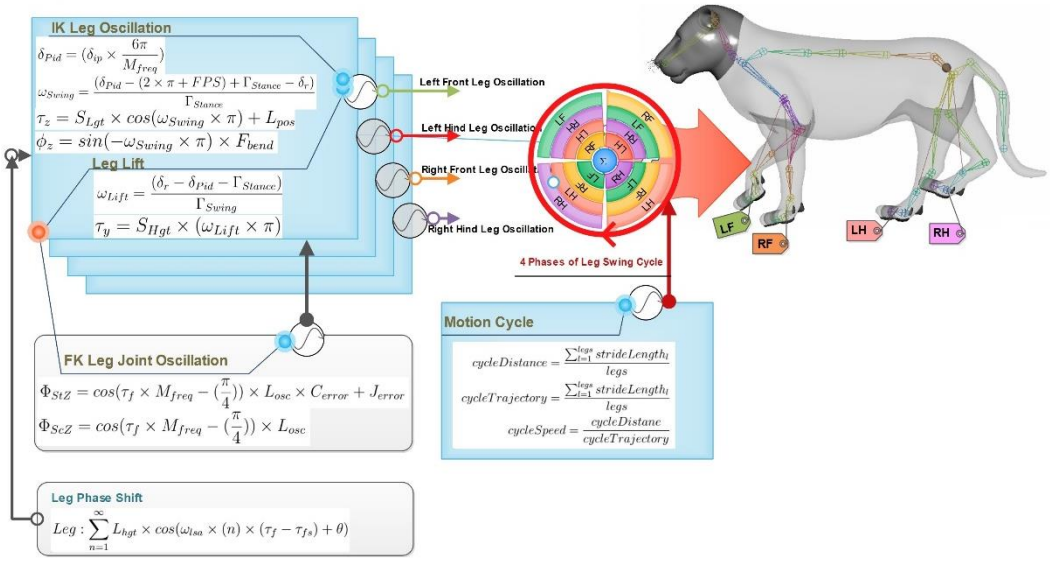


Fig 5: Mathematical model for CPG based Leg Simulation

5. Optimization Model for Motion Curves

To optimize the animation curve, a Time series problem is applied to motion curves generated for quadruped animation. The time series can be applied on various data sets that change with respect to times, to determine and predict complex, nonperiodic, irregular, and chaotic sequential data that vary with respect to time [27]. In order to optimize the animation of the quadruped, the motion curve is considered as Time Series, and the Genetic algorithm is applied to the keyframe data.

A. Optimization with Time Series

Animation Motion curve data in a time series (T) can be formulated as $T=\{x_t, t=1,\ldots, N\}$, where *t* is known as the time in frames, N is the total number of Frames. Since, typically a time series is defined as "a sequence of observed data, usually ordered in time" [28], the proposed framework can be used with a Genetic algorithm for curve optimization and prediction of next motion curve values, generated by the Central Pattern Generator (CPG). The problem of removing noise from a motion curve generated procedurally or through motion capture data can be better understood from figure 4. The diamond shape point represents the keyframe generated automatically by CPG, which can be seen as to be noisy, irregular, and nonperiodic, resulting in non-smooth animation. Whereas, the square boxes indicate the key poses that may be considered as the most important and required frames. Now, here the goal is to predict and optimize these motion curves as accurately as possible.

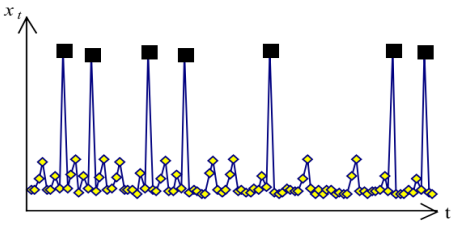


Fig 4: Time series values ([27]).

In a time, series, an event is considered important, whereas in our model the event is known as Key Pose. Within a time, series, temporal pattern, and keyframe characterization function are adopted as the fundamentals. Here, the temporal pattern is considered as unknown keyframe data that is characterized and used for the prediction of possible accurate key poses within a motion series.

The formula for the temporal pattern is obtained from [27], where a cluster of the temporal pattern (**p**) is defined as the set of all points within δ and it's a vector of length Q.

$$P = \{a \in \mathbb{R}^Q : d(\mathbf{p}, a) \leq \delta\} \quad (4)$$

where, the distance between frames is d, with Q defined as hypersphere of dimension, δ is the radius, **p** here is center. The $\mathbf{p} \in \mathbb{R}^Q$ is the representation of a point Q dimensional real metric space of a temporal pattern [27].

B. Optimization with Genetic Algorithm

Genetic Algorithm is used and adapted to the characterization of Motion curve with time-series framework. The typical implementation model of a genetic algorithm for optimization is described as

- The population of key poses and keyframes with respect to time in frames, that are evaluated with fitness function.
- Generation of a large population of random key poses, based on a genetic operation involving the selection of next generations, crossover mechanism, mutation of key poses, and tuning of keyframes.
- Determines the fitness by using a gradient search method to improve convergence performance [29].
- Select the top 1/n of the top population to begin
- While all fitness has not met
    - Next Generation Selection
    - Crossover
    - Mutation
    - Tuning

Selection of the Next Generation

The core structure of GA is based on the survivor of the fittest principle. According to this principle, certain key poses and their keyframes will be selected from the population, based on their fitness scores. This produces the foundation for the next generation resulting in producing individual offspring knows as parents. These parents are randomly selected based on the fittest individuals. This leads to a crossover ratio, in which the best parents are obtained. Then the mutation of key poses is done on randomly selected parents.

The crossover Mechanism

Crossover typically is a key stage in GA which works at chromosome level and splits the string of chromosomes at a random position. This produces two individual segments of each chromosome knowns as heads and tails as shown in figure 5.

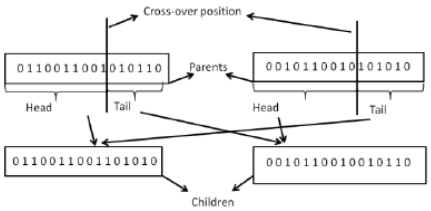


Fig 5: A sample crossover

The Mutation Mechanism

Mutation comes after the crossover process, which alters the gene of randomly chosen individuals key poses on a time frame. This provides us with the mechanism to random search each small keyframe with a small amount and ensures that all in-between frames with small pose change are searched with zero probability of missing the search space as illustrated in Figure 6.

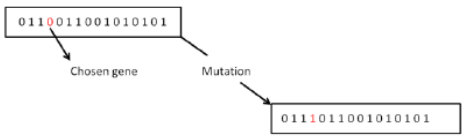


Fig 6: Mutation Scheme

C. The Tuning process.

The final tuning of motion curves was achieved by defining complete parameters and individual keyframes and their corresponding key poses with a given set of the population as shown in the figure. The total amount of cross-over population was at 55%, with the number of individual mutations at 16%. The elite individual keyframe for the animation within 30 frames per second (fps), was also around 16%, as discussed in [8]. The total number of populations of keyframes opted for crossover and mutation were initially parameterized with the selected elite parents of the population.

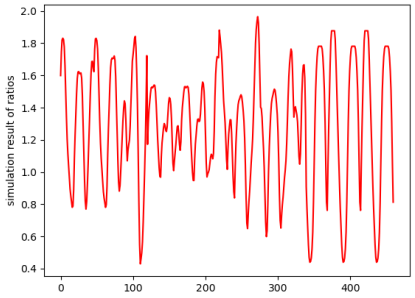


Fig 7: Motion curve of front leg joint

The Optimization model used based on genetic algorithm is illustrated in Figure 8. This model was applied on a quadruped model with 18 main joints of all four legs. The leg locomotion is automated through CPG as discussed in [18] with the biomechanics of joints having multiple degrees of freedom of joints already discussed in [21].

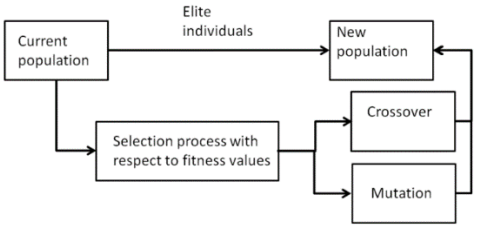


Fig 8: Genetic Algorithm based optimization scheme (source: [8])

This prototype model was used with only walk motion achieving curves at different

joints and optimized using the time series parameters with a genetic algorithm. Figure 9 (a-d) shows the final motion curves of each joint of quadruped while in walk motion.

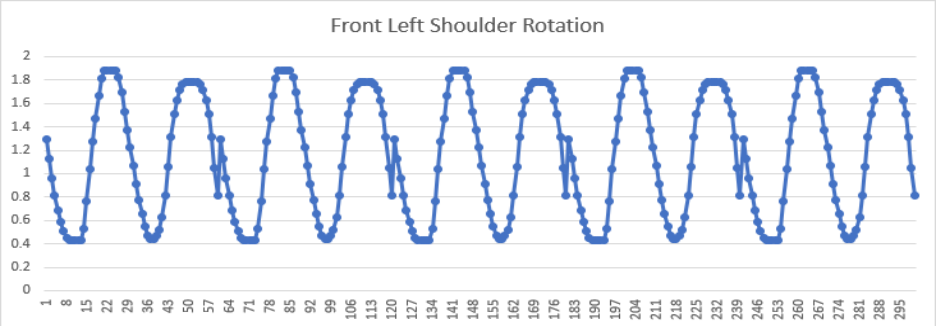


Fig 9(a): Motion curve of Front Left Shoulder Joint of a tiger during the walk

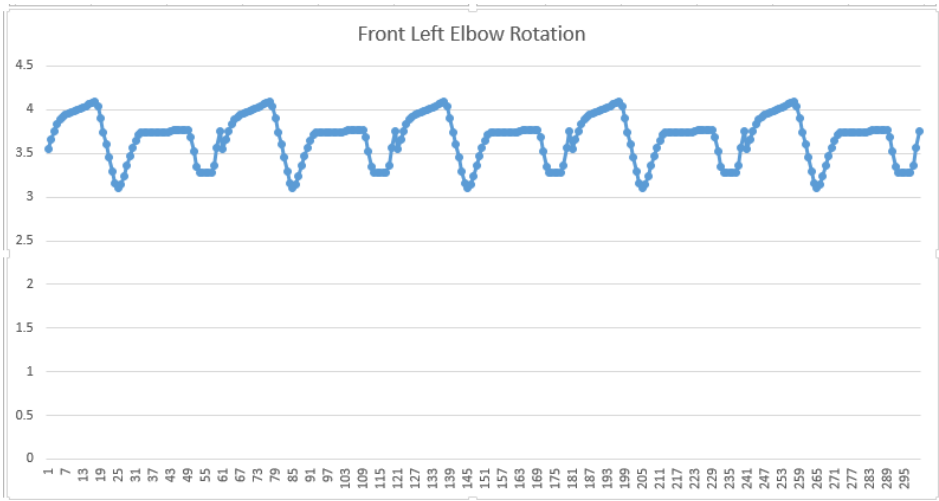


Fig 9(b): Motion curve of Front Left Elbow Joint of a tiger during the walk

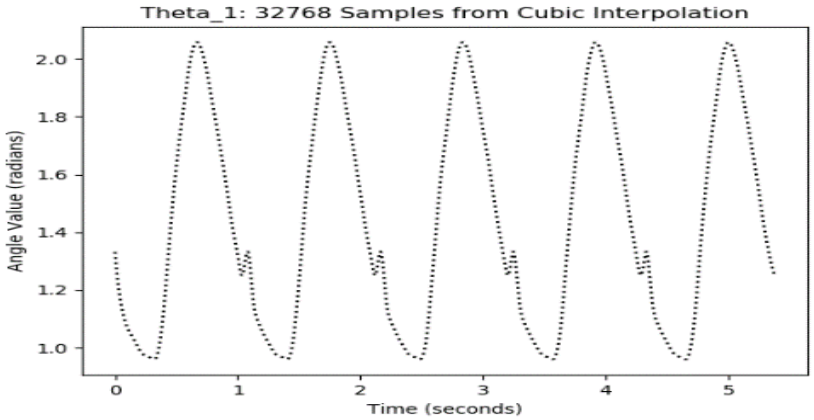


Fig 9(c): Optimized Motion curve of Right Shoulder Joint of a tiger during the walk

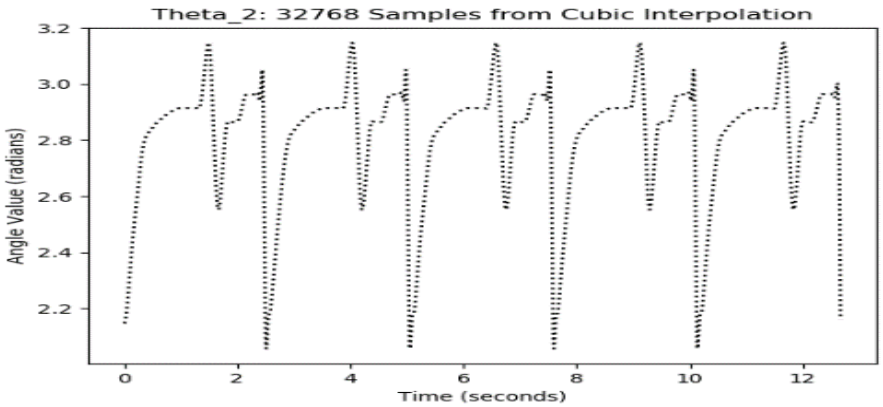


Fig 9(d): Optimized Motion curve of Right Elbow Joint of a tiger during the walk

6. Conclusion

In this paper, an optimization model is discussed using a genetic algorithm with the time series to correct and optimize the motion curve of a quadruped generated through Central Pattern Generator (CPG). CPG is a neurological mechanism, used by quadruped to generate various different locomotion's. While, this is fairly complex, generating accurate and believable motion curves based on Oscillating CPG is a difficult task. The use of an optimization technique based on a genetic algorithm, while characterizing the motion curve with respect to time series, generated a very believable animation and reduced the noise and anomalies in animation. The results showed to be very promising with the animation of each joint looking more natural and believable.

Reference

[1] Z. Bhatti, A. Shah, A. Waqas, and M. Karbasi, "Automated animation of quadrupeds using procedural programming technique," *Asian J. Sci. Res.*, vol. 8, no. 2, pp. 165–181, 2015.

[2] Z. Bhatti, A. Shah, and F. Shahidi, "Procedural Model of Horse Simulation," in 12th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and Its Applications in Industry (ACM-SIGGRAPH VRCAI 2013), 2013, pp. 139–146.

[3] H. Castellini, E. Yudiarsah, L. Romanelli, and H. A. Cerdeira, "Coupled chaotic oscillators and their relation to a central pattern generator for artificial quadrupeds," *Pramana - J. Phys.*, vol. 64, no. 4, pp. 525–534, 2005.

[4] J. A. Acebrón, L. L. Bonilla, C. J. P. Vicente, F. Ritort, and R. Spigler, "The Kuramoto model: A simple paradigm for synchronization phenomena," *Rev. Mod. Phys.*, vol. 77, no. 1, pp. 137–185, 2005.

[5] Ö. K. Adak, O. Ayit, M. Gülhan, and K. Erbatur, "Genetic Tuning of a Central Pattern Generator for Quadruped Locomotion," in *In 3rd International Electrical and Electronic Engineering and Technologies Conference (ELECTROTECH 2015).*, 2015, no. October.

[6] C. Liu, Y. Chen, J. Zhang, and Q. Chen, "CPG driven locomotion control of quadruped robot," *Conf. Proc. - IEEE Int. Conf. Syst. Man Cybern.*, no. 60875057, pp. 2368–2373, 2009.

[7] ÖMER KEMAL ADAK, "QUADRUPED LOCOMOTION REFERENCE SYNTHESIS WITH CENTRAL PATTERN GENERATORS TUNED BY EVOLUTIONARY ALGORITHMS," Sabanci University, 2013.

[8] Ö. K. Adak, O. Ayit, M. Gülhan, and K. Erbatur, "Genetic Tuning of a Central Pattern Generator for Quadruped Locomotion," *3rd Int. Electr. Electron. Eng. Technol. Conf. (ELECTROTECH 2015).*, no. October, 2015.

[9] A. P. Gerdelan, "Optimising Animated Character Motion with a New Fuzzy-Genetic Hybrid Method : Fuzzy Controllers in Ani- mation," 2009.

[10] Z. H. Akpolat, M. Bingöl, M. Ay, G. Özmen Koca, C. Bal, and D. Korkmaz, "Dynamic Model and Simulation of One Active Joint Robotic Fish," *e-Journal New World Sci. Acad.*, vol. 12, no. 1, pp. 29–39, 2017.

[11] H. Kimura, Y. Fukuoka, and A. H. Cohen, "Adaptive dynamic walking of a quadruped robot on natural ground based on biological concepts," *Int. J. Rob. Res.*, vol. 26, no. 5, pp. 475–490, 2007.

[12] K. Tsujita, K. Tsuchiya, and A. Onat, "Adaptive gait pattern control of a quadruped locomotion robot," *IEEE Int. Conf. Intell. Robot. Syst.*, vol. 4, pp. 2318–2325, 2001.

[13] C. Liu, Q. Chen, and G. Wang, "Adaptive walking control of quadruped robots based on central pattern generator (CPG) and reflex," *J. Control Theory Appl.*, vol. 11, no. 3, pp. 386–392, 2013.

[14] S. Shivani and S. Tiwari, "Simulation of intelligent target hitting in obstructed path using physical body animation and genetic algorithm," *Multimed. Tools Appl.*, vol. 78, no. 8, pp. 9763–9790, 2019.

[15] L. Gritz and J. K. Hahn, "Genetic programming for articulated figure motion," *J. Vis. Comput. Animat.*, vol. 6, no. 3, pp. 129–142, 1995.

[16] T. K. Singh, R., & Bera, "Walking Model of Jansen Mechanism-Based Quadruped Robot and Application to Obstacle Avoidance," *Arab. J. Sci. Eng.*, vol. 45, no. 2, pp. 653–664, 2020.

[17] J. J. Collins and S. A. Richmond, "Hard-wired central pattern generators for quadrupedal locomotion," *Biol. Cybern.*, vol. 71, no. 5, pp. 375–385, 1994.

[18] Z. Bhatti, "Oscillator driven central pattern generator (CPG) system for procedural animation of quadruped locomotion," *Multimed. Tools Appl.*, vol. 78, no. 21, pp. 30485–30502, 2019.

[19] A. R. S. de Oliveira Floriano, B. R., de Freitas Porphirio, C., Santana, P. H. M., Borges, G. A., & Romariz, "Walking pattern design and balance control of a quadruped platform," in *Latin American Robotic Symposium, 2018 Brazilian Symposium on Robotics (SBR) and 2018 Workshop on Robotics in Education (WRE)*, 2018, pp. 242–247.

[20] Z. Bhati, A. Shah, A. Waqas, H. Abid, and M. Malik, "Template based Procedural Rigging of Quadrupeds with Custom Manipulators," in *International Conference on Advanced Computer Science Applications and Technologies*, 2013, pp. 259–264.

[21] Z. Bhatti, A. Waqas, A. W. Mahesar, and M. Karbasi, "Gait Analysis and Biomechanics of Quadruped Motion for procedural Animation and Robotic Simulation," *Bahria Univ. J. Inf. Commun. Technol.*, vol. 10, no. 2, pp. 1–7, 2017.

[22] F. Lacquaniti, R. Grasso, and M. Zago, "Motor Patterns in Walking," *News Physiol. Sci.*, vol. 14, no. August, 1999.

[23] J. Morimoto, S. Hyon, G. Cheng, D. Bentivegna, and C. G. Atkeson, "Modulation of simple sinusoidal patterns by a coupled oscillator model for biped walking," in *Proceedings 2006 IEEE International Conference on Robotics and Automation, 2006. ICRA 2006.*, 2006, pp. 1579–1584.

[24] Y. Kawamura, "Phase synchronization between collective rhythms of fully locked oscillator groups.," *Sci. Rep.*, vol. 4, no. C, p.

4832, Jan. 2014.

[25] Z. Bhatti, A. Shah, M. Karabasi, and W. Mahesar, "Expression driven Trignometric based Procedural Animation of Quadrupeds," in *Informatics and Creative Multimedia (ICICM), 2013 International Conference on*, pp. 104–109.

[26] R. A., *Principles of Locomotion*. Princeton, New Jersey: Princeton University Press, 2003.

[27] R. J. Povinelli, "Using Genetic Algorithms To Find Temporal Patterns Indicative Of," *GECCO 2000 Work. Data Min. with Evol. Algorithms*, no. March, pp. 80–84, 2000.

[28] S. M. Pandit and S.-M. Wu, *Time series and system analysis, with applications*. New York: Wiley, 1983.

[29] J. H. Lee and J. H. Park, "Time-dependent genetic algorithm and its application to quadruped's locomotion," *Rob. Auton. Syst.*, vol. 112, pp. 60–71, 2019.

Vol. 4, No. 2 | Jul – Dec 2020

On Study Of Generalized Nonlinear Black Scholes Equation By Reduced Differential Transform Algorithm

Naresh Kumar Solanki[1] , Syed Feroz Shah[1]

Abstract:

The objective of the work is essential to construct an approximate solution of the generalization of nonlinear Black-Scholes partial differential equation, modeling price slippage impact of transaction coast option, through promising computational algorithm called Reduced Differential Transform Algorithm. This work also shows that the algorithm can be efficiently employed to construct explicit solutions highly nonlinear equations arising in the financial market. We have also shown a graphical behavior of the constructed solutions.

Keywords: *Nonlinear Black-Scholes model, PDE, differential transform algorithm*

1. Introduction

This paper is intended to construct an approximate and closed-form solution to the following initial value problem,

$$\frac{\partial u}{\partial t}+\frac{1}{2}\sigma^2 s^2\frac{\partial^2 u}{\partial s^2}\left(1+2\rho s\frac{\partial^2 u}{\partial s^2}\right)+rs\frac{\partial u}{\partial s} - ru = 0 \qquad (1)$$

subject to the initial condition,

$$u(s,0)=\frac{1}{\rho}\left[\frac{-4}{\sigma^2}(r-c)\sqrt{Ks}e^{\frac{-c}{2}\tau}+\left(\frac{r-c}{\sigma^2}+\frac{1}{4}\right)(1-\ln s)s + \frac{(r-c)}{\sigma^2}K(e^{-c\tau}-(r-c)e^{-rt})\right]$$

Where S represents the stock price, $\rho \geq 0$ it shows the measure of liquidity of the market, and also represents volatility as well. $u(s,t)$ represents the option price and it's a measure of the price of slippage impact of a trade felt by all participants of a market.

2. Description of Differential Transform Algorithm

This section has been dedicated to give a precise description of the Reduced Differential Transform algorithm and how it works. Assume that we have a function $u(x,t)$ with arguments x and t, that can express as the product two functions of x and t i.e. i.e., $u(x,t)=f(x)g(t)$. Then differential transform of the function $u(x,t)$ can be explicitly written as,

$$u(x,t)=\left(\sum_{i=0}^{\infty}F(i)x^i\right)\left(\sum_{i=0}^{\infty}G(i)t^i\right)=\sum_{k=0}^{\infty}U_k(x)t^k,$$

where $U_k(x)$ is transformed function in x.

The more careful and precise definitions of transform of function $u(x,t)$ is following, (cf. [14-16]).

Definition: Consider a function $u(x,t)$ is call option where u represents the price of option and t represents the time $t \geq 0$ and

[1]Basic Science and related science MUET, Jamshoro, Pakistan
Corresponding Author: feroz.shah@faculty.muet.edu.pk

space $x \in \mathbb{R}$. Then define the transform of $u(x,t)$ as,

$$U_k(x) = \frac{1}{k!}\left[\frac{\partial^k}{\partial t^k}u(x,t)\right]_{t=0}.$$

where the $U_k(x)$ can be treated as transformed $u(x,t)$, and is essentially analogous to Taylor's coefficient in the 2D Taylor expansion.

To recover the function $u(x,t)$ from transformed functions $U_k(x)$, we define the following inverse of differential transform in the following manner.

Definition: Consider a function $u(x,t)$ is call option where u represents the price of option and t represents the time $t \geq 0$, Then we can define the transform of $u(x,t)$ as,

Then define the transform of $U_k(x)$, as,

$$u(x,t) = \sum_{k=0}^{\infty} U_k(x)t^k \qquad (2)$$

Or more explicitly,

$$u(x,t) = \sum_{k=0}^{\infty}\frac{1}{k!}\left[\frac{\partial^k}{\partial t^k}u(x,t)\right]_{t=0} t^k.$$

Next, we discuss how the above-described transformations can be implemented to solve the concrete nonlinear partial differential equations. Consider a nonlinear PDE in its generalized form,

$$Lu(x,t) + Ru(x,t) + Nu(x,t) = g(x,t) \qquad (3)$$

Subject to the initial condition $u(x,0) = f(x)$. Here L denotes an operator $\frac{\partial}{\partial t}$, $Ru(x,t)$ denotes the linear part of PDE that contains the linear expressions of u and its derivatives, $Nu(x,t)$ denotes the operator/expression containing the nonlinear terms involving u, and its derivatives operator, $g(x,t)$ stands for an in-homogeneous term that can be treated a forcing factor in the model. Taking the differential transform of the equation (3) leads to the following recursive relation,

$$(k+1)U_{k+1}(x) = G_k(x) - RU_k(x) - NU_k(x) \qquad (4)$$

where $U_k(x), RU_k(x), NU_k(x)$ and $G_k(x)$ denotes the differential transformation of $Lu(x,t), Ru(x,t), Nu(x,t)$ and $g(x,t)$ respectively. Hence the key computation that one need to is the computation of functions U_1, U_2, U_3 ... through recursive relation (4), by choosing $U_0(x) = f(x)$.

Once $U_1, U_2, U_3 \ldots U_n$ are found then we can write n-term approximate solution of PDE as follows:

$$\tilde{u}_n(x,t) = \sum_{k=0}^{n} U_k(x)t^k. \qquad (5)$$

Thus, by increasing n more and more we get an exact solution of nonlinear PDE (4),

$$\tilde{u}(x,t) = \lim_{n\to\infty} \sum_{k=0}^{n} U_k(x)t^k \qquad (6)$$

Based on the definition of the reduced differential transform algorithm following table of transformations (see next page) can be proved. For the readers interested in the proofs we refer to [14], [15], and [16].

Table 1 Reduced differential transformation

Functional form	Transformed form
$u(x,t)$	$U_k(x) = \frac{1}{k!}[\frac{\partial^k}{\partial t^k}u(x,t)]_{t=0}$
$w(x,t) = u(x,t) \pm v(x,t)$	$W_k(x) = U_k(x) \pm V_k(x)$
$w(x,t) = \alpha u(x,t)$	$W_k(x) = \alpha U_k(x)$ (α is a constant)
$w(x,t) = x^m t^n$	$W_k(x) = x^m \delta(k-n)$, $\delta(k) = \begin{cases} 1, & k=0 \\ 0, & k \neq 0 \end{cases}$
$w(x,t) = x^m t^n u(x,t)$	$W_k(x) = x^m U_{k-n}(x)$
$w(x,t) = u(x,t)v(x,t)$	$W_k(x) = \sum_{r=0}^{k} V_r(x)U_{k-r}(x) = \sum_{r=0}^{k} U_r(x)V_{k-r}(x)$
$w(x,t) = \frac{\partial^r}{\partial t^r}u(x,t)$	$W_k(x) = (k+1)\cdots(k+r)U_{k+r}(x) = \frac{(k+r)!}{k!}U_{k+r}(x)$
$w(x,t) = \frac{\partial}{\partial x}u(x,t)$	$W_k(x) = \frac{\partial}{\partial x}U_k(x)$

3. The solution of Generalized form of nonlinear Black-Scholes equation by Reduced Differential Transform Algorithm

For following the Nonlinear Black-Scholes equation, we are applying the RDTM method to get an approximate solution.

Let us restart by rewriting the equation (1) in the following form,

$$\frac{\partial u}{\partial t} = -\left[\frac{\sigma^2 s^2}{2}\frac{\partial^2 u}{\partial s^2}\left(1 + 2\rho s\frac{\partial^2 u}{\partial s^2}\right) + rs\frac{\partial u}{\partial s} - ru\right] \quad (7)$$

On the application of RDTM on the above last equation, using Table 1of transforms, we get

$$(k+1)u_{k+1} = -\left[\frac{1}{2}\sigma^2 s^2\frac{\partial^2 u_k}{\partial s^2} + \rho\sigma^2 s^3\left(\frac{\partial^2 u_k}{\partial s^2}\right)^2 + rs\frac{\partial u_k}{\partial s} - ru_k\right] \quad (8)$$

where $u_k(x)$ is transformed function and dimensional spectrum function is t,

$$A_k = \sum_{k=0}^{n}\frac{\partial^2 u(s,k)}{\partial s^2}\frac{\partial^2 u(s,h-k)}{\partial s^2} \quad (9)$$

Let us start by computing the u_1. The explicit expression for it can be obtained by setting $k=0$ in (9), as follows,

$$u_1 = -\left[\frac{1}{2}\sigma^2 s^2\frac{\partial^2 u_0}{\partial s^2} + \rho\sigma^2 s^3 A_0 + rs\frac{\partial u_0}{\partial s} - ru_0\right]$$

It is clear that to compute the above expression we need values of A_0, $\frac{\partial u_0}{\partial s}$ and $\frac{\partial^2 u_0}{\partial s^2}$. From the initial condition equation (9), we solve the first and second partial derivatives of equation (9), we have

$$\frac{\partial u_0}{\partial s} = \frac{1}{\rho}\left[\frac{-2}{\sigma^2}(r-c)\frac{\sqrt{K}}{\sqrt{s}}e^{\frac{-c}{2}T} - \ln s\left(\frac{(r-c)}{\sigma^2} + \frac{1}{4}\right)\right] \quad (10)$$

$$\frac{\partial^2 u_0}{\partial s^2} = \frac{1}{\rho}\left[\frac{(r-c)}{\sigma^2}\frac{\sqrt{K}}{s^{\frac{3}{2}}}e^{\frac{-c}{2}T} - \frac{1}{\mathrm{s}}\left(\frac{(r-c)}{\sigma^2} + \frac{1}{4}\right)\right] \quad (11)$$

Now taking $k=0$ in Equation (9) and plugging partial derivatives from (10) and (11), we get the following value of A_0

$$A_0 = \left(\frac{\partial^2 u_0}{\partial s^2}\right)^2 = \frac{1}{\rho^2}\left[\frac{(r-c)^2}{\sigma^4}\frac{\mathrm{K}}{s^3}e^{-\mathrm{c}T} - 2\left(\frac{(r-c)}{\sigma^2}\frac{\sqrt{K}}{s^{\frac{3}{2}}}e^{\frac{-cT}{2}}\right)\left(\frac{1}{\mathrm{s}}\left(\frac{(r-c)}{\sigma^2}+\frac{1}{4}\right)\right) + \frac{1}{\mathrm{s}^2}\left(\frac{(r-c)}{\sigma^2}+\frac{1}{4}\right)^2\right] \quad (12)$$

On substituting values A_0, $\frac{\partial u_0}{\partial s}$ and $\frac{\partial^2 u_0}{\partial s^2}$ in expression for u_1 and simplifying we obtain

$$u_1 = \frac{1}{\rho}\left[-\frac{2c(r-c)}{\sigma^2}\sqrt{Ks}\,e^{\frac{-c}{2}T} - \frac{(r-c)^2}{\sigma^2}Ke^{-cT} - \frac{\sigma^2 s}{2}\left(\frac{(r-c)^2}{\sigma^4} - \frac{1}{16}\right) - rs\left(\frac{r-c}{\sigma^2}+\frac{1}{4}\right) + \frac{r(r-c)}{\sigma^2}Ke^{-cT} - r(r-c)e^{-rt}\right] \quad (13)$$

Next, let us move towards computing the valued u_2. To do so let us substitute *k=1* in recursive relation (8),

$$u_2 = -\left[\frac{1}{2}\sigma^2 s^2\frac{\partial^2 u_1}{\partial s^2} + \rho\sigma^2 s^3 A_1 + rs\frac{\partial u_1}{\partial s} - ru_1\right]$$

Therefore, to compute u_2, we need to explicitly find A_1, $\frac{\partial u_1}{\partial s}$ and $\frac{\partial^2 u_1}{\partial s^2}$. Using equation (13), we may find the partial derivatives as following,

$$\frac{\partial u_1}{\partial s} = \frac{1}{\rho}\left[\frac{-\mathrm{c}(r-c)}{\sigma^2}\frac{\sqrt{K}}{s^{\frac{1}{2}}}e^{\frac{-c}{2}T} - \sigma^2\left(\frac{(r-c)^2}{\sigma^4} - \frac{1}{16}\right) + r\left(\frac{r-c}{\sigma^2}+\frac{1}{4}\right)\right] \quad (14)$$

$$\frac{\partial^2 u_1}{\partial s^2} = \frac{1}{\rho}\left[\frac{\mathrm{c}(r-c)}{2\sigma^2}\frac{\sqrt{K}}{s^{\frac{3}{2}}}e^{\frac{-c}{2}T}\right] \quad (15)$$

On employing (9), (14), and (15), we can explicitly compute A_1 as,

$$A_1 = \frac{1}{\rho^2}\left[\frac{c(r-c)^2}{\sigma^4}\frac{\mathrm{K}}{s^3}e^{-\mathrm{c}T} - \frac{\mathrm{c}(r-c)}{\sigma^2}\left(\frac{(r-c)}{\sigma^2} + \frac{1}{4}\right)\frac{\sqrt{K}}{s^{\frac{5}{2}}}e^{\frac{-c}{2}T}\right] \quad (16)$$

$$A_1 = 2\frac{\partial^2 u_0}{\partial s^2}\frac{\partial^2 u_1}{\partial s^2}$$

Now we are in a position to compute u_2 using the values of A_1, $\frac{\partial u_1}{\partial s}$ and $\frac{\partial^2 u_1}{\partial s^2}$ from (16), (14), (15) respectively,

$$u_2 = \frac{1}{\rho}\left[-\frac{c^2(r-c)}{2\sigma^2}\sqrt{Ks}\,e^{\frac{-c}{2}T} - \frac{c(r-c)^2}{2\sigma^2}Ke^{-cT} - \frac{r(r-c)^2}{2\sigma^2}Ke^{-cT} + \frac{r^2(r-c)}{2\sigma^2}Ke^{-cT} - \frac{r^2(r-c)^2}{2\sigma^2}Ke^{-rt}\right] \quad (17)$$

Finally, we aim to compute u_3. To do, by substituting *k=2* in recursive relation (8) we get,

$$3u_3 = -\left[\frac{1}{2}\sigma^2 s^2\frac{\partial^2 u_2}{\partial s^2} + \rho\sigma^2 s^3 A_2 + rs\frac{\partial u_2}{\partial s} - ru_2\right]$$

Hence to compute u_3, we need to compute A_2, $\frac{\partial u_2}{\partial s}$ and $\frac{\partial^2 u_2}{\partial s^2}$. The partial derivatives of u_2 can be computed using equation (17),

$$\frac{\partial u_2}{\partial s} = \frac{1}{\rho}\left[-\frac{\mathrm{c}^2(r-c)}{4\sigma^2}\frac{\sqrt{K}}{\sqrt{s}}e^{\frac{-c}{2}T}\right] \quad (18)$$

$$\frac{\partial^2 u_2}{\partial s^2} = \frac{1}{\rho}\left[\frac{c^2(r-c)}{8\sigma^2}\frac{\sqrt{K}}{s^{\frac{3}{2}}}e^{\frac{-c}{2}T}\right] \quad (19)$$

Next, an explicit expression for A_2 can be obtained by putting *k=2* in (9),

$$A_2 = \frac{\partial^2 u_0}{\partial s^2}\frac{\partial^2 u_2}{\partial s^2} + \frac{\partial^2 u_1}{\partial s^2}\frac{\partial^2 u_1}{\partial s^2} + \frac{\partial^2 u_2}{\partial s^2}\frac{\partial^2 u_0}{\partial s^2}$$

Using (11), (15), and (17) in the above, and we get,

$$A_2 = \frac{1}{\rho^2}\left[\left(\frac{c^2(r-c)^2}{2\sigma^4}\frac{K}{s^3}e^{-cT} - \left(\frac{c^2(r-c)}{4\sigma^2}\frac{\sqrt{K}}{s^{\frac{5}{2}}}e^{\frac{-c}{2}T}\right)\left(\frac{(r-c)}{\sigma^2}+\frac{1}{4}\right)\right)\right] \quad (20)$$

Now employing the A_2, $\frac{\partial u_2}{\partial s}$ and $\frac{\partial^2 u_2}{\partial s^2}$ from (20), (18), and (19), in u_3, we get,

$$u_3 = \frac{1}{\rho}\left[-\frac{c^3(r-c)}{4.3\sigma^2}\sqrt{K}se^{\frac{-c}{2}T} - \frac{c^2(r-c)^2}{3.2\sigma^2}Ke^{-cT} - \frac{cr(r-c)^2}{3.2\sigma^2}Ke^{-cT} - \frac{r^2(r-c)^2}{3.2\sigma^2}Ke^{-cT} + \frac{r^3(r-c)}{3.2\sigma^2}Ke^{-cT} - \frac{r^3(r-c)^2}{3.2\sigma^2}Ke^{-rt}\right] \quad (20)$$

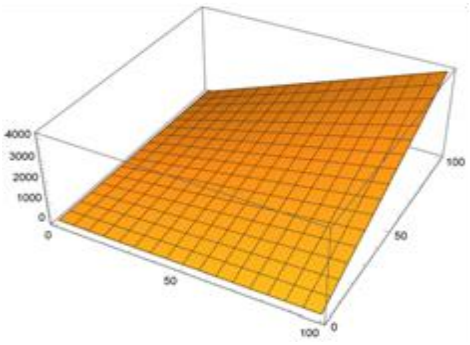
Finally, the approximate solution to our main problem can be given as,

$$u(x,t) = \sum_{k=0}^{\infty} U_k(x)t^k \approx u_0 + u_1 t + u_2 t^2 + u_3 t^3$$

On substituting, values of $u_0, u_1, u_2 \; and \; u_3$ from (13), (17), and (20) in the last equation, we get the following closed-form approximate solution of problem (1),

The 3D graph of the solution has been computed using Mathematica,

$$u(s,t) \approx \frac{1}{\rho}\left[\frac{-4}{\sigma^2}(r-c)\sqrt{K}se^{\frac{-c}{2}(T-t)} + \left(\frac{r-c}{\sigma^2}+\frac{1}{4}\right)(1-\ln s)s + \left(\frac{\sigma^2+4r}{16}+\frac{c(r-c)}{\sigma^2}\right)st + \frac{(r-c)}{\sigma^2}K\left(e^{-c(T-t)} - (r-c)e^{-r(T-t)}\right)\right]$$



4. Conclusion

Transaction cost Black-Scholes model is highly nonlinear in its form. In this article, we have computed an explicit approximation solution to a highly nonlinear version of the generalized nonlinear Black-Scholes equation through a highly efficient algorithm known as the reduced differential transform method. This solution obtained can be used for pricing European call and put option at time $t \geq 0$, and when $c \neq r$. Our work shows that Reduced differential transform methods are very convenient for constructing the explicit scheme of higher nonlinear problems arising in the financial world.

References

[1] B. Lin and Z. Yin, "The Cauchy problem for a generalized Camassa--Holm equation with velocity potential.," Applicable Analysis, vol. 97, no. 3, pp. 354-367, 2018.

[2] R. Camassa and a. D. Holm, "An integrable shallow water equation with peaked solitons," *Physical review letters*, vol. 71, pp. 1661-1664, 1993.

[3] C. A, "On the scattering problem for the Camassa--Holm equation," *Proceedings of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, vol. 457, pp. 953-970, 2001.

[4] Y. Keskin and G. Oturanc, "Reduced differential transform method for

generalized KDV equations," *Mathematical and Computational applications,* vol. 15, pp. 382-393, 2010.

[5] Y. Keskin and G. Oturan, "Application of reduced differential transformation method for solving gas dynamics equation," *International Journal of Contemporary Mathematical Sciences,* vol. 22, pp. 1091-1096, 2010.

[6] Y. Keskin and G. Oturanc, "Reduced differential transform method for solving linear and nonlinear wave equations," 2010.

[7] Zheng, R. a. Yin and Zhaoyang, "Global weak solutions for a generalized Novikov equation," *Monatshefte fur Mathematik,* vol. 188, pp. 387-400, 2019.

[8] Novikov and Vladimir, "Generalizations of the Camassa–Holm equation.," *Journal of Physics A: Mathematical and Theoretical,* vol. 42, p. 342002, 2009.

[9] Henry and D., "Infinite propagation speed for the Degasperis-Procesi equation," *Journal of mathematical analysis and applications,* vol. 311, pp. 755-759, 2005.

[10] Lenells and Jonatan, "Travelling wave solutions of the Degas," *Journal of mathematical analysis and applications,* vol. 306, pp. 72-82, 2005.

[11] Oclite, G. M. a. Karlsen and K. H, "On the well posedness of the Degasperis-Procesi equation," *Journal of Functional Analysis,* vol. 233, pp. 60-91, 2006.

[12] Degasperis, A. a. Procesi and Michela, "Asymptotic Integrability, in symmetry and Perturbation Theory," *Symmetry and perturbation theory,* vol. 1, pp. 23-37, 1999.

[13] Tu, X. a. Yin and Zhaoyang, "Global weak solutions for a generalized Casmassa-Holm equation," *Mathematische Nachrichten,* vol. 291, 2018.

[14] Blaszak and Maciej, The Theory of Hamiltonian and Bi-Hamiltonian Systems. In: Multi-Hamiltonian Theory of Dynamical Systems., Berlin: Springer, 1998, pp. 41-85.

Vol. 4, No. 2 | Jul – Dec 2020

Hybridization Techniques To Detect Brain Tumor

Asif Hussain[1], Muhammad Abrar[2], Roha Masroor[1], Ifra Masroor[1]

Abstract:

Diagnosing brain tumor in the present era through digital techniques need serious attention as the number of patients is increasing in an awkward manner. Magnetic Resonance Imaging is a tool that is used for the detection of brain tumors. Deploying Machine learning models to detect the abnormality pattern of the brain on MRI scans is quite beneficial in this modern era. This paper deploys GLCM on MRI scans to extract 66 features. Then, Feature selection and classification are applied to the given data set. Classification on a given data set is done through K- Nearest Neighbor. The given article classifies scans, i.e., normal and abnormal brain images. In the given study, we have taken normal and abnormal samples from the MRI department, Nishtar Medical hospital, Multan under doctor supervision. The scans were T2 weighted and having 256*256 pixels. In order to classify brain images, first, it needs to pre-process by skull stripping technique then the proposed algorithm is followed. The algorithm involves feature extraction through GLCM and feature selection through ACO in order to reduce the dimensions for optimal features. Results have proved its efficiency level up-to 88% on testing data.

Keywords: *Brain; classification; extraction; selection; Magnetic resosnance imaging.*

1. Introduction

The individual central nervous system is entirely commanded by means of the human brain. The brain feeds in from the sensory body organs along with directs information towards muscles. The normal human brain is composed of mainly three elements namely white matter, bleak matter, and also cerebrospinal fluid. The actual, white-colored matter is referred to as white matter for its bright appearance. It adds up pertaining to 60% to entire human brain volume. The particular white matter includes fiber content similar to the composition of the neuron identified as axon. The white-colored matter offers a mean of communication among various areas of the particular central nervous system such as greyish matter, spinal cord as well as other portions of the body. The gray matter is the part of the human brain accountable for the whole processing of the nervous signals. It involves dendrites along with the neuron nucleus. It adds up forty percent to whole-brain volume. The entire control of the nervous alerts is done in the gray matter and the effect can result in transmitted to the human body through the extension associated with the white matter which usually is made up of axons. Cerebrospinal fluid is an actually colorless fluid that provides defense against physical shocks and in addition sends out some significant hormones in order to make the connection possible involving white matter, gray matter, and the spinal cord of the central nervous system. The white matter, greyish matter along cerebrospinal fluid associated with the human brain are mainly impacted by a variety of brain irregularities,

[1] National College of Bussiness & Econmics (NCBA&E), Multan, Pakistan
[2] 2Bahauddin Zakriya University, Multan Paksitan

therefore our attention concerning the intensities of numerous pixels addressing most of these sections will be typically considered. Generally, there are many varieties of brain problems that induce modifications in human brain distinct sections. A few of them particularly intense mental brain stroke, Huntington's disease, and brain tumor. Each one of these irregularities presents a new appearance towards the human brain that completely sets itself apart from an affected brain by an ordinary one.

Brain disorders now have considerable attention because of their harmful plus life taking characteristics. The conventional approach to recognition of numerous disorders within human brain images continues to be the particular manual evaluation which in turn is deficient in the attributes regarding reproducibility and may even bring in various results within diverse situations and may additionally present different analysis consequence done by several experts. In an effort to bring out the correct evaluation regardless of countless situations, there is a rigorous demand for automating this particular process. To carry out the diagnosis of different conditions in the human brain, a variety of illustrations or photos may possibly be kept under account however most appropriate and also aim to accomplish is MRI (Magnetic Resonance Imaging). The MRI [1] is useful for the automated human brain disorders recognition for the reason that it can record significantly quality information that happens to be overlooked simply by other sorts of images. In order to process MRI images with regard to automatic recognition associated with irregularities in them, we require the expertise of digital image digesting techniques. Prior to commencing information on processing the MRI images of the brain, we have to understand the design regarding the brain, a variety of brain conditions, in addition to different types of images which can be used as processing in order to identify diseases within the brain and will compare and contrast the feasibilities associated with other brain images together with MRI images pertaining to processing. The neurological system associated with humans involves a couple of sections namely CNS (Central Nervous System) and peripheral nervous system. The Central Nervous System is additionally broken into two areas specifically the brain and spinal cord. There are plenty of compact portions of the brain however in terms of our region of attention is concerned, we are going to contemplate just three sections including white matter, bleak matter, and also cerebrospinal fluid. We are going to consider only abnormalities that may have an effect on these portions of the brain.

2. Literature Review

Current research has proved that classification involving the human brain within magnetic resonance (MR) images [2] are quite possible through supervised methods including artificial neural networks in addition to supporting vector machine (SVM), and unsupervised classification techniques unsupervised which include anomaly detection and additionally fuzzy c-means along with feature extraction techniques [3]. Some other supervised classification techniques, which include k-nearest neighbors (k-NN)[4] Moreover, group pixels depending on their own similarities within each feature image are useful to classify typically the normal and abnormal T2-weighted MRI images. We tend to put into use a supervised machine learning algorithm (k-NN) to achieve the classification regarding images placed under two classes, possibly normal or possibly abnormal. Wavelet transform is an effective technique intended for feature extraction; due to the fact they permit analysis regarding images at diverse degrees of resolution. This method demands considerable storage area as well as being computationally costlier [5]. Consequently, an alternative approach for the dimension diminishment method can be used. GLCM [6] is an effective technique for texture feature extraction. On the basis of the evaluation method, feature selection algorithms are of two types. **Filter approach (open loop approach),** includes correlation coefficient residual mean square, mutual information [7]**,** RELIEF [8], Focus [9], based on selecting feature applying between-class separability criterion and it performs feature selection independently of any learning algorithm. **Wrapper approach (closed-loop**

approach) which is based on searching through feature subset space implementing the estimated accuracy from an induction algorithm as a measure of subset suitability. These two are further classified into five main methods including forward selection, backward elimination, forward/backward combination, instance based and random choice method. Feature selection initiates with an initial subset that may consist of all features, no feature, selected features or random features. Features are removed (backward elimination), added (forward selection), repetitively added or removed or produced randomly. Features once selected/removed cannot be later discarded/re-selected urged many researchers to address this problem. Pudil et al. [10] proposed floating search method; to flexible add or remove features. Amongst several closed-loop approaches which have been proposed regarding Feature Selection, population-based optimization algorithms including Genetic Algorithm (GA)-based method and also Ant Colony Optimization (ACO) [11]-[15] based method have drawn plenty of attention. These methods aim to attain much better solutions by applying knowledge from prior iterations. Genetic algorithms (GA's) are optimization techniques depending on the mechanics associated with natural selection. They applied operations within natural genetics to guide by itself because of the paths in the search space [16]. Due to their benefits, recently, GA's have already been widely used as a tool regarding feature selection within pattern recognition. Meta-heuristic optimization algorithm depending on ant's actions (ACO) was represented during the early 1990s by M. Dorigo along with colleagues [17]. ACO is actually a part associated with newly developed type of artificial intelligence referred to as Swarm Intelligence. Swarm intelligence is an area which usually studies "the emergent group intelligence associated with sets of basic agents [16].

ACO algorithm is certainly impressed involved with ant's social behavior. Ants don't have any sight regardless of that they can handle locating the shortest path from a food source and their own nest simply by chemical substance termed as pheromone which they leave whenever moving.

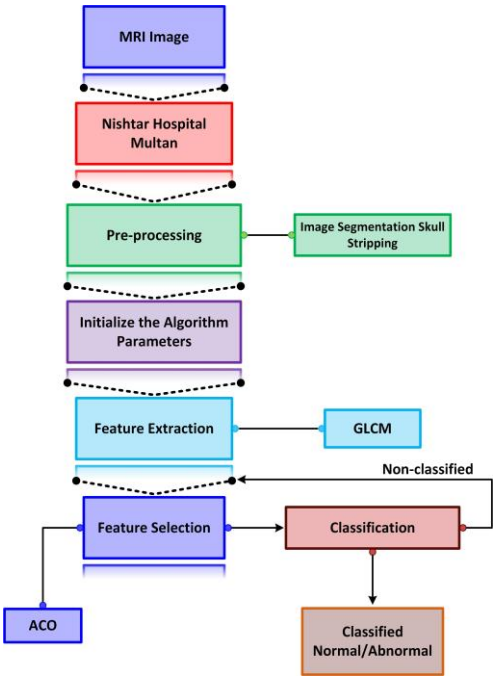


Fig. 1. Flow chart of Methodology

3. Methodology

The suggested algorithm is classified into two parts. First is feature selection then classification. At first skull stripping is done through histogram method then we have done feature extraction. It is done through Gray Level Co-occurrence (GLCM). Sixty-six features have been extracted then we have randomly selected three best features through ACO[11]. It is then passed through classification step through K-Nearest Neighbor Algorithm (KNN). This whole procedure is done under supervised learning. Fig. 1 is showing a pictorial view of whole paper.

4. Feature Extraction

Description of whole data set can be given by features. It differentiates abnormal image from normal image. Its basic function is to reduce original data sets by extracting certain features.

GLCM: Gray level co-occurrence matrix (GLCM) also renowned as gray level spatial dependence matrix is used in this paper. This method makes a difference between abnormal brain tumor and normal brain. Gray level image can be calculated from the equivalency of rows and columns. It is basically a two-dimensional (2D) histogram. A spatial connection between different gray level pixels is made. Then, it calculates distance d between two different pixels. Let l and m in given case with orientation θ. Hence, a co-occurrence matrix is made which is Z (l, m, d, θ). Since, l, m, d and θ are function of matrix. Mathematically, a co-occurrence matrix of l*m can be written as (1).

$$\mathbb{C}_{\Delta x,\Delta y^{(l,m)}} = \sum_{p=1}^{l}\sum_{q=1}^{m} \begin{cases} 1, & \text{if } Z(p,q) = l \\ 0, & \text{otherwise} \end{cases}$$

$$\text{and } Z(p+\Delta x, q+\Delta y) = m \qquad (1)$$

Since, l and m are representing image intensity values, Δx and Δy are the offset values at angle θ. P and q are representing spatial position in image Z. This matric can be calculated at four directions: 0, 45, 90, 135 degrees.

Following is a calculation of statistical texture feature.

Entropy: Texture of input image can be calculated through measurement of randomness. The result of entropy become 0 when all $p_{l,m}$ =0.

$$E_0 = \sum -p_{l,m} * \lambda o \gamma_2 p_{l,m} \qquad (2)$$

Correlation: It shows correlation between a pixel to it neighbor pixel. Its range varies from 1 to -1 i.e. positively correlated to negative correlated. Mathematically, it can be written as;

$$X_o = \sum_{l,m} \frac{(l-ul)(m-um)p_{l,m}}{\partial l \partial m} \qquad (3)$$

Energy: It is actually return of square elements sum in GLCM. Its range varies from 0 to 1. When range is 1, image will be constant.

$$E = \sum_{l,m} (p_{l,m})^2 \qquad (4)$$

Homogeneity: It measure spatial distance between GLCM and GLCM diagonal. Its range also varies from 0 to 1. It value is 1 for diagonal GLCM. Mathematically, it can be written as,

$$H = \frac{\sum_{l,m} p_{l,m}}{1+(l-m)} \qquad (5)$$

Contrast: It measure intensity between given pixel and the neighbor pixel. For constant image value is 0. It is written as;

$$X = \sum_{l,m} / l - m /^2 (p_{l,m}) \qquad (6)$$

5. Feature Selection

Different type of feature selection methods is used. This paper is using Ant Colony Algorithm. Ant Colony Algorithm: Researchers named Dorigo and Gambardell was known to be father of Ant Colony Algorithm(ACO)[18],[19]. It was first introduced in ninety's as a multi-agent method to optimize problems such as challenges faced by travelling salesperson. Different researchers have already showed that ants are social insects. They focused to find food for their colonies than for individually oneself. Thought-provoking process of food searching makes ant different from other insects. Adding attributes to this, it makes a shortest distance between source and destination. These skills of food searching by ant is known as Mass Intelligence (MI). MI is description of random behavior of elements. It is an indirect type of communication in which ant communicate through stimuli. Ant left a footprint for other ants through a stimulus known as pheromone. It depends on quality of food and distance. Other ants got attracted by this pheromone and then came through this path. Suppose an ant gets shorter path to get their destination it will get more pheromone. Pheromone will get evaporated in short interval of time. Hence selection of path makes it probabilistic strategy rather than deterministic strategy. Leaving pheromone as footprint is basically instinctive behavior. Hence, here comes the importance of pheromone and probabilistic approach of ant. Time is making limitations on this strategy because as time passes pheromone get

evaporated and probabilistic selection of path will decrease.

Basically, ACO is a heuristic technique in which problem is solved through graph. A number of ants start to move on problem set and each ant add its contribution in solving problem. As it has already discussed that selection of direction by ants depends on quantity of pheromone. Let us consider L as path used by ant. Probability of l^{th} path when ant moves from n to j can be given by;

$$G_{nm}^{l} = \frac{[\tau_{nm}]^{\alpha}[\mu_{nm}]^{\beta}}{\sum_{k \in R_n^l}[\tau_{nk}]^{\alpha}[\mu_{nk}]^{\beta}}, \iota\phi\ \mu \in R_n^l \quad (7)$$

Where; $[\tau_{nm}]$= pheromone stored between nodes n and m, R_n^l= Neighbor node for ant l in node n,α, β=Constraints controlling pheromone and heuristic technique. μ_{nm}= Heuristic value.

Completion of path will result in updating of data that is given by;

$$\tau_{nm}^{new} = \tau_{nm}^{current} + \sum_{l=1}^{t} \Delta\tau_{nm}^{k} \quad (8)$$

Since, $\Delta\tau_{nm}^{k}$= Pheromone amount when l is added to travel from n to m. total number of ants is represented by t. Each addition of pheromone is given by;

$$\Delta\tau_{nm}^{k} = \begin{cases} \frac{1}{B^l} \; if\ arc\ is\ in\ the\ path\ of\ arc\ l \\ 0 \quad otherwise \end{cases} \quad (9)$$

Where, B^l= final cost of path crossed by ant l.

After completion of first iteration, pheromone evaporation will be applied on pheromone matrix using £ factor given by;

$$\tau_{nm} = (1 - £)\tau_{nm}, 0 < £ \leq 1 \quad (10)$$

6. Feature Classification:

In this process, set of samples are taken. They are assigned class on the basis of training done by the classifier. It helps in assigning input pattern to predefined classes. KNN: In this paper, classification is performed through K-Nearest Neighbor (KNN) method [20]. It was done by taking more discriminative feature then end with ordinary discriminative features.

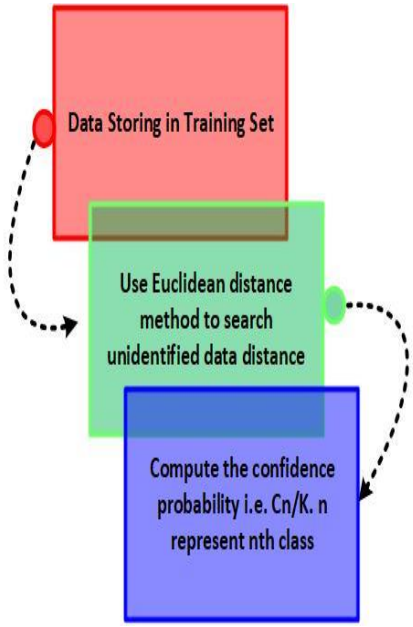


Fig.2. Rules of KNN Classifier

K-NN Classifier:

It is a non-parametric method in which any information about previous data is not required. One can add data at any stage of training to previous data set. Output of K depends on the probability on the pattern taken at input side. If the value of K increases the chances of getting close to discriminative result will increase. Fig. 2 is pictorial overview of K-NN classifier.

Binary Phase of KNN:

KNN classifier consists of two steps:
Training Stage: In this step, data sets are assigned with their classes.
Testing Stage: In this step, algorithm makes a set of data which have not assigned classes. They will give n class here.

Rules of KNN:

It follows three steps:
i) It needs stored data sets.

ii) It involves distance metric parameter in which distance between unidentified and identified data is measure.

iii) Identification of undefined data is done. Then, label to them is given through majority voting.

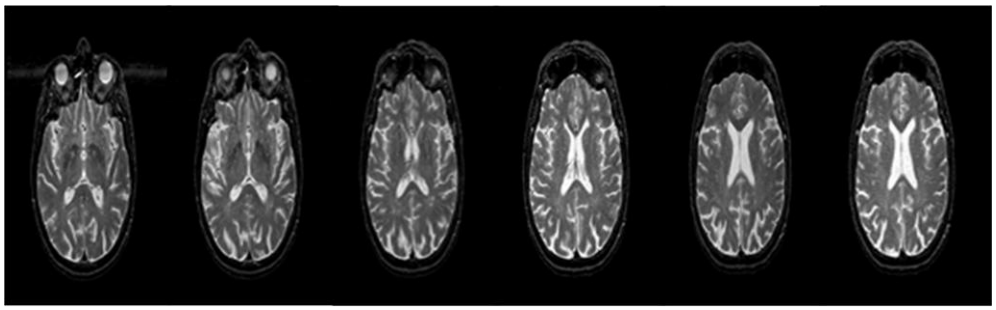


Fig.3.Normal brain images

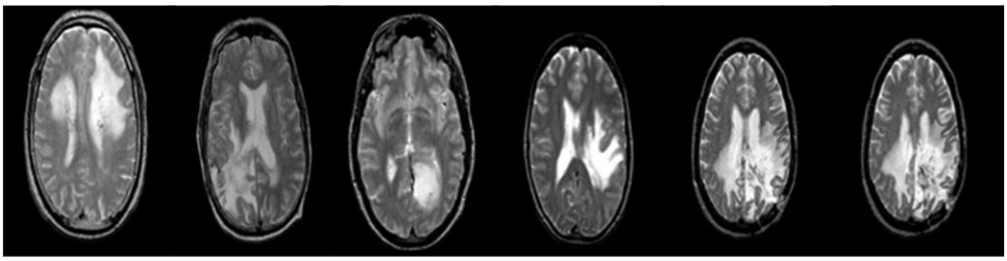


Fig.4. Abnormal brain images

7. Result and Discussion

Table 1 is showing different number of features for optimum results by using ACO and KNN, while doing this we achieved 88% as maximum accuracy for **3** features that are Homogeneity, Inverse Difference Moment Normalized and Difference Entropy. For four features, we achieved 86% accuracy. For all features, we have achieved 66% accuracy.

Graph of accuracy Fig.5 shows blue peak for selected feature and here number of selected features are "three" out of 66 extracted features while three other peaks are accuracy against different value of K, it is clearly presenting that for K=5 the model achieved its highest accuracy of 88%.

Confusion Matrix (Table 2) which evaluates the performance of classifier on a set of test data whose values are known.

- There are two possible predicted classes: "Normal" and "Abnormal". If we were predicting the presence of a disease, for example, "Abnormal" would mean they have the disease, and "Normal" would mean they don't have the disease.
- The classifier made a total of 50 predictions (e.g., 50 MRI scans were being tested for the presence of deformity).
    - In reality, 30 MRI scans in the sample are Normal, and 20 MRI scans are Abnormal.
    - Out of those 50 cases, the classifier predicted "Normal" 27 times, and "abnormal" 17 times.

TABLE I: Results for KNN (K=1, K=3, K=5) Nishtar Dataset

Accuracy	No. of Feature	Value of K	Sensitivity	Specificity	Selected Feature
80%	3	K=1	65%	90%	Difference Entropy(r), Inverse difference moment normalized(v), Homogeneity(j)
88%	3	K=5	85%	90%	Difference Entropy(r), Inverse difference moment normalized(v), Homogeneity(j)
76%	4	K=1	65%	83.3%	Difference Entropy(r), Inverse difference moment normalized(v), Homogeneity(j), 'Inverse difference normalized
76%	4	K=3	65%	83.3%	Difference Entropy(r), Inverse difference moment normalized(v), Homogeneity(j), 'Inverse difference normalized
86%	4	K=5	90%	83.3%	Difference Entropy(r), Inverse difference moment normalized(v), Homogeneity(j), 'Inverse difference normalized
68%	All extracted features	K=1	60%	73.3%	All GLCM Feature
68%	All extracted features	K=3	40%	83.3%	All GLCM Feature
66%	All extracted features	K=5	40%	83.3%	All GLCM Feature

Let's now define the most basic terms, which are whole numbers (not rates):

- True positives (TP): These are cases in which we predicted yes (Abnormal), and they are actually Abnormal.
- True negatives (TN): We predicted no (Normal), and they are actually Normal.
- False positives (FP): We predicted yes (Abnormal), but they are actually Normal.
- False negatives (FN): We predicted no (Normal), but they actually are Abnormal.

TABLE II. Confusion Matrix

N=50	Predicted no	Predicted yes	
Actual no	TN= 27	FP= 3	30
Actual yes	FN= 3	TP= 17	20
	30	20	

8. Comparison of Results

Different researchers have used different techniques in diagnosing brain tumors. Some researchers have used KNN, ACO, GLCM and many more. It depends on the type of results everyone wants to achieve. This paper is already detecting abnormal brain patterns through ACO, GLCM and KNN. Here is a short, reviewed comparison of different papers that why the suggested techniques are preferred. In [21] authors have used Wavelet transform (Feature Selection) and Support Vector Machine method (Classification).

TABLE III. Comparison with other Studies

Feature Extraction Technique	Feature Selection	Classif - ication	Acc u- racy (%)
	Wavelet Transfor m	SVM [13]	65
LoG ,GLCM, RILBP,IBF ,DGIF,RIC GF[14]	PCA	PCA-ANN	85.5
GLCM [15]		KNN	86
GLCM	ACO	KNN	88

They have achieved 65% accuracy through assigning labels to set of data. Basically, SVM divides the set of data into training and testing phase and apply both phases to set of normal and abnormal images. To make results more productive researchers in the given table have provided a combination with digital image processing. Still, their efficiency is quite low i.e. 65%. Similarly, the researchers as mentioned in Table 3 have used a bunch of feature extraction, selection and classification techniques but the accuracy of result goes to 85.5% [22]. More or less the study done by [23] seems similar with a single method change with comparison to the given research in this paper. Survey on papers realized that accuracy need more work to do that's why in current situation we suggested a combination of ACO, GLCM and KNN. Results goes to 88% which can be increased more in future work using different models.

9. Dataset

Fig.3 and Fig.4 are the sample images taken from Nishtar Medical Hospital data set as 'Normal Images' and "abnormal Images" respectively. These scans are collected under the supervision of medical officer at MRI department. These scans are of 256*256 pixel and are T2 weighted.

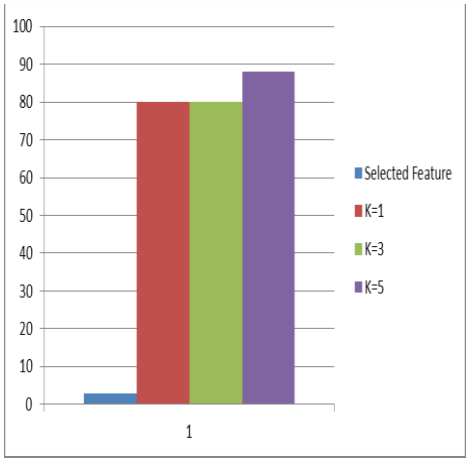


Fig. 5: Accuracy Graph

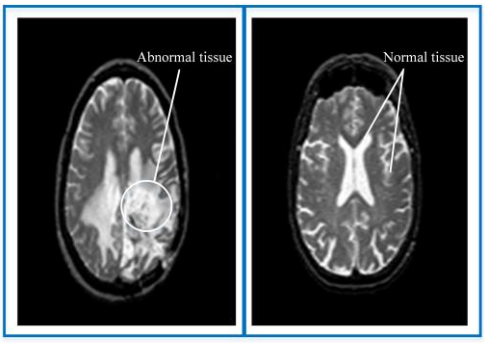


Fig.6.Normal and Abnormal brain tissues

Figure 6 depicts the major lesions and deformity in textural pattern of abnormal tissue, so we labeled it as abnormal scan while

the other which is quite normal and having a textural pattern is labeled as Normal scan.

10. Conclusion

Increased diseases of brain tumors need fast and accurate way to detect the problem. Currently, world is still lack of finding ways to these problems. In this paper, three popular methods are used to give an optimum solution. These are based on feature extraction, Selection and classification. GLCM is a feature extraction technique, ACO is feature selection which proved its result through decision making and finally classification is done through KNN. It has been observed that by reducing features, the classification and average hit time increases. The best accuracy results we obtained is 88% for three features i) (Differnce Entropy(r), ii) Inverse difference moment normalized(v), iii) Homogenity(j)) using KNN.

References

[1] A. Kharrat, K. Gasmi, and M. B. E. N. Messaoud, "A Hybrid Approach for Automatic Classification of Brain MRI Using Genetic Algorithm and Support Vector Machine," no. 17, pp. 71–82, 2010.

[2] E. I. Zacharaki *et al.*, "Classification of Brain Tumor Type and Grade Using MRI Texture and Shape in a Machine Learning Scheme," vol. 1618, pp. 1609–1618, 2009.

[3] C. Geetha and D. Pugazhenthi, "Classification of alzheimer ' s disease subjects from MRI using fuzzy neural network with feature extraction using discrete wavelet transform .," no. Mci, pp. 1–8, 2017.

[4] P. A. Charde and S. D. Lokhande, "Classification Using K Nearest Neighbor for Brain Image Retrieval," vol. 4, no. 8, pp. 760–765, 2013.

[5] R. S. Andersen, A. U. Eliasen, N. Pedersen, M. R. Andersen, S. T. Hansen, and L. K. Hansen, "Eeg Source Imaging Assists Decoding in a Face Recognition Task," pp. 939–943, 2017.

[6] K. Hemalatha and K. U. Rani, "Data Engineering and Intelligent Computing," vol. 542, 2018.

[7] H. J. Holz and M. H. Loew, *Relative feature importance: A classifier-independent approach to feature selection*, vol. 16, no. C. Elsevier B.V., 1994.

[8] N. Kwak and C. H. Choi, "Input feature selection by mutual information based on Parzen window," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 24, no. 12, pp. 1667–1671, 2002.

[9] D. Hall, "From: AAAI - 91 Proceedings. Copyright © 1991 , AAAI (www.aaai.org). All rights reserved.," vol. 3, pp. 547–552, 1991.

[10] P. Pudil, J. Novovičová, and J. Kittler, "Floating search methods in feature selection," *Pattern Recognit. Lett.*, vol. 15, no. 11, pp. 1119–1125, 1994.

[11] P. Mohan, D. AL V, and B. Kavitha, "Intelligent based brain tumor detection using ACO," *Int J Innov. Res Comput Commun Eng*, pp. 2143–2150, 2013.

[12] Q. Shen, "Combining rough and fuzzy sets for feature selection," *Proc. 2005 UK Work. Comput. Intell. UKCI 2005*, pp. 12–13, 2005.

[13] S. Hodnefjell and I. Costa, "Classification rule discovery with ant colony optimization algorithm," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 7435 LNCS, no. January 2004, pp. 678–687, 2012.

[14] A. Al-Ani, "Ant Colony Optimization for Feature Subset Selection," *Int. J. Comput. Electr. Autom. Control. Inf. Eng.*, vol. 1, no. April, pp. 999–1002, 2007.

[15] H. H. Gao, H. H. Yang, and X. Y. Wang, "Ant colony optimization based network intrusion feature selection and detection," *2005 Int.*

Conf. Mach. Learn. Cybern. ICMLC 2005, no. August, pp. 3871–3875, 2005.

[16] S. Mangaiarkarasi, "MEDICAL IMAGE SEGMENTATION USING ANT COLONY OPTIMIZATION ALGORITHM," 2016.

[17] M. Yeganeh, F. Mir, K. Mirnia, T. Branch, and T. Branch, "MRI medical images edge detection using ant colony optimization," pp. 1193–1199, 2015.

[18] G. Mohan and M. M. Subashini, "Biomedical Signal Processing and Control MRI based medical image analysis : Survey on brain tumor grade classification," *Biomed. Signal Process. Control*, vol. 39, pp. 139–161, 2018.

[19] S. Shah and N. C. Chauhan, "Techniques for Detection and Analysis of Tumours from Brain MRI Images : A Review," no. January 2016.

[20] S. Goyal, N. Johari, N. Singh, and A. Pal, "Survey on Different Brain Tumor Detection Methods or Algorithms," no. 5, pp. 94–99, 2015.

[21] N. Abdullah, U. K. Ngah, and S. A. Aziz, "Image Classification of Brain MRI Using Support Vector Machine," *Imaging Syst. Tech. (IST), IEEE Int. Conf. on. IEEE*, pp. 242–247, 2011.

[22] J. Sachdeva, V. Kumar, I. Gupta, N. Khandelwal, and C. K. Ahuja, "Segmentation, feature extraction, and multiclass brain tumor classification," *J. Digit. Imaging*, vol. 26, no. 6, pp. 1141–1150, 2013.

[23] V. Wasule, "Classification of Brain MRI Using SVM and KNN Classifier," pp. 218–223, 2017.

Vol. 4, No. 2 | Jul – Dec 2020

Analyzing the Effects of Error Messages Presentation on Debugging and Programming

Muhammad Shumail Naveed[1], Muhammad Sarim[2]

Abstract:

Programming is a fundamental skill of computer science students. However, it can be troublesome to learn. It is notable that programming error messages can be hard for beginners to comprehend, hampering progress and prompting disappointment. Effectively, translating compiler error messages is significant to rectify errors and advance toward victory in programming. However, these messages are often hard to understand and pose an obstruction to progress for many beginners. Descriptive messages are helpful for students in the beginning phase of learning a programming language. In this article, the effect of error message presentation on debugging and programming score is analyzed. The controlled experiment suggests that the presentation of error messages can have a strong effect on debugging score and also helpful to increase the programming score. However, no correlation between debugging score and programming score is identified. On the whole, a positive impact of the descriptive error messages is observed during the study.

Keywords: *compiler error messages; Java; introductory programming; debugging*

1. Introduction

Introductory programming has reliably been a center of computing science education [1], and one of the careers rewarding discipline [2]. The career openings of software development will increase through 2026 [3], however, learning to program is still a hard challenge for beginners and therefore high dropout is observed in the introductory programming courses [4].

Introductory programming courses include theory and practice of programming language with an integrated programming environment (IDE). Many programming environments are available and used in the educational context. The knowledge of IDEs is essentially important for students because there is an evidence of an association between the programming environment and learners metacognition [5].

Studies on the individual elements of programming environments remain an important topic, particularly from pedagogical aspect. One area of programming environment that has obtained much consideration in recent years is error messages. The errors are encountered during the process of developing code. When the error occurs, the developers expect an error message that describes what

[1]Department of Computer Science & Information Technology, University of Balochistan Quetta, Pakistan
[2]Department of Computer Science, Federal Urdu University of Arts, Science & Technology Karachi, Pakistan
Corresponding Author: mshumailn@gmail.com

has gone erroneous and attempt to correct the errors.

It is widely recognized that presentation of error messages had a significant impact on program comprehension. Errors may or may not cause compilation failure and the approaches for handling the two categories of errors fundamentally vary essentially. While runtime errors are critical, various studies center primarily on compile-time errors. Beginners may battle with the both types of errors; however, compile-time errors are more critical in that a program that compiler doesn't execute is unable to give the learners any important outcome of their efforts.

One of the numerous challenges' novices confronts from the begin are famously enigmatic compiler error messages, and there is an evidence on these challenges since 1965 [6]. It is widely observed that compiler error messages are frequently ambiguous, loose, confounding and erroneous, particularly for novice programmers. For beginners who are new to programming, learning the structure of a programming language can be troublesome, especially when the messages they get are confounding. Traver [7], identified that, the inadequately designed error messages affect the novices more negatively.

The analysis of errors made by beginners is of extensive enthusiasm of researchers in the domain of computing education; a comprehension of the errors that novices will in general experience, and how they manage them, is valuable in fitting teaching method and programming environments [8]. Since 1970's, it has become apparent that by and large, compiler error messages were not good as intended. Study of error messages in COBOL established that their feedback was not useful for users, especially beginners. As the education in computer science turned out to be increasingly broad, Pascal secured its position as the primary programming language for teaching. Brown examined the issues with the error messages in Pascal, seeing them as insufficient [9]. Similarly, a study on C language [10], explored the error messages, and gave vital knowledge into the developing notions over poor error messages. Denny et al. [11] identified that for over 20% of errors, the messages delivered by the Java compiler were not adequate to effectively distinguish the related error.

Beginners learn programming in different kinds of environments, from plain command-line to trade strength environments. These programming environments can contrast significantly in the presentation of error messages. Some environments provide very typical error messages, whereas some support very descriptive error messages.

Recently, some programming environments and compiler designers have shown an enthusiasm for giving descriptive error messages expected to be increasingly usable than previous. These studies are significant as connections can be drawn among compiler error messages and performance of users in programming. However, no notable study has mutually analyzed the impact of the error message presentation on debugging and programming. Likewise, no formal study has been found that examine the correlation between adeptness in debugging and programming proficiency.

The study presented in this article has three objectives. The first is to analyze the impact of error messages presentation on the capacity of debugging the programs. Specifically, the comparative analysis of enhanced compiler error messages and conventional compiler error messages in a controlled experiment. The second objective is to identify the effect of error messages presentation on the programming score. The third objective is to examine the association between adeptness in debugging and performance in programming. To the best of our knowledge no rigorous study with these objectives has been reported. This article lays out as follows. Related work is presented in section 2. Research method is described in section 3. Section 4 presents the results and discussion and followed by the conclusion.

2. Literature Review

The compiler error messages have been investigated in different dimensions and series of landmark studies on error messages have described blended findings. Dong and Khandwal [12], analyzed the effect of cosmetic changes on the ease of use of error messages. During study three visual dialects of the illustrative error message in a topical user interface framework are created. An online experiment which is based survey-based questionnaire included 52 participants. The results described that cosmetic changes to the introduction of an error message can have a strong effect on its usability.

Denny et al. [11] used CodeWrite a web-based environment wherein novices attempts a range of exercises that expect them to develop the body of a function in Java. The study of controlled experiment found no impact of extended compile time error message on the several metrics: number of submissions and the number of endeavors required to settle the most common syntax errors.

Becker examined the adequacy of enhanced compiler error messages [13]. This study focused on Java and employed an educational called Decaf, particularly developed for the research. The foremost thought that impacted the plan of Decaf was that Java compiled error messages might, and ought to be progressed upon. Decaf utilized the necessary information to develop more particular and accommodating enhanced compiler error messages which are displayed to the client. Two groups of around 100 subjects participated in the analysis. The study recorded 48,800 errors constructing a bunch of 74 different compiler error messages. The controlled group reported 32% less error than the control group and so demonstrates the viability of enhanced compiler error messages.

A landmark study of Traver [7] on the issues of compiler error messages described that the most recurrent errors do not fundamentally epitomize the complex errors to fix. Additionally, errors are not as it were due to the lack of information, or misguided judgments, but due to incidental slips. The study also identified that the significance of the quality of compiler error messages as suitable messages support the beginners to not essentially make arbitrary modifications to handle the error. In addition, useful error messages can decrease the workload of educates clarifying the same error messages again and again to understudies.

Nienaltowski et al. [14], analyzed the messages delivered by various compilers for different programming languages, and clustered them into three groups, and associated the degree of experience and error type with response and performance. The examination included two groups of subjects taking a basic programming course; they utilized messages in these three styles to troubleshoot incorrect code. The outcomes demonstrate that more definite messages don't really streamline the comprehension of errors yet that it makes a difference more where data is put and how it is organized. However, another study [15] on error messages reported that from their examination with C programmers that the individuals who extended feedback required less assistance from the tutors.

Becker et al. [16], analyzed the impact of enhanced error messages on the performance of novice programmer. The study adopted a different strategy by determining what number of syntax errors are fixed by novice programmers while investigating programs. During analysis, the impact of enhanced compiler error messages in a control experiment is analyzed where novices were given the task of correcting syntax of non-translated program code they didn't compose. A significant positive effect is found on the number of errors corrected, as well as the frequency of particular error types; however, no critical impact on the number of non-translating submission or novices scores.

Watson [17] presented BlueFix, a web-based environment amalgamated with BlueJ IDE and intended to help novices in diagnosing and repairing the errors. In contrast to other methodologies, BlueFix suggests a feedback approach dependent on systems

joined from the human computer interaction and educational spaces, which can offer different novices with dynamic degrees of help dependent on their compiler behavior. An assessment was conducted recommending a 19% improvement and uncovering that students viewed the tool positively.

Karvelas et al. [18], investigated the programming behavior of novices in Java. During the study, Blackbox data is used and BlueJ versions 3 and 4 are analyzed. These two versions vary radically in terms of message presentation and behavior of compilation. The study identified that compilation method and presentation of error messages have a significant effect on the behavior of novice programmer.

On the whole the compiler error messages have been investigated in an endeavor to ease the issues and hardness that programming understudies proceed to confront. Several studies have been attempted to analyze the impacts of error messages with different approaches and expanding observation. To date the results of several studies are inconclusive whereas many studies have reported positive results. It is vital to note that for the foremost part, these researchers have been utilizing diverse metrics.

3. Design & Method

The investigation of programming errors made by beginners is of significant intrigued to researchers of computing education. A comprehension of the errors that novices will in general experience, and how they manage them, is valuable in fitting pedagogical method and educational programming environments. The study aims to analyze the effect of the compiler message presentation on program debugging, programming score and correlation between debugging abilities and programming performance.

The experiment was conducted on the undergraduate graduate (n = 44) of computer science in 2018. This study centers around Java, one of a most famous programming language for instructing beginners to the program and one of the most well-known language utilized in industry. It ought to be noticed that the decision of Java as an introductory programming language is not without criticisms, and other languages like Python has gained popularity as an introductory programming language.

A total of 44 subjects participated in the study and divided control and treatment group (each with 22). Subjects voluntarily participated in the study. The course was delivered by the same instructor, content and teaching strategy. The subjects were new to Java programming yet comprehended fundamental programming concepts.

Virtually, the stratified sampling is used to group the participants of the study. The participants were carefully clustered in two subgroups in a way that both groups share the same characteristics. In order to ensure the equivalence of sample groups the age, previous background of programming and basic mathematical skills of participants are considered while grouping the subjects. These characteristics are considered because they a notable impact on programming performance and may affect the result of the study. The participants of both groups of study were equivalent in terms of age as identified by independent sample t-test which shows no significant difference in the age of participants of control group (M=23.05, SD=2.89) and treatment group (M=22.73, SD=2.41) conditions; $t(42) = 0.397$, $p=0.694$. Similarly, the independent sample t-test on the pretest score of programming and mathematical skills shows no significant difference in the participants of control group (M=34.45, SD=17.52) and treatment group (30.36, SD=10.65) conditions; $t(42) = 0.936$, $p = 0.355$).

The course comprised of 14 lectures and included a weekly session of computer laboratory in which subjects attempted a series of programming problems and illustrated to the instructor. The study used BlueJ 2.0 to introduce programming to control group, whereas BlueJ 4.0 is used for the treatment

group. The basic level of error messages in BlueJ 2.0 is the key reason for its selection for control treatment, whereas the descriptive error messages of BlueJ 4.0 is the pivotal motivation behind its selection for the treatment group.

There are multitude of programming environments for Java and some of them are BlueJ, Eclipse, NetBeans and IntelliJ IDEA. For presented study the BlueJ is selected because it is developed typically for beginners as identified by Becker et al. [19] and Yan [20]. Simplicity, visualization and interaction are the pedagogical features of BlueJ that makes it more superior over other environments. Unlike other environments, BlueJ support syntax highlighting and offers persistent pictorial feedback which allows beginners to visualize the execution path and the current state of the code in the program code [21]. Alkazemi and Grami [22], analyzed that BlueJ is more suitable for students than another environment.

During the study two initial sessions were devoted to the theory and introduced the fundamental concepts of programming to the participants. From third session the elementary programming with laboratory section was started and the data of students were properly logged for analysis. In every laboratory session a prewritten source code was provided to both groups of study and participants were asked to debug the provided programs by identifying and correcting the errors. The same practice was followed in every laboratory session and a debugging score of each participant is logged by enumerating the pre-existing errors corrected by novices while debugging programs. The detail of the debugging score of the control group is shown in Table I.

TABLE I. Debugging score of the control group

Students	**Session**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Theory	Theory	10	8	21	15	12	18	41	48	60	15	47	61
2	Theory	Theory	21	29	31	30	33	41	35	57	65	62	53	70
3	Theory	Theory	11	16	20	10	16	19	20	37	34	60	19	55
4	Theory	Theory	4	6	15	20	5	12	17	19	12	22	30	24
5	Theory	Theory	4	19	19	25	32	28	21	12	28	33	42	63
6	Theory	Theory	16	21	10	12	6	16	19	32	19	18	32	23
7	Theory	Theory	9	18	25	26	18	37	23	43	59	50	37	45
8	Theory	Theory	8	11	17	19	16	36	30	43	31	52	27	59
9	Theory	Theory	16	11	15	27	5	32	27	32	42	17	41	62
10	Theory	Theory	10	6	12	11	12	21	28	20	30	40	29	33
11	Theory	Theory	11	15	17	21	29	21	23	48	35	44	31	27
12	Theory	Theory	15	9	30	21	14	11	24	52	57	29	22	15
13	Theory	Theory	5	6	14	16	17	20	19	33	41	34	18	29
14	Theory	Theory	8	18	17	14	22	20	35	33	60	59	27	28
15	Theory	Theory	4	14	6	14	15	13	37	16	61	56	30	34
16	Theory	Theory	15	19	23	28	31	11	16	33	24	25	32	45
17	Theory	Theory	6	14	26	23	32	24	31	38	27	15	40	50

18	Theory	Theory	4	8	7	19	20	14	21	25	18	28	26	33
19	Theory	Theory	13	21	30	10	8	22	26	22	22	17	23	53
20	Theory	Theory	19	19	19	28	27	23	32	47	30	36	30	60
21	Theory	Theory	4	13	23	26	27	34	25	44	61	42	28	25
22	Theory	Theory	15	18	24	28	37	42	45	53	60	62	51	66

A clear variation of debugging score is observed in the control group. A minimum score of a participant in the study is 186 whereas the maximum score is 527. The accumulated debugging score of participants in the control group is 7109. The debugging score of subjects in the treatment group is Table II.

TABLE II. Debugging score of the treatment group

Students	**Session**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Theory	Theory	10	8	21	15	12	18	41	48	60	15	47	61
2	Theory	Theory	21	29	31	30	33	41	35	57	65	62	53	70
3	Theory	Theory	11	16	20	10	16	19	20	37	34	60	19	55
4	Theory	Theory	4	6	15	20	5	12	17	19	12	22	30	24
5	Theory	Theory	4	19	19	25	32	28	21	12	28	33	42	63
6	Theory	Theory	16	21	10	12	6	16	19	32	19	18	32	23
7	Theory	Theory	9	18	25	26	18	37	23	43	59	50	37	45
8	Theory	Theory	8	11	17	19	16	36	30	43	31	52	27	59
9	Theory	Theory	16	11	15	27	5	32	27	32	42	17	41	62
10	Theory	Theory	10	6	12	11	12	21	28	20	30	40	29	33
11	Theory	Theory	11	15	17	21	29	21	23	48	35	44	31	27
12	Theory	Theory	15	9	30	21	14	11	24	52	57	29	22	15
13	Theory	Theory	5	6	14	16	17	20	19	33	41	34	18	29
14	Theory	Theory	8	18	17	14	22	20	35	33	60	59	27	28
15	Theory	Theory	4	14	6	14	15	13	37	16	61	56	30	34
16	Theory	Theory	15	19	23	28	31	11	16	33	24	25	32	45
17	Theory	Theory	6	14	26	23	32	24	31	38	27	15	40	50
18	Theory	Theory	4	8	7	19	20	14	21	25	18	28	26	33
19	Theory	Theory	13	21	30	10	8	22	26	22	22	17	23	53
20	Theory	Theory	19	19	19	28	27	23	32	47	30	36	30	60
21	Theory	Theory	4	13	23	26	27	34	25	44	61	42	28	25
22	Theory	Theory	15	18	24	28	37	42	45	53	60	62	51	66

Like control group, a variation in a debugging score of participants in the treatment group is clearly observed. The minimum score of participants in module is 298 and the maximum is 666. The accumulated debugging score of participants in the treatment group is 10012.

For comparative analysis the descriptive statistics of the debugging score of each group are calculated and results are shown in Table III.

The highest mean score is observed in a treatment group and similarly the highest debugging score in the study is also identified in a treatment group. For further analysis of debugging score the normality tests are conducted with SPSS. The Shapiro-Wilk test applied to the debugging score of control group confirms a normal distribution, $W(22) = 0.92$, $p = 0.08$. Similarly, a Shapiro-Wilk test on debugging score of treatment group identify a normal distribution, $W(22) = 0.95$, $p = 0.36$. The Kolmogorov-Smirnov test also identifies a normality in a debugging score of the control group ($W(22) = 0.16$, $p = 0.15$) as well in a treatment group ($W(22) = 0.17$, $p = 0.11$).

Table III. Descriptive statistics of debugging score

Group	Mean	Median	Std. Dev.	Min	Max	Range	Skewness	Kurtosis	Total
Control	323.14	324.00	80.573	186	527	341	0.911	1.586	7109
Treatment	455.09	447.50	92.838	298	666	368	0.589	0.380	10012

The distribution observed in the debugging score of both groups of study is graphically represented with detrended normal Q-Q plots shown in Fig. 1.

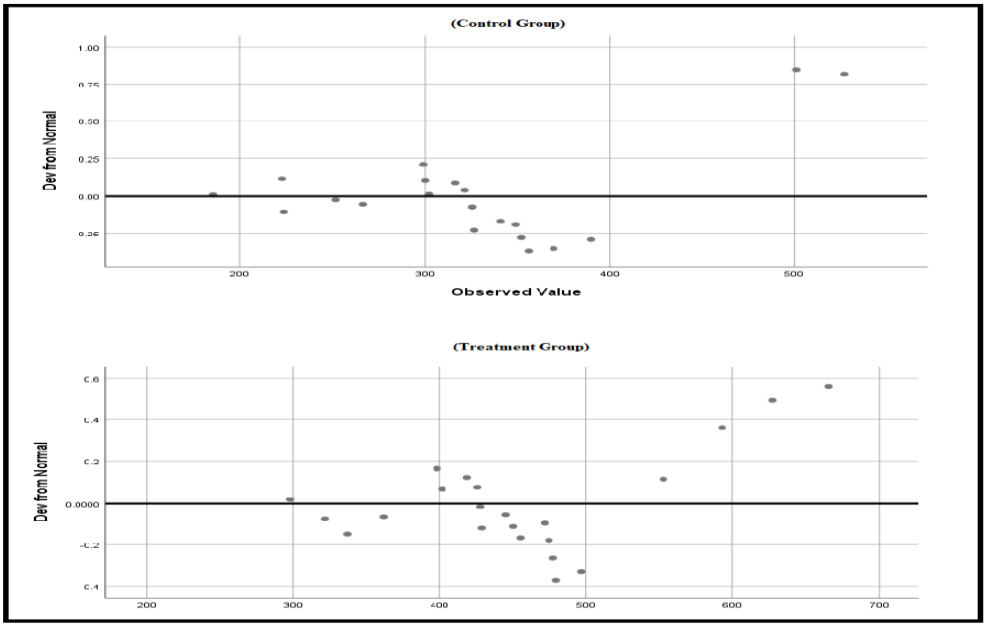


Fig 1. Detrended Normal Q-Q Plots of Debugging Score

The symmetric trend shown in the detrended normal Q-Q plots shows the normality of a debugging score of both groups in the study. The difference between score of two groups in study is further elaborated with boxplots shown in Fig. 2.

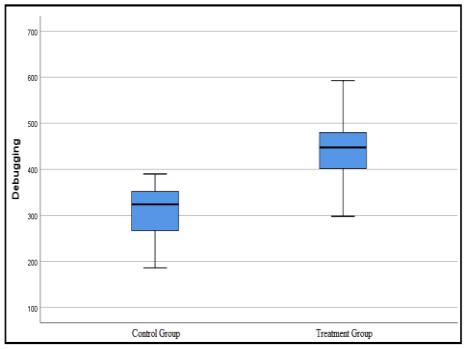


Fig. 2. Boxplots of Debugging Score

The quartiles of debugging score represented in the boxplots demonstrate the high performance of treatment group over the control group. The independent sample t-test was conducted to compare the debugging score of treatment group and the control group. There was a significant difference in the scores of a control group (M=323.14, SD=80.57) and treatment group (M=455.09, SD=92.84) conditions; $t(42) = 5.03$, $p < 0.05$.

During study the impact of error messages presentation on programming score is determined by conducting laboratory-based exam of contents covered during the module. During internal examination the participants of both groups are evaluated with same programming tasks and results are shown in Table IV.

Table IV. Detail of programming score

Group	Mean	Median	Min	Max
Control	49.50	54.00	15	75
Treatment	58.27	59.50	23	90

High mean score in programming is observed in a treatment group. For further analysis of programming score the normality tests are conducted. The Shapiro-Wilk test applied to programming score of control group confirms a normal distribution, $W(22) = 0.95$, $p = 0.31$. Similarly, a Shapiro-Wilk test on a programming score of treatment group identify a normal distribution, $W(22) = 0.97$, $p = 0.74$. The Kolmogorov-Smirnov test also identifies a normality in a programming score of the control group ($W(22) = 0.13$, $p = 0.20$) as well in a treatment group ($W(22) = 0.15$, $p = 0.20$).

The distribution observed in a programming score of both groups is graphically represented with detrended normal Q-Q plots shown in Fig. 3.

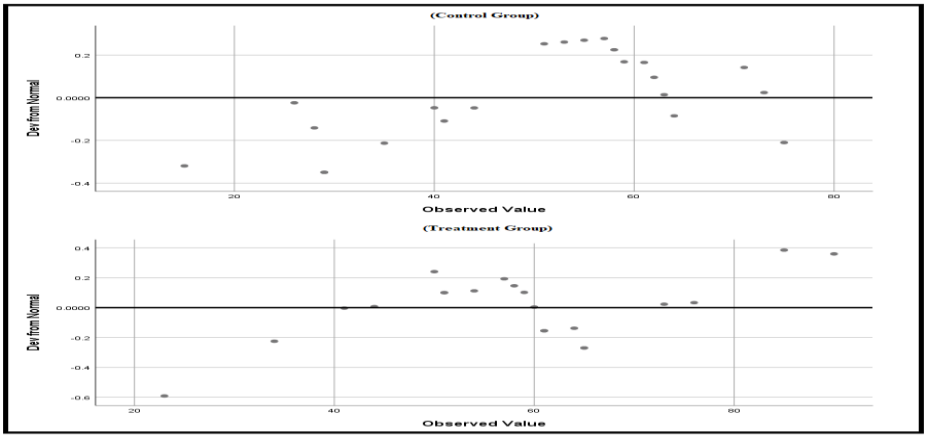


Fig. 3. Detrended Normal Q-Q Plots of Programming Score

The symmetrical trend revealed in the detrended normal Q-Q plots show the normality of programming score of both groups in the study. The difference between score of two groups in study is further elaborated with boxplots shown in Fig. 4.

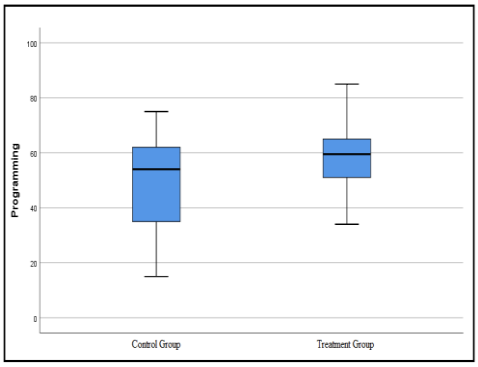


Fig 4. Boxplots of Programming Score

The quartiles represented in boxplots demonstrates the high score of programming in the treatment group than the programming score of a control group. The independent sample t-test was conducted to compare programming score of treatment group and a control group. There was no significant difference in the scores of a control group (M=49.60, SD=16.94) and treatment group (M=58.27, SD=15.32) conditions; t (42) = 1.80, p = 0.079.

A bivariate Pearson correlation was run to determine the relationship between debugging score and performance score. There was a moderate and positive correlation between debugging and programming, which was statistically significant (r = .453, n = 44, p = .002).

4. Discussion

The study presented in this article aims to analyze the effect of error messages presentation on the debugging score and programming score. The study also analyzed the correlation between the debugging score and programming score. A total of 44 subjects clustered in two groups. The BlueJ 2.0 is offered to the control group whereas, BlueJ 4.0 is offered to the treatment group. From the third session of a module the participants of both groups were given the problems of eliminating error from the source code they didn't develop and accumulated debugging score of 7109 is observed in control group and 10012 for the treatment group. The percentage difference of 33.91% between the accumulated scores of two groups suggests that presentation of error messages positively effects the adeptness in debugging. The t-test conducted on the debugging score of groups in a study described that descriptive error messages are helpful in debugging the program and certainly increased the adeptness in debugging.

The programming skill of participants in both groups is evaluated at the end of module by conducting a laboratory-based exam. The mean score of 49.50 is found in the control group, whereas 58.27 in a treatment group. The percentage difference of 16.27% in programming score of two groups suggests that presentation of error messages affects the programming abilities. However, t-test identified no significant difference between the programming score of a control group and treatment group which statistically described that the descriptiveness of error messages does not inevitably increase the programming score of novice programmers.

The correlation between debugging score and programming score is examined during the study. Technically, bivariate Pearson correlation identified a positive association; however, the relationship between variables is so weak, which signifies that adeptness in debugging does not reflect the proficiency in programming.

5. Conclusion

There are numerous challenges confronted by novices learning to program, and some are generally experienced as those in translating compiler error messages. These error messages are amazingly imperative as the novices' essential source of knowledge in their work, giving instantaneous feedback expecting to assist student find, analyze and rectify the errors. The presentation of errors has a

profound effect on programming. In this article the effect of error messages presentation on debugging score and programming score is analyzed. The results suggest that descriptiveness of error messages significantly increased the proficiency of debugging the programs. Similarly, the programming score is increased by using programming environments that support descriptive error messages yet no statistical significance of descriptive error messages in improving the programming score is observed. Likewise, no strong correlation between the debugging score and programming score is found during the study. On the whole the study suggests the positive impact of descriptive error messages in introductory environments. However, there are several threats to the validity of results. First, the experiment is conducted on a small sample of participants, so the different results may be obtained on large and different kind of samples. Second, the effect of error messages presentation is examined on a single programming language. Third, the severity of errors is not examined during the study. As for further work, the study would be repeated on a large class of samples by examining the error messages of different programming languages. Similarly, other techniques and methods like principal component analysis shall be unified for further comprehensive analysis.

ACKNOWLEDGMENT

The authors would like to acknowledge all the students who voluntarily participated in the study. Special thanks to Muhammad Tahaam and Muhammad Aayaan for their valued comments and encouragement that made this research possible.

References

[1] M. S. Naveed, M. Sarim, and K. Ahsan, "Learners Programming Language a Helping System for Introductory Programming Courses," Mehran University Research Journal of Engineering & Technology, vol. 35, no. 3, pp. 347-358, 2016.

[2] M. S. Naveed, M. Sarim, and A. Nadeem, "C in CS1: Snags and Viable Solution," Mehran University Research Journal of Engineering & Technology, vol. 37, no. 1, pp. 1-14, 2018.

[3] https://insights.dice.com/2019/01/03/software-developer-jobs-increase-2026/ (Last Accessed: 12th September, 2020)

[4] L. E. Margulieux, B. B. Morrison, and A. Decker, "Reducing withdrawal and failure rates in introductory programming with subgoal labeled worked examples," International Journal of STEM Education, vol. 7, pp. 1-16, 2020.

[5] J. Prather, R. Pettit, B. A. Becker, P. Denny, D. Loksa, A. Peters, Z. Albrecht, and K. Masci, "First things first: Providing metacognitive scaffolding for interpreting problem prompts," in proceedings of the 50th ACM Technical Symposium on Computer Science Education, pp. 531-537, 2019.

[6] S. Rosen, R. A. Spurgeon, and J. K. Donnelly, "PUFFT - The Purdue University Fast FORTRAN Translator," Communications of the ACM, vol. 8, no. 11, pp. 661-666, 1965.

[7] V. J. Traver, "On Compiler Error Messages: What They Say and What They Mean," Advances in Human Computer Interaction, pp. 1–26, 2010.

[8] D. McCall, and M. Kölling, "A New Look at Novice Programmer Errors", ACM Transactions on Computing Education, vol. 19, no. 4, pp. 1-30, 2019.

[9] P. J. Brown, "Error messages: The Neglected Area of the Man/Machine Interface", Communications of the ACM, vol. 26, pp. 246–249, 1983.

[10] S. K. Kummerfeld, and J. Kay, "The Neglected Battle Fields of Syntax Errors," in proceedings of the Fifth Australasian conference on Computing Education. Australian Computer Society, pp. 105–111, 2003.

[11] P. Denny, A. Luxton-Reilly, and D. Carpenter, "Enhancing syntax error messages appears ineffectual", in proceedings of the 2014 Conference on Innovation and Technology in Computer Science Education, pp. 273–278, 2014.

[12] T. Dong, and K. Khandwala, "The Impact of 'Cosmetic' Changes on the Usability of Error Messages," Extended abstracts of the chi conference on human factors in computing systems, pp. 1-6, 2019.

[13] B. A. Becker, G. G., R. Iwashima, C. McDonnell, K. Goslin, and C. Mooney, "Effective compiler error message enhancement for novice programming students", Computer Science Education, vol. 26, no. 2-3, pp. 148-175, 2016.

[14] M. Nienaltowski, M. Pedroni, and B. Meyer, "Compiler error messages: What can help novices," in proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education, pp. 168–172, 2008.

[15] E. Odekirk-Hash, and J. L. Zachary, "Automated feedback on programs means students need less help from teachers," in proceedings of the 32nd SIGCSE Technical Symposium on Computer Science Education, pp. 55–59, 2001.

[16] B. A. Becker, K. Goslin, and G. Glanville, "The Effects of Enhanced Compiler Error Messages on a Syntax Error Debugging Test," in proceedings of the 49th ACM Technical Symposium on Computer Science Education, pp. 640-645, 2018.

[17] C. Watson, F. W.B. Li, and J. L. Godwin, "BlueFix: Using Crowd-Sourced Feedback to Support Programming Students in Error Diagnosis and Repair," Lecture Notes in Computer Science, vol. 7558, pp. 228-239, 2012.

[18] I. Karvelas, A. Li, and B. A. Becker, "The Effects of Compilation Mechanisms and Error Message Presentation on Novice Programmer Behavior," in proceedings of the 51st ACM Technical Symposium on Computer Science Education, pp. 759-765, 2020.

[19] B. A. Becker, P. Denny, R. Pettit, D. Bouchard, D. J. Bouvier, B. Harrington, A. Kamil, A. Karkare, C. McDonald, P. Osera, J. L. Pearce, and J. Prather, "Compiler Error Messages Considered Unhelpful: The Landscape of Text-Based Programming Error Message Research," in proceedings of the Working Group Reports on Innovation and Technology in Computer Science Education, pp. 177-210, 2019.

[20] L. Yan, "Teaching Object-oriented Programming with games," in proceeding of sixth international conference on Information Technology: New Generations, pp. 969-974, 2009.

[21] K. V. Haaster, and D. Hagan, "Teaching and Learning with BlueJ: an Evaluation of a Pedagogical Tool," Issues in Informing Science & Information Technology, vol. 1, pp. 455-470, 2004.

[22] B. Y. Alkazemi, and G. M. Grami, "Utilizing BlueJ to Teach Polymorphism in an Advanced Object-Oriented Programming Course," Journal of Information Technology Education: Innovations in Practice, vol. 11, pp. 271-282, 2012.

Vol. 4, No. 2 | Jul – Dec 2020

Significance of National Spatial Planning for Economic Development of Secondary Cities in India: Critical Analysis of JNNURM Programme

Saima Kalwar[1], Irfan Ahmed Memon[1], Sabeen Qureshi[1]

Abstract:

Secondary cities are the vital economic link along with megacities in the system of cities of a nation. Whereas spatial planning and local economic development are the major factors in fostering regional and national economic development. If the national spatial planning strategies failed to improve economic functions and linkages in the system of cities at a secondary cities level, the disparities among the regions will increase. This can result in a lagging regional economy. Therefore, the national government should develop innovative approaches to stimulate and manage the development of secondary cities. The main purpose of the paper was to critically review the spatial planning strategies carried out at the national level in the developing world. The selection of India as a case study country is based on population density and the presence of a vast network of secondary cities. The paper had critically reviewed the spatial planning strategies carried out in JNNURM National Programme to strengthen the local economic development of secondary cities during 1995-2015. The secondary data collection resources like research papers, reports, and books were used to gather the required data. The results revealed that the JNNURM had focused only on the development of cluster secondary cities around megacities in order to reduce congestion and accommodate the rural immigrants. Unfortunately, the JNNURM neglected the sub-national (regional headquarter) secondary cities, which are vital players for regional economic development. Therefore, it was suggested that the Indian government should also initiate spatial planning strategies and programs for the local economic development of sub-national secondary cities to achieve dual benefits: balanced regional and national economic development and a balanced system of cities.

Keywords: *Secondary cities; spatial planning; economic development, JNNURM; India.*

1. Introduction

Cities are the major driving mechanism to enrich local economic development and boost trade and investment [1,2,3]. Cities help in shaping a regional, national, and global economy and culture. Similarly, they got affected if there is growth or decline in regional, national, and global economies [4]. "A city's or a town's prospects depend critically on its place within the urban system, national and international" [5].

However, megacity-uncontrolled nations have lower regional inequalities in growth, better production at the national level, and per capita income. This has created a significant impact on the functioning and status of cities.

[1]Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan
Corresponding Author: irfanahmed04crp26@gmail.com

As a result, a new hierarchy of cities has emerged.

The secondary city is a term frequently used to define the second-tier level of a hierarchical system of cities based on population verge. In the past, secondary cities caught little attention from researchers, planners, and policymakers in comparison to the megacities. Rondinelli was one of the pioneers in introducing and popularizing the term secondary cities in the 1970s [1,2,3 6]. But because of widening gap arising between the development of megacities and secondary cities, the governments and international agencies has been showing renewed interest in the development of secondary cities in recent years most notably by Cities Alliance [6,7, 8, 9].

These cities, on one hand, boost local production by industry agglomeration, create diversified economic and employment base for the city and regional inhabitants and offer localized supply chain and transportation services throughout a country. On the other hand, helps in reducing the flow of rural migrants to mega-cities in search of jobs by offering those opportunities at local level. Hence, many poor cities and rural areas might double or even triple their GDP with a successful system of secondary cities and reduce congestion from megacities [6]. "Secondary Cities are asset rich and cash poor", how to better use these assets is a key for development" [1]. Means efficient secondary cities leads towards a balanced system of cities which offer great provincial and national economic growth ability. The United States and South Africa are the two good examples.

Although the secondary cities share 40% allocation of global GDP, but they are the facilitators of the resources needed to mega cities such as it exists in Bangkok. However, due to negligence from local, central and international organizations, many secondary cities are facing development challenges like the revitalization of their economies, with a thirst for the investment needed for supportive economic infrastructure and the creation of attractive employment opportunities. This failure leads towards creating disparities and distortions in the regional economic development and poverty in many countries [6, 10].

The secondary cities of southeast Asia have risen their importance over the last two decades as manufacturing hubs, regional development centers for agricultural goods and urban facilities. Consequently, administrative bases for district or sub-district governments, as well as destinations for migration from rural areas, smaller towns and neighboring countries increased in southeast Asian cities. As a large population, information, institutions and economic development concentration, secondary cities play an important role in the urban and economic structure of their own regions and in the South-East Asian zone [9].

India has a well-established democratically elected government and a wide network of secondary and lower-order towns [11]. In India, there are over 200 cities with populations of more than 200,000. There are two great cities, Mumbai and Delhi, and even more than 30 cities with more than 10% of the nation's largest city populations that can be identified as secondary cities [1]. These secondary cities serve as gateways and exchanges to facilitate business processes, supply chain networks, multimodal transit hubs and as focal points for the administration of sub-national / regional government and economic growth. In national and global growth, they are also major centres for innovation, research, community and business creation [1, 4]. However, due to weak governance system, these secondary cities are coping with the problems of rapid urbanization and insufficient urban infrastructure & services, necessary to boost their economic development [12]. All that can be prohibited by developing and implementing the spatial planning strategies considering the local economic sectors of secondary cities. Giridharidas in 2007 quoted

Ahluwalia, India's chief economic planner, that "One hundred million people will be moving to cities from rural areas in the next 10 years. It is important that these 100 million migrants should be absorbed in the second tier cities (secondary cities) instead of showing up in Delhi or Mumbai" [12]. Therefore, the national and provincial governments should give priority to the planning, governance and development of secondary cities. This will help in building a balanced national system of cities and sustainable local and regional development.

Especially the central government has an important role to play in local economic development phenomenon of secondary cities. National governments may stimulate collaboration between cities and help them boost the quality of their governance and the prosperity of industry. In comparison, decentralization also helps these cities to become more competitive, diverse, and self-sufficient cities [1, 10].

Therefore, the paper seeks to examine the spatial planning strategies carried out at the national level in India to strengthen the local economic development of secondary cities. The purpose of selecting is that India has a developed structure of local government and a wide network of secondary and lower-order towns in comparison to other South Asian countries. The research had critically reviewed the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) initiates carried out in 2005 to boost the local economic development in secondary cities of India.

Before moving into the discussion and key issues addressed in the paper, it is useful to describe the system of secondary cities set by Cities Alliance and urbanization background of India.

2. System of Secondary Cities

A universally declared definition for secondary cities does not exist [9]. Most of the countries denote as part of a hierarchical grouping of cities, secondary cities resolute by population size, function, and economic status. Consequently, there is a significant variation in the definition among countries. Generally, a secondary city can likely have a population ranging between 10-50% percent of the nation's prime city [6,13]. "A secondary city as an urban area generally having a population of between 100,000 and 500,000". The size of these cities can be from a few hundred thousand to millions. Most of the other authors suggest that secondary cities should be defined in accordance with their performance in their national and regional integrated functional system, not by their hierarchy or population [9, 14, 15].

2.1. Typology of Secondary Cities

The Cities Alliance has divided secondary cities into three wide typologies or groups:

(i) Sub-national cities being centers of local government, agriculture, tourism, industry and mining.
(ii) Cluster cities in the form of satellite and emerging development cities that overlap major metropolitan areas, and
(iii) Economic trading corridors designed or built by urban development centres or positions along major transport corridors.

The sub-national secondary cities are the oldest form of secondary cities, mostly developed as regional administrative centres. In other cases, they were developed as industrial or logistic centres due to their unique location for competitive advantage. Others were developed due to historical or cultural advantage like Kumasi in Ghana, Varanasi, India and Mecca in Saudi Arabia.

Historically, most of the sub-national secondary cities were founded as regional administration hubs in the sense of a centrally devolved government structure. Some cities also became major industrial, resource and logistic centres, because of competitive and unique locational advantage. The remaining cities were developed because of cultural and historical advantages. The examples are Kumasi in Ghana, Varanasi, India and Mecca in Saudi Arabia [1, 10].

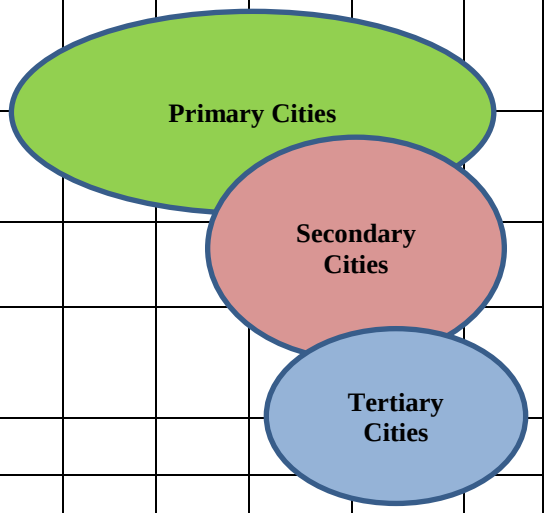
With the development of countries, their small regional settlements and towns also expand into secondary cities and megacities. Though mega cities lead in trade and investment, but secondary cities play a vital role in a sub-national regional development by providing knowledge, industries, market, logistics, transport and cultural hubs, which create attractive employment opportunities and enhance the consumption, trade, import and export services [2,3,4]. However, very limited work has been done at national level to develop sub-national secondary cities and achieve regional economic development in South Asia context [1, 9].

2.2.1 Population Based Classification of Secondary Cities

From the population point of view world cities are classified into six categories: supra, mega, metro, meso, micro and mini types [1]. Table 1 describes the population range for primary, secondary and tertiary cities which comes under this classification of cities presented by Cities Alliance. cities along with the types of functions they perform. The primary cities can fall in the supra, mega to even mini category of cities. Whereas, the size of secondary cities varies from 150,000 to 5 million population and has a wide variety of roles in international and domestic urban systems. Therefore, the secondary cities fall in the meso, micro and mini categories (see table 1).

TABLE I. Spatial Scale and Functional Framework for Defining System of Secondary Cities [1]

Order of City	Functional and Market Orientation	Supra 50 m+	Mega 10 m+	Metro 5-10m	Meso 1-5 m	Micro 0.2-1m	Mini >0.2
Global	Wide, numerous high-value resources and development clusters engaged in international trade						
Sub-Global	Service and industrial clusters are primarily interested in international commerce.						
National	National government, transportation, utilities and development centers						
Sub-national	Provincial sub-national administration, transportation, utilities and industrial centers						
District	Business, utilities and production at district level						
Sub-district	Service sector centres focused on rural capital						



According to United Nation (2012) [17], in 2010 53% of the world population was living in urban areas. It is expected that 70 percent of the world 's population will live in urban areas by 2025. It is also estimated that in 2025 out of that 70%, 40% will be living in secondary cities. Globally, more than 2,400 cities around the world with populations ranging from 150,000 to 5 million may be classified as secondary cities. In Africa and Asia, about two-thirds of them are [1]. These cities are projected to rise to 460 million people, compared to 270 million between 2010 and 2025 for large cities worldwide [1, 6]. It is clear from the figure 1 that the urban growth in Asia is highest in comparison to other

continents. The highest urban growth is occurring in 500,000 population ranges. Whereas the growth is second highest in 1-5 million ranges and both types fall in the secondary city's population range.

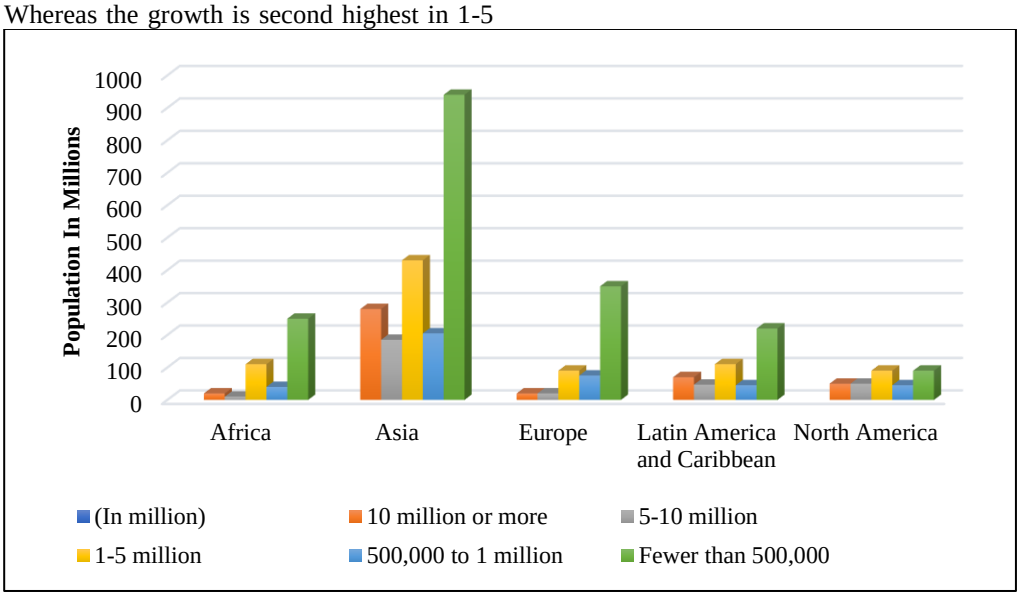


Fig 1. The Unrecognized Primacy of Secondary Cities Worldwide [17]

2.2. Economic Functional Based Classification of Secondary Cities

The secondary city is more determined by its location and its place in the urban network and the global financial system [9, 18]. Geographically, secondary cities may facilitate growth at the state level, which increases the distribution of income and resources, prevents migration to primary cities, and thus relieves urban pollution and infrastructure constraints by creating alternative sites for economic, manufacturing and other productive activities. Promoting regional economic growth by the agglomeration and nurture of small and medium-scale enterprises serving local markets [9]. The table 2 presents the functional typology of secondary cities [9, 18].

3. Demographic Trends in India

India is a country, comprise of 29 states and 7 Union Territories. There are 640 total numbers of districts (counties) in India. The country had a population of 1.21 billion (census 2011) with a share of 17.5% of the world's population. India 's average rate of urban population growth is 3.35 per cent [19]. The percentage of urban dwellers rose from 17.35% in 1951 towards 31.2% in 2011. Fast population growth rates, decreasing rural prospects, and the change from a static and low-paying farm sector to higher compensated urban occupations lead to urban growth in major part. It is important to keep in mind that presently 1 in 3 people live in urban areas and it is estimated that as many as 50 per cent of India's population will remain in cities in the next 10 years [19, 20]. It is interesting to note that from 1901 to 2011, India remains a rural population dominating country (see table 3).

TABLE II. Typology of Urban Functions of Secondary Cities [1, 9, 18]

1.	Regional market	The city is a major driver for commodities development and trade services at the level of the provincial and simultaneous central economy.
2.	Service center	The city provides both the local society and the local populace with a variety of public health facilities, secondary and tertiary education institutions, as well as private sector, industries, recreation, and knowledge centers.
3.	Regional capital	The city hosts separate regional and national legislative and administrative structures.
4.	Economic location	As a large-scale production and trading area, the city establishes a cohesive national and international policy, by making the requisite improvements in infrastructure and by promoting the actions of economic actors.
5.	Tourist centre	To encourage activities directly linked to national and foreign tourism, the city uses its competitive advantages of location, natural wealth, historical heritage, history, etc.
6.	Communication hub	The city serves as a forum for the trade of people , goods and knowledge due to its strategic position and the growth of the related infrastructure.
7.	Metropolitan periphery	The growth and prosperity of the region is highly based on its incorporation into the metropolitan region, with national and international complexities underlying it.
8.	National/ International	The geographical position of the city (border region, coast, city-state) and its growth interface policy (duty-free zone, "maquiladoras", foreign tourism) give it a role influenced primarily by growing international trade networks.
9.	Cities in a conurban area	The growth of the city depends on the incorporation of many major municipalities into an agglomeration connected together at different levels of the metropolitan system, with each municipal maintaining its own identification.
10.	Association of a group	In a largely rural area, many small towns form a community and cities affect each other.
11.	Urban region	Settled regions within scattered metropolitan areas

Although after independence, Absolute population growth is more common in urban areas than in rural areas. The overall growth of 181.4 million inhabitants over the last decade, i.e. from 2001 to 2011, 90.4 million are in rural areas, while 91.0 million are in urban areas. In addition, the urban areas had shown a significant increase and their number of settlements increased from 5,161 to 7,935 during 2001-2011 census period.

However, 68.8% population of the country is still residing in rural areas [19,20]. It is clear from these available census statistics of India

that the rural areas are still settling major part of country's population. Therefore, the national urban spatial planning strategies of the country should be favourable and supportive for rural areas too, as they are directly or indirectly dependent on urban service centres.

TABLE III. Demographic Trends in India, 1901-2011 [19, 20]

Year	No of Urban Areas	Population in Millions			% of Total population	
		Total	Rural	Urban	Rural	Urban
1901	1827	232.9	212.5	25.8	89.0	11.0
1911	1825	252.0	226.1	25.9	89.6	10.4
1921	1949	251.3	223.2	28.1	88.7	11.3
1931	2072	278.9	245.5	33.4	87.8	12.2
1941	2250	318.6	274.5	44.2	85.9	14.1
1951	2843	361.1	298.7	62.4	82.7	17.3
1961	2363	439.2	360.3	78.9	82.0	18.0
1971	2590	598.2	489.1	109.1	80.1	19.9
1981	3378	685.2	525.7	159.5	76.7	23.3
1991	3768	844.3	627.1	217.2	74.3	25.7
2001	5161	1027.0	741.6	285.1	72.2	27.8
2011	7935	1210.1	833.0	377.1	68.8	31.8

4. Methods for Data Collection

It is the duty of planners to collect and review accessible data and to correctly present the potential impacts of the multiple intervention plans to all stakeholders [21]. Considering these points, the study had adopted the Cities Alliance classification of cities. The required data were collected from research papers, books, and reports through on-line resources available in MUET. That had helped a lot in the study to establish a link between spatial planning strategies and local economic development in secondary cities. The gathered data was analysed by using population projection models and graphs were produced in MS Excel.

5. Jawaharlal Nehru National Urban Renewal Mission (JNNURM)

In 2005, one of the most ambitious projects to enhance urban infrastructure and promote local economic growth in secondary cities was launched by the Indian government [11, 22]. The National Urban Regeneration Task of Jawaharlal Nehru targeted 63 urban agglomerations in India to strengthen basic infrastructure facilities and urban revitalization programmes [22]. Those 63 urban agglomerations were divided into three categories on the basis of the 2001 population census:

1. **Cities with 4 million plus population:** Delhi, Greater Mumbai, Ahmedabad, Bangalore, Chennai, Kolkata, Hyderabad.

2. **Cities with 1 million plus population**: Patna, Faridabad, Bhopal, Ludhiana, Jaipur, Lucknow, Madurai, Nashik, Pune, Cochin, Varanasi, Agra, Amritsar, Vishakhapatnam, Vadodara, Surat, Kanpur, Nagpur, Coimbatore, Meerut, Jabalpur, Jamshedpur, Asansol, Allahabad, Vijayawada, Rajkot, Dhanbad, Indor.

3. **Cities with less than 1 million population**: Guwahati, Itanagar, Jammu, Raipur, Panaji, Shimla, Ranchi, Thiruvananthapuram, Imphal, Shillong, Aizawl, Kohima, Bhubaneshwar, Gangtok, Agartala, Dehradun, Bodhgaya,

Ujjain, Puri, Ajmer-Pushkar, Nainital, Mysore, Pondicherry, Chandigarh, Srinagar, Mathura, Haridwar, Nanded.

The concerned authorities were given the responsibility to prepare the city development plans [11]. Larger cities such as Mumbai, Delhi and Chennai have drawn up proposals to establish secondary cities on the outskirts of these areas. Many of those cities were expanded towns, developed to reduce overcrowding and congestion from large urban agglomerations. The concerned development authorities, as a part of a master plan had brought sizeable areas of land and developed them into new towns. For instance, Gurgaon in South-East Delhi is one of India 's fastest growing and most lucrative business investment and growth location. In 2006, Indian secondary cities, urban revitalization programmes have been used to rejuvenate and promote restructuring and investment in infrastructure and real estate programmes in secondary cities. Plans were also planned by the local planning authorities for the creation of public utilities, highways, industrial developments, and community amenities.

6. Results and Discussion

6.1 Urbanization Trends of India

South Asia shares 30% urban population of Asia continent. India is the second densely populated country in Asia after China and top populated country of Southern Asia. India shares around 20% and more than 67% urban population of Asia and South Asia respectively. Table 4 presents the urban population trends in Asia, South Asia, and India in the five population-based categories of cities set by Cities Alliance from 1995 to 2015. Considering these categories, the study has analysed India's urban settlements growth trends during 1995-2015. The data was taken from Indian census reports (on-line sources) and Un-habitat reports.

TABLE IV. Urban Population of Asia, South Asia and India by Size, Proportion and Growth, 1995-2015 [17]

Region/ Country	**Class of Urban Settlement**	**Urban Population**		
		1995	2005	2015
Asia	10 million or more	104,168	163,806	251,463
	5-10 million	81,154	155,697	221,879
	1-5 million	234,984	307,177	424,740
	500,000-1 million	95,690	148,723	228,219
	< 500,000	695,264	846,440	986,836
	Total	**1,211,260**	**1,621,843**	**2,113,137**
South Asia	10 million or more	38,465	84,070	108,026
	5-10 million	29,307	50,249	49,330
	1-5 million	60,812	90,244	108,651
	500,000-1 million	31,138	42,294	54,325
	< 500,000	206,613	282,487	304,098
	Total	**366,335**	**483,648**	**624,430**
India	10 million or more	26,703	51,009	72,649
	5-10 million	20,345	23,132	33,175
	1-5 million	42,216	50,416	73,069
	500,000-1 million	21,617	25,735	36,535
	< 500,000	143,433	179,224	204,510
	Total	**254,314**	**329,516**	**419,938**

If one observes the urbanization trends in India in 1995, the 10 million plus and 5-10 million categories had a combined share of 18 percent. Whereas, the 500,000-1 and 1-5 million categories had a combined share of 26 percent. The remaining 56% of urban areas were living in the small cities and towns. The 10 million and more cities category had shown an increase of 6% during 10 years (2005) and only 1% during 2005-2015. The reason is the rapid expansion of Kolkata, Chennai and Hyderabad cities as they are still in their development phase and have room for expansion, in comparison with Mumbai and Delhi cities

The second category of 5-10 million population, remained in a static form of a share of 6-8% during the years 1995 to 2015. Together these two categories share 25% of the urban population in 2015. The third category, 1-5 million populated cities had a share of 17% in 1995, 15% in 2005, and 17% in 2015. The fourth category, 500,000-1 million population of cities was sharing 9% urban population in 1995, 8% in 2005 and 9% in 2015.

The last category of cities is of less than 500,000 population. This category had a share of 56% in 1995%, which have gradually reduced to 54% in 2005 and 49% in 2015.

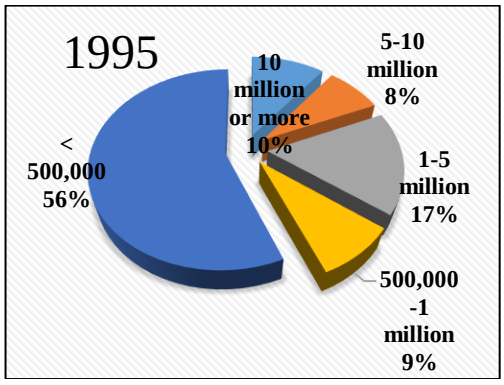


Fig.2. Population Share of Urban Settlements of India in 1995

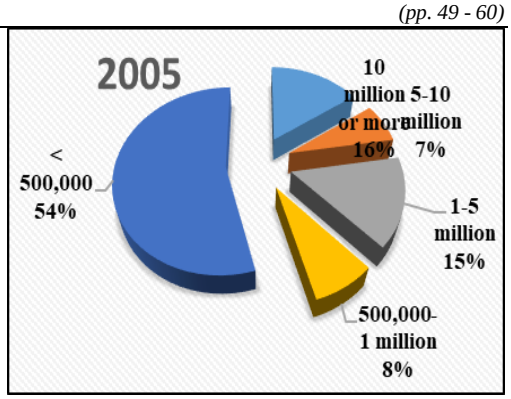


Fig. 3. Population Share of Urban Settlements of India in 2005

It is clear from the above statistics that the 1-5 million and 500,000-1 million categories of cities are unable to compete in the race of urbanization. Their combined share remained static between 23-26% during 20 years (1995-2015). The reason might be the migration of rural population to megacities. The figures 2, 3 and 4 present the population share in all five population-based categories of cities in 1995, 2005 and 2015 years respectively. The secondary cities of India fall in the categories of 500,000-1 million and 1-5 million population [12]. That means, these secondary cities are struggling for their sustenance. They are unable to cater the economic needs of their local and surrounding rural areas. Therefore, the inhabitants migrate to metropolitan cities for better employment opportunities.

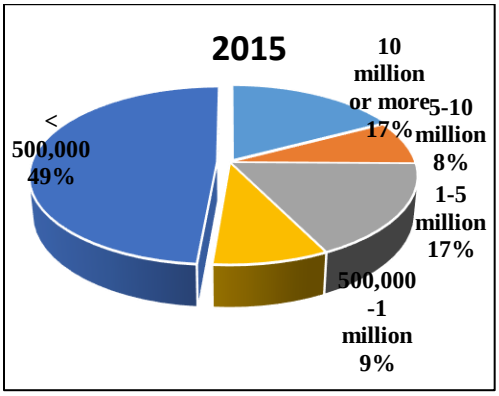


Fig. 4. Population Share of Urban Settlements of India in 2015

Although, the country has a 31.2% share of urban population, but 68.8% population of the country is still living in rural areas [19]. Below 500,000 and 500,000-1 million cities, which comprise more than 50% urban population of India, also include the regional headquarter cities of these districts. These regional headquarter cities are also the secondary cities. These cities serve as regional market and service centres to cater the goods exchange, health, education, leisure and activities of local and surrounding communities and for the strengthening of a local and regional economy. "The cities, ranging in size from between 150,000 and five million, represent one of the biggest opportunities for urbanizing economies globally" [1,6].

6.2 Rural Urban Migration in India

India has a population of 419,938 million people (2015 estimates). About 29% of the country's total population live in urban areas [19]. The country is comprised of 7935 cities, out of which 3 cities with 10 million plus population, 4 city with 5-10 million population, 43 cities with 1-5 million population, 49 cities with 500,000-1 million population and remaining cities have less than 500,000 population [1]. The Mumbai, Delhi and Kolkata are the three cities of India with 10 million plus population. Chennai, Bangalore, Hyderabad, Ahmedabad and Pune cities have a population between 5-10 million. The Ahmadabad, Chennai, Hyderabad and Kolkata are cities 1-5 million population [19].

India's urbanisation rate is greater (1.1%) than the global average (0.9%) [23]. This shows that, like other countries in Asia, India is highly urbanized. The urban population of India had grown from 329 million in 2005 to 419 million in 2015 with 31% of total population living in urban areas. However, 69% of Indian population was still living in rural areas in 2015. That means India is a country having largest rural population of 936 million by 2015 [24]. The rural population migrates to 10 million plus cities and 5-10 million cities in search of jobs. Out of total population of Mumbai and Delhi, about 45% of the population are comprised of migrants who migrated there to seek employment [24]. This rural-urban displacement has placed the urban structures under tremendous pressure. This has created significant challenges in spatial planning, administration and development in these cities. Therefore, out of 419 million inhabitants of urban India, 48.57% (203.5 million) are living in slums people living in Indian cities [24].

7. Conclusion:

Based on the above research findings, it is concluded that although JNNURM was strong example of secondary urban revitalization programme that have effectively promoted the growth of local economies and created new job opportunities. However, the limitation of the programme was that the 0.05 million population category of cities, which comprised of 54% urban population of India in 2005 (see figure 3), remained unattended.

The other drawback was that JNNURM was more focused to develop cluster secondary cities on the periphery of selected urban agglomerations. That was ultimately a remedy to solve the problems of megacities instead of strengthening the local economic development of secondary cities.

It is, however, a good attempt to accommodate the rural migrants and urban poor in those cluster secondary cities. But this trend of absorbing the excessive urban population in those cluster cities is not a feasible spatial planning strategy. In contrast, these types of national programmes can motivate the rural-urban migration. As a resultant, the overcrowding can become an unending issue in megacities. Ultimately, the national, state and local governments are bound to invest the major part of their budget on the provision of housing and infrastructure services, instead of focusing on the economic development of cities.

Some 75 per cent of the world's population lives in urban settlements of fewer than 500,000 people. "A balanced system of cities with strong secondary cities offers tremendous potential for regional and national economic development. Many poor cities and rural regions could double or even triple their GDP," [1].

Secondary cities are a vital link in the chain of system of cities, which is becoming more global and efficient. There is a need to improve the functions and linkages in the system of cities at the secondary level that must became a focus for national governments [1,2,3].

The spatial planning strategies have a key role to play in raising both national and regional prosperity and reducing prosperity gaps between cities within regions [4,7,10]

Therefore, if India want secondary cities to became more efficient like metropolitan cities, it is essential that its national government along with regional and local government should focus on spatial planning policies and programmes to support a balanced development of their system of cities.

References:

[1] B. H. Roberts, "Managing systems of secondary cities: Policy responses in international development," *Brussels: Cities Alliance: Cities without Slums*, 2014.

[2] S. Kalwar, M. M Dali and N. Hassan, "Development Framework for Agro-Based Industries in Secondary Cities of Sindh Province, Pakistan: SWOT Analysis of Ten-Year Perspective and Medium-Term Development Framework Plans", *Sustianability*, pp. 1197-1217, 2018.

[3] S. Kalwar, N. Sahito, I. A. Memon, J. Hwang, M. Y. Mangi and Z. a Lashari, "National Planning Strategies for Agro-based Industrial Development in Secondary Cities of Sindh Province, Pakistan," *Sustainability*, pp. 7066-7081, 2019.

[4] X. Chen and A. Kanna, "Secondary Cities and the Global Economy," 2012.

[5] G. Bruntland, "Our common future," *The World Commission on Environment 1 and Development*, pp. 45-65, 1987.

[6] B. H. Roberts and R. P. Hohmann, "The Systems of Secondary Cities: The neglected drivers of urbanising economies," The World Bank, 2014.

[7] L. John, "Secondary cities in South Africa: The start of a conversation," *Cape Town: South African Cities Network*, 2012.

[8] M. Brezzi, *Redefining" urban": A New Way to Measure Metropolitan Areas*. OECD, 2012.

[9] L. Song, "Southeast Asian secondary cities: frontiers of opportunity and challenges," *Community Innovators Lab*, 2013.

[10] L. Marais, E. Nel, and R. Donaldson, *Secondary cities and development*. Routledge, 2016.

[11] N. Ferguson, "Civilization: the six ways the West beat the rest," *Allen Lane Publ*, 2011.

[12] A. K. Biswas and H. Kris, "Why India's Secondary Cities Are the Future," ed.

[13] U. Habitat, "Planning sustainable cities: UN-Habitat Practices and Perspectives," *UN Habitat, Nairobi*, 2010.

[14] P. Hall and M. Tewdwr-Jones, *Urban and regional planning*. Routledge, 2019.

[15] S. Angel, *Planet of cities*. Lincoln Institute of Land Policy Cambridge, MA, 2012.

[16] A. Altaf and N. Ahmed, "Economics of Urbanization," *The Urban Gazette, July-Sep*, 2013.

[17] U. Habitat, *State of the world's cities 2012/2013: Prosperity of cities*. Routledge, 2013.

[18] J.-C. Bolay and A. Rabinovich, "Intermediate cities in Latin America risk and opportunities of coherent urban development," *Cities*, vol. 21, no. 5, pp. 407-421, 2004.

[19] P. INDIA, *Census of India 2011 Provisional Population Totals*. Office of the Registrar General and Census Commissioner New Delhi, 2011.

[20] S. Khurshid and S. Sethuraman, "In New India all roads lead to city," *Hindustan Times*, vol. 31, p. 10, 2011.

[21] X. Wang and R. vom Hofe, "Input-Output Analysis for Planning Purposes," *Research Methods in Urban and Regional Planning*, pp. 218-272, 2007.

[22] S. Khan, "The Other Jawaharlal Nehru National Urban Renewal Mission: What Does It Mean for Small Town India?," in *Subaltern urbanisation in India*: Springer, 2017, pp. 337-370.

[23] U. DeSA, "New York: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat; 2011," *World population prospects: the*, 2012.

[24] R. B. Bhagat, "Urban migration trends, challenges and opportunities in India," *World Migration Report*, 2015.

Vol. 4, No. 2 | Jul – Dec 2020

An Indoor Tracking System using iBeacon and Android

Mohammed Moneer[1] , Mahmoud Mahmoud Aljawarneh[2] , Lachman Das Dhomeja[1], Gulsher Laghari[1], Bisharat Rasool Memon[1]

Abstract:

Context-aware applications use context to provide relevant information and services to users with minimal user intervention with the system. User location is such a context for location-aware services. While in the outdoor location-aware systems Global Positioning System can provide the user location within the accuracy of 20 meters, it lacks to precisely determine user location for indoor tracking systems. Thus, different other techniques and mechanisms have been proposed for indoor tracking systems, such as trilateration, triangulation, fingerprinting, etc. However, they have added disadvantages including high cost and high-power consumption. To overcome such problems, iBeacon is a low-cost, low-power solution for such indoor tracking systems. In this paper, we explore the use of iBeacon for user tracking in an indoor user tracking system with a prototype implementation and evaluate the system on some general use cases. The prototype serves as a prelude towards the goal of developing context-aware (in particular, location-aware) applications.

Keywords: *location-aware systems; Bluetooth low energy; iBeacon; Android*

1. Introduction

Context-awareness provides the applications with the ability to adapt their services for each individual user. Thus, a context-aware application uses context to provide relevant information to users [1], [2]. As such, the user interaction with the application is minimized, and the current context of the user determines the information or service the application needs to provide to the user [3]. One such context is the user location, which is the key enabler for location-aware services [3].

While in the outdoor location-aware systems Global Positioning System (GPS) suffices to acquire the user location within the accuracy of 20 meters, it cannot precisely determine user location for indoor context-aware systems [4]. In an indoor context-aware system, to determine the users' precise location in a particular building (e.g. room, floor, etc.), the location information for such an indoor system needs to be updated regularly, which also captures and reflects the movement of users inside the building on the map. Such indoor context-aware systems provide customized indoor location-based services necessary for numerous environments. Some of these environments include universities, hospitals, airports, shopping centers, and schools, etc.

There exist various techniques for indoor tracking systems, such as trilateration, triangulation, fingerprinting, etc. Yet there is no one-size-fits-all solution that works well in every setting, due to the complexity and requirements in designing such systems [5], [6], [7], [8], [9], [10], [11], [12]. Various technologies used in developing indoor

[1] University of Sindh, Jamshoro Pakistan
[2] SZABIST, Larkana Pakistan
Corresponding Author: gulsher.laghari@usindh.edu.pk

tracking system such as Wi-Fi, ultrasound, Bluetooth, and RFID have their inherent limitations and disadvantages. Wi-Fi based systems are inexpensive yet have lower precision values. Despite being expensive, the ultrasound provides reasonable precision value. On the other hand, Bluetooth technology being inexpensive with good precision involves more power consumption. RFID based system need a user intervention in order to work.

Bluetooth Low Energy (BLE) is an enhancement in the Bluetooth standard which remarkably reduces the power consumption besides being less costly [13], [14]. BLE device with even a coin cell battery can operate for a couple of years [15]. This makes BLE ideal medical, industrial, or consumer applications that require infrequent or periodic transfers of short messages [14]. Thus, it is likely that BLE to be used by billions of smartphones in the near future [16]. iBeacon, a proximity-based framework proposed by Apple that uses BLE, allows mobile devices to approximate their location by calculating how close they are to an iBeacon— a low-cost BLE transmitter [14]. Since an iBeacon is a low-cost, low-power BLE device, many indoor tracking systems have been introduced based iBeacon technology. Such systems serve many purposes including, advertising [20], crowdsourced sensing [21], and recently enabling the social distancing in wake of COVID19 pandemic [22].

In this paper, we propose an iBeacon based indoor user tracking system and implement a proof-of-the-concept prototype. We evaluate the system on some general use cases. The prototype serves as a prelude towards the goal of developing context-aware applications.

We organize the paper as follows. In Section 2, we provide review of some related literature and then propose our approach and the proof-of-the-concept implementation of indoor user tracking system in Section 3. Then, we evaluate our prototype in Section 4. Finally, in Section 5, we provide the concluding remarks and future directions.

2. Related Work

In this section, we provide the review of the related literature on indoor tracking systems, which use different mediums.

2.1. WiFi

Jiang has proposed an indoor positioning system exploiting WiFi Received Signal Strength (RSS) in mobile phones along with the record of previously tracked locations [5]. The system improved accuracy over five percent compared to other positioning systems that used WiFi.

Similarly, Au et. al. developed an indoor tracking system with WiFi Received Signal Strength (RSS) [6]. The system obtains indoor location by providing users with wireless internet access using IEEE 802.11. They use theory of Compressive Sensing (CS) on the devices. For experimental test setup, they use windows mobile. Resultantly, the system overperformed to the existing fingerprinting methods.

WiFiPoz system uses a combination of propagation and zoning method (i.e. dividing building into geographical information zones) to position through the WiFi [7]. The fingerprint method comprises two phases (1) offline training phase that is a record of all the received signal strengths and (2) online phase that uses the result obtained from the offline phase. Experimental results showed better results compared to traditional fingerprinting algorithms with the improved accuracy of the location estimation.

The common problem with the WiFi based indoor positioning system is that the accuracy is not absolute as the attenuation with these signals is the main cause of their less accuracy, in many cases multi-WiFi access point are needed to compute the position of a specific device.

2.2. Bluetooth

Bekkelien used Bluetooth fingerprinting technique where the Bluetooth device works together as beacons to estimate the location of the mobile device [8]. The work is divided into

two phases, the first phase is offline phase where all Bluetooth devices start emitting the signals to form a map, and the second phase is used to estimate the location of that Bluetooth device based on the RSSI and the number of beacons visible to that mobile device. This method works well when the device is stationary, however, soon the device starts moving the accuracy of the results decreases drastically.

Gu and Ren performed an empirical study to elicit the impact of various factors including the distance, orientation, and obstacles on the Bluetooth signals in a setting of real-world scenarios [9]. Then built a localization model characterizing the relationship between changes of RSSI values and the target location. Pursuant to this, exploiting the user motion, they propose a scheme that can localize the target device.

The fingerprint based indoor location systems are hard to implement owing to the quality of measurement of RSSI, even devices of the same brand have varied recorded values [10].

2.3. Camera

Mulloni et. al. used camera phones to determine user location [11]. They used the camera to assist navigation and localization of the users with marker-based tracking techniques. The inherent limitation of the proposed system is that for improved detection accuracy, it requires users' training.

2.4. RFID

Seco et. al. used Received Signal Strength (RSS) of radio frequency signal coupled with Bayesian method. The gaussian processes, an observation model, is used in Bayesian method [12]. The results demonstrated that the gaussian processes enhances the positioning accuracy.

Daly modified the RFID tag with the electromagnetic and dielectric properties of the concrete [17]. The modified new passive RFID tags when embedded in concrete, could be easily read one meter above the surface.

2.5. BLE and iBeacon

Since BLE provides low-cost, low-power devices, it has been used in many contemporary indoor systems. Rida et. al. proposed an indoor positioning system using BLE and smart devices, by measuring the RSSI of the Bluetooth signals using the trilateration technique [18]. The algorithm is based on Trilateration technique that needs availability of more than two devices in a specific room to estimate the location of the device; soon the smart device enters the environment, it connects to the nearest three nodes by measuring the RSSI and determines the distance between the devices and nodes.

To increase the efficiency in the emergency room, Lin et. al. proposed a system that can monitor the patient location using the mobile application and Bluetooth low energy (BLE) [19]. They used RSSI based algorithm to determine the location, based on the signal advertised from the beacons.

Yang et. al. proposed a three-layered architecture of an indoor positioning system for hospitals-based iBeacon [13]. They used shortest distance algorithm to help patients find their department or ward.

BlueSentinel, an iBeacon-based indoor localization system, provides a prototype system for the use case of a smart home to solve the occupancy detection problem [16].

To explore the strengths and limitations of iBeacons and determine a good architectural model for context-aware applications, Sykes et. al. developed four applications for different use cases [4]. They concluded that iBeacons offer a low energy alternative with more accuracy compared to wireless access points, however, to their disadvantage signal strength is susceptible to fluctuations due to the surrounding environment hence negatively affects proximity accuracy.

In this paper, we also propose an iBeacon based indoor user tracking system and implement a prototype. The prototype serves as a prelude towards the goal of developing context-aware applications.

3. Proposed Approach

At the core of any indoor tracking system is to localize the objects. Thus, there involves the choice to choose certain sensing devices to locate the objects. In our proposed system, we choose Bluetooth Low Energy (BLE) beacons or more specifically iBeacons.

iBeacon is a technology introduced by Apple where a transmitter device, referred to as a beacon, transmits push notifications to other receiver devices using Bluetooth Low Energy (BLE) [16]. BLE standard comparatively offers low power consumption as well as lower cost for Bluetooth communication. Thus, iBeacon has been used in many contemporary systems [16], [4], [13], [14]. Essentially, iBeacon technology provides coarse-grained indoor location positioning primarily based on the proximity—the proximity to some nearby object serves as the proxy to the location. In a typical iBeacon deployment, the beacons periodically advertise the information and the app on receiving devices periodically listens for that information to know about the surrounding beacons [13]. The advertised information includes (i) Universally Unique IDentifier (UUID), which identifies the beacon region, (ii) Major value, which is used to group related beacons when they all have the same UUID, (iii) Minor value, which is used to distinguish between the beacons with same UUID and Major value [16], and (iv) the received signal strength indicator (RSSI), which is used to measure the proximity of a mobile device to a pre-installed iBeacon to approximate the location of the mobile device [14].

Using iBeacon, we propose a 3-tier architecture for the indoor tracking system. First, we propose to install iBeacons in pre-selected areas in a building (such as rooms) to monitor the location of the users in the building relative to those iBeacons. Second, to locate the users in the building we propose each user has a BLE enabled mobile device that can approximate the users' location relative to nearby iBeacons and send that information to the server. Third, we propose a server application to visualize the presence of the users in the building. Fig. 1. depicts the architecture of the proposed approach.

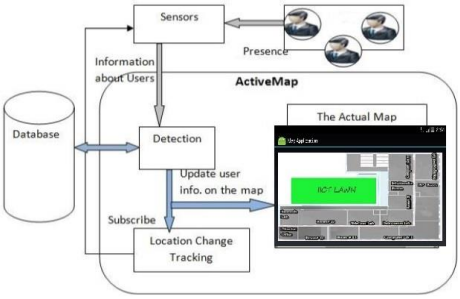


Fig. 1. Architecture of the proposed approach.

3.1. Implementation

We implement a proof-of-the-concept system to demonstrate and evaluate our approach. We deploy our system at the Institute of Information and Communication Technology (IICT), University of Sindh, Jamshoro. Below, we describe how each step is handled for our 3-tier architecture.

1. Installing the iBeacons. We install one iBeacon device in each room of the IICT building in a specific position so that it covers the room space and can precisely indicate the users' position relative to the room. Thus, each room maps to the UUID of the iBeacon.

2. Android app on the users' mobile devices. To localize the users in the building, each user is expected to carry the BLE enabled Android phone to receive the advertised information from the iBeacon to approximate their location relative to the iBeacon. Since knowing the advertised information such as the UUID of the iBeacon and RSSI alone is not helpful to monitor the users in the building, we develop an Android app that uses this information to calculate the users' location and send it to the server.

The app is developed for Android devices with Bluetooth 4.0 support and runs as a service so that it keeps running even when the mobile is locked. The app essentially performs following main tasks:

- *Monitoring the iBeacons*. This allows the app to monitor the entry and/or exit to a specific room.
- *Ranging*. The app periodically listens to the advertised information from the iBeacon and measures the distance between the mobile device and iBeacon using RSSI.
- *Send the location to the server*. During the ranging, the app has already calculated the user's location (i.e., the room where the user currently is inside) that is sent to the server via SMS.

The app starts monitoring when the user enters the building. When the mobile device reaches in range of a certain iBeacon, the app starts ranging to measure the proximity to the iBeacon. Soon this proximity distance becomes less than a set threshold, the app sends an SMS text to inform the server app about the user's location. We set the proximity distance threshold to 0.5 meter. To avoid the battery, drain, the app then stops ranging, yet it keeps monitoring.

3. Visualizing the users on the Server. To visualize the physical location of the users on the building map, we design a server app. The app consists a GUI representing architectural layout of IICT building as a map as shown in Fig. 2.

The app has an SMS listener to receive the SMS text that embodies the users' location information sent by the app running on the users' mobile devices. When the SMS listener determines that the received SMS text is from the registered user, it parses the text to extract the user location. Once the location (i.e., the room which is mapped to a specific UUID of a beacon) is extracted, the server fetches the picture of the user from the database and places it on that specific room in the map. Here the individual user is distinguished from other users based on their mobile number.

Similarly, when the users move around the building, leave a room and enter in another room, the server app updates the visual map correspondingly.

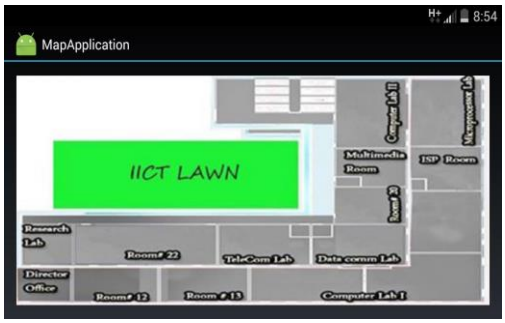


Fig. 2. Map of the IICT building on the server app.

4. Evaluation and Results

In this section, we evaluate the proof-of-the-concept system with two simple use cases to demonstrate that the proposed approach is effective.

The first use case is to demonstrate how the implemented system tackles it when a single user moves around the building. While the second use case tests the system when two users simultaneously move around the building.

4.1. Single User Scenario

In this scenario, a single user is assigned the task to first enter the research lab, then leave the research lab and enter in data communication lab, and finally leave the data communication lab and enter computer lab II. Meanwhile, the server app is monitored to check that it correctly tracks and visualizes the user activity on the map.

This whole exercise is depicted in Fig. 3. The user enters the research lab (a), which is reflected on the map on server app (b). Then, the user leaves the research lab and moves to data communication lab (c), the map on the server app is updated correspondingly; the picture of user is reflected on the data communication lab (d) and removed from the research lab (e). Finally, the user leaves data communication lab and enters computer lab II (f), which is also reflected on server app; the picture of user is placed on computer lab II (g) and removed from the data communication lab (h).

(a) User1 enters research lab (b) Reflect user1 on map (c) User1 enter to data communication lab (d) User1 enters data communication lab on map (e) User1 removed from research lab (f) User1 enters computer lab II (g) Reflect user1 in computer lab II on map (h) Remove user1 from data comm lab on map

Fig. 3. Demonstration of a single user scenario.

(a) user1 enters research lab (b) show user1 on map (c) user2 enters to computer lab II (d) reflect user2 on map (e) user1 enters to data communication lab (f) reflect on the map (g) user1 and user2 data comm lab (h) reflect the results on map

Fig 4. Demonstration of two user's scenario.

4.2. Two-user Scenario

In this scenario, the system is evaluated on whether it can track two users when they are in different rooms and when they gather in a single room. Thus, to demonstrate this, two users (user1 and user2) are assigned the task to first enter in different rooms, user1 to enter in the research lab while the user2 to enter in the computer lab II. Finally, they need to meet in the data communication lab.

Similarly, this whole exercise is depicted in Fig. 4. First, the user1 enters the research lab (a), which is reflected on server map (b) and user2 enters the computer lab II (c), which is also reflected on server map (d). Then, user1 leaves the research lab and enters the data communication lab (e), the server map is updated correspondingly (f). Finally, user2 also leaves the computer lab II and enters the data communication lab (g), which the server app correctly tracks and updates the map accordingly (h).

5. Conclusion and Future Work

In this paper, we presented an indoor user tracking system and implemented a proof-of-the-concept prototype as a prelude towards the goal of developing context-aware applications. The system uses iBeacon technology for user tracking. We evaluated the working of the system on a couple of general uses cases. It turns out that iBeacon is a good choice for indoor tracking as its inexpensive and is a low power consumption solution. However, iBeacon has also its limitations. As pointed out by Paek et. al. [14], iBeacon RSSI values and the signal propagation model have significant variations for iBeacon vendors, indoor environment, and obstacles. Thus, in future these limitations need to be addressed for specific location-aware solutions.

References

[1] A. K. Dey, "Understanding and using context." Personal and ubiquitous computing 5, no. 1 (2001): 4-7.

[2] P. Rosenberger and D. Gerhard, "Context-awareness in industrial applications: definition, classification and use case." Procedia CIRP 72 (2018): 1172-1177.

[3] E. Kaasinen, "User needs for location-aware mobile services." Personal and ubiquitous computing 7, no. 1 (2003): 70-79.

[4] E. R. Sykes, S. Pentland and S. Nardi, "Context-Aware Mobile Apps using iBeacons: Towards Smarter Interactions" (2015). Faculty Publications and Scholarship. Paper 3. [Online] Available: http://source.sheridancollege.ca/fast_appl_publ/3.

[5] L. Jiang, "A WLAN fingerprinting based indoor localization technique." M. Sc. Thesis, The graduate College at the University of Nebraska (2012).

[6] A. W. S. Au, C. Feng, S. Valaee, S. Reyes, S. Sorour, S. N. Markowitz, D. Gold, K. Gordon, and M. Eizenman. "Indoor tracking and navigation using received signal strength and compressive sensing on a mobile device." IEEE Transactions on Mobile Computing 12, no. 10 (2013): 2050-2062.

[7] Y. Xiaoyi, "WiFiPoz–an accurate indoor positioning system" MS thesis, Eastern Washington University 2012. [Online] Available: http://dc.ewu.edu/theses/81/ (accessed 20/11/2018).

[8] A. Bekkelien, "Bluetooth indoor positioning." Master's thesis, University of Geneva (2012).

[9] Y. Gu and F. Ren. "Energy-efficient indoor localization of smart hand-held devices using Bluetooth." IEEE Access 3 (2015): 1450-1461.

[10] B. Viel and M. Asplund. "Why is fingerprint-based indoor localization still so hard?" In Pervasive Computing and Communications Workshops (PERCOM Workshops), 2014 IEEE International Conference on, pp. 443-448. IEEE, 2014.

[11] A. Mulloni, D. Wagner, I. Barakonyi, and D. Schmalstieg. "Indoor positioning and navigation with camera phones." IEEE Pervasive Computing 2 (2009): 22-31.

[12] F. Seco, C. Plagemann, A. R. Jiménez, and W. Burgard. "Improving RFID-based indoor positioning accuracy using Gaussian processes." In Indoor Positioning and Indoor Navigation (IPIN), 2010 International Conference on, pp. 1-8. IEEE, 2010.

[13] J. Yang, Z. Wang, and X. Zhang. (2015), "An ibeacon-based indoor positioning systems for hospitals." International Journal of Smart Home 9, no. 7, pp. 161-168.

[14] J. Paek, J. Gil Ko, and H. Shin. "A measurement study of BLE iBeacon and geometric adjustment scheme for indoor location-based mobile applications." Mobile Information Systems 2016 (2016).

[15] C. Gomez, J. Oller, and J. Paradells, "Overview and evaluation of bluetooth low energy: An emerging low-power wireless technology." Sensors 12, no. 9 (2012): 11734-11753.

[16] G. Conte M. De Marchi, A. A. Nacci, V. Rana, and D. Sciuto, "BlueSentinel: a first approach using iBeacon for an energy efficient occupancy detection system." In BuildSys@ SenSys, 2014, pp. 11-19.

[17] D. Daly, T. Melia, and G. Baldwin. "Concrete embedded RFID for way-point positioning." In Indoor Positioning and Indoor Navigation (IPIN), 2010 International Conference on, pp. 1-10. IEEE, 2010.

[18] M. Er Rida, F. Liu, Y. Jadi, A. A. A. Algawhari, and A. Askourih. "Indoor location position based on bluetooth signal strength." In Information Science and Control Engineering (ICISCE), 2015

2nd International Conference on, pp. 769-773. IEEE, (2015).

[19] X. Y. Lin, T. W. Ho, C. C. Fang, Z. S. Yen, B. J. Yang, and F. Lai. "A mobile indoor positioning system based on iBeacon technology." In Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE, pp. 4970-4973. IEEE, (2015).

[20] Ting-Ting Yang and Hsueh-Wen Tseng. 2020. "A service-aware channel partition and selection for advertising in bluetooth low energy networks." In Proceedings of the 35th Annual ACM Symposium on Applied Computing (SAC '20). Association for Computing Machinery, New York, NY, USA, 2144–2150. DOI:https://doi.org/10.1145/3341105.3373950.

[21] L. -W. Chen, J. -X. Liu and W. -C. Huang, "GuidingAll: A Smart Proactive iBeacon System with Crowdsourced Sensing Based on IoT Technologies," 2020 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops), Austin, TX, USA, 2020, pp. 1-3, doi: 10.1109/PerComWorkshops48775.2020.9156090.

[22] K. R. Tiwari, I. Singhal and A. Mittal, "Smart Social Distancing Solution Using Bluetooth® Low Energy," *2020 5th International Conference on Computing, Communication and Security (ICCCS)*, Patna, 2020, pp. 1-5, doi: 10.1109/ICCCS49678.2020.9277175.

0.7” Margin Top

Paper Formatting Guidelines

Title: 14pts Bold

Author Name: 11pts Bold

Affiliation: 11pts Italic

Abstract: Single Paragraph (Min: 150 – Max: 250 words)

Paper Length: Formatted as guided (Min: 4,000 – Max: 8,000 words)

Font: Times New Roman 10pts

Font Color: Black

Line Spacing: 1.0 (single line space throughout the paper)

Indentation: Justify

References & In-text Citations: Follow the IEEE & Use EndNote X7 for In-text citations and Bibliography.

Headings: 12pts Bold

1. **12pts Bold**
   1.1. **11pts Bold**
      1.1.1. ***11pts Bold Italic***

Margin Left **0.8”**

Margin Right **0.5”**

6.5”x10”

Page Size: 6.5” (Width) x 10” (Height)

Submission: Formatted paper as guided can be submitted through our online submission system at http://sjcms.iba-suk.edu.pk

1.9” Margin Bottom

Sukkur IBA Journal of Computing and Mathematical Sciences

SUKKUR IBA UNIVERSITY
Merit - Quality - Excellence

SUKKUR IBA UNIVERSITY
Airport Road, Sukkur -65200
Sindh, Pakistan
Tel: +92-71-5644233
Fax: +9271-5804419
Email: sjcms@iba-suk.edu.pk
URL: sjcms.iba-suk.edu.pk

HEC Recognized Journal