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Voice Assisted Key-In Building Quantities Estimation System

Oludolapo Ibrahim Olanrewaju[1], Malindu Sandanayake[2], and Sunday Ajiboye Babarinde[3]

[1]Senior Researcher, Dollahills Research Lab, Dollasoft Technologies, Lagos, Nigeria. E-mail: oludolapoolanrewaju2012@gmail.com (corresponding author).

[2]Lecturer, College of Engineering and Science, Victoria University, Melbourne, Australia. E-mail: Malindu.Sandanayake@vu.edu.au

[3]Researcher I, Dollahills Research Lab, Dollasoft Technologies, Lagos, Nigeria. E-mail: spenpe196@gmail.com

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Abstract: Voice recognition technology has been in existence over several decades but its application in the construction industry has been minimal. Despite the several advantages it offers, its application has been limited to smart building integration only. This study has made a significant contribution by integrating voice recognition technology into key-in building quantities estimation software. The Visual Basic programming language was used to design and code the interface of the voice recognition system and key-in estimating software model. The prototype model continues to have some challenges because it cannot work efficiently in a noisy work environment and there is limited range of vocabulary it can recognize. This paper seeks to challenge the stakeholders of the construction industry to maximize the benefits of voice recognition technology and integrate it into other construction tasks. In addition, future research can consider integrating building information modeling and voice recognition technology.

Keywords: Voice recognition, bill of quantities, estimating, software.

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1. Introduction

The construction industry is forecasted as one of the major growth contributors in a nation's economic growth yielding as much as a 5% increase in GDP growth. Other sectors of the economy like education, health, transportation and the likes have heavy dependencies on the construction industry. Furthermore, the construction industry can be sectioned into three essential components which are the building industry, heavy and civil engineering works and specialist contractors who engage in the services of carpentry, plumbing, electrician, tiling and painting (Sanusi, 2008; Olanrewaju, 2017; Olanrewaju et al., 2018).

The construction industry has in recent time received heavy criticism due to the sluggish pace of implementation of embryonic technologies, recently this trend has been evolving. Increased need for tools that will utilize the available technologies in a bid to increase the output and cost efficiency of project management processes (O'Connor and Yang, 2004; Chitrakala, 2010). Engineering supervisors these days are confronted with the responsibility of proficiently and meritoriously organizing manifold workflows for the achievement of a task. In most cases in the construction sector, information technology (IT) is utilized in the simplification of communications, interactions and in the reduction of organization costs between sub-tasks and participants on projects.

Nowadays, mobile technological innovations are being succinctly integrated into knowledge work to provide simplification in communication and coordination (Greenwald, 2014; Uddin et al., 2015). Development and utilization of specialized software is a potential tool that can assist quantity surveyors and other construction professionals to produce bills of quantities and estimate building quantities accurately (Olatunji et al., 2010). Therefore, it is imperative for the quantity surveyors to adopt IT to the fullest. For instance, the integration of voice recognition technology into building quantities estimation software would help construction professionals limit full concentration on computer screens. Many programs are used for building quantity estimation some of which are; Manual data input programs, Automated quantity extraction programs, and Integrative quantity data extraction and exchange management programs (Chitrakala, 2010). Most quantity surveying software packages have not embraced the concept of the voice recognition system.

Further, the integration of voice recognition technology has enhanced the efficiency of workflows and has resulted in reduced transcription holdups and costs, hence being a major contributor to improved turnaround time in surgical pathology (Henricks, Roumina, Skilton, Ozan, and Goss, 2002). Additionally, it was revealed by Alapetite (2008), that the traditional interfaces of keyboard and touch-screen have imposed a progressively increasing mental workload on the users. In obvious disparity with the traditional interface medias, speech/voice input interface allows anaesthesiologists to input medications and observations almost simultaneously in the existing IT-based database. For scenarios with stringent time restraints, speech/voice input reduced the mental workload often accompanied by the memorization of events to be registered, this provided reduced time delays between event occurrence and event registration. Nevertheless, existing speech/voice recognition technology and speech/voice interfaces require the adequate training to ensure effective utilization (Uddin, et al., 2015). Implementation of voice recognition has been functional in different facets of life such as; nurse dictation (Carter-Wesley, 2009), healthcare services (Lee et al., 2003; Stanford, 2003; Rana et al., 2005; Uddin et al., 2015), language education (Yalçin and Altun, 2013), teaching disabled persons (Seng Yue and Mat Zin, 2013), smart home (Rao et al., 2016; Ali et al., 2017), field data collection (Becker, 2016), speech therapy tool (Tan et al., 2007), prosthetic hand (Asyali et al., 2011), wheelchair system (Malik et al., 2017), and security systems (Shah et al., 2014). Table 1 shows a summary of the reviewed applications of voice recognition technology.

Table 1. Voice recognition technology applications and sources

Application	Source
Nurse dictation	Carter-Wesley (2009)
Healthcare services	Lee *et al*. (2003); Stanford (2003); Rana *et al*. (2005); Uddin *et al*. (2015)
Language education	Yalçin and Altun (2013)
Teaching disabled persons	Seng Yue and Mat Zin (2013)
Smart home	Rao *et al*. (2016); Ali *et al*. (2017)
Field data collection	Becker (2016)
Speech therapy tool	Tan *et al*. (2007)
Prosthetic hand	Asyali *et al*. (2011)
Wheelchair system	Malik *et al*. (2017)
Security systems	Shah *et al*. (2014); Adekola *et al*. (2019)

Despite various benefits that could be derived from the application of voice recognition technology, it is rarely used in the estimation of building quantities. Owing to the complexity of construction projects these days, a large amount of time is spent in the bill preparation process (Olanrewaju, 2016). This consequently results in long concentration time on computer screens which contributes to computer induced health dangers. However, the incorporation of a speech recognition system will aid the flexibility of building quantities estimation software packages and prevent or reduce some computer-induced health dangers. This paper therefore, aimed at filling this gap by developing a model that integrates voice recognition technology into key-in building quantities estimation software. The paper provides answers to the following research questions:

- Can voice recognition be integrated into building quantities estimation software?
- Is training important while using voice recognition technology?

2. Speech/Voice Recognition

The history of speech recognition can be traced back to an article by Davis et al. (1952), where the researchers recognized spoken telephone quality digits at normal speech rates by a single individual who had an accuracy varying from 97 and 99 percent precision. Since then speech recognition has been discussed further by different researchers leading to the proliferation of the speech recognition concept, hence making speech recognizers develop to become more efficient and accurate in variance to the early history of software speech recognizers where the computing power and algorithms were not good enough to give satisfying results.

In recent times, algorithms are being run in a parallel and sequential method in a bid to provide better results. Furthermore, the corporation has developed over the years to become more and more all-embracing (Baker et al. 2009). Following the introduction of smartphones, it has been made easier to capture the speech of the user in the phone and offload such speech recognition to cloud data centres. This has made speech recognition available to users anywhere they are as long as they are connected to the internet. Barra (2012), stated that speech recognition is also available offline with minor losses of accuracy in the recognition capabilities.

On 4th October, 2011, Apple Inc. included an intelligent personal assistant application named “Siri” coming with the release of IOS5, a little period thereafter Google Inc. launched an equivalent on the Android OS called “Google Now” both working on speech recognition abilities on smartphones. The introduction of these tools has made speech recognition available to the general public. The availability and usage of voice recognition technology have advanced significantly steadily maturing in recent times, hence the potentials of its application for healthcare purposes as well is fast expanding as stated by Zhao (2009).

Voice recognition is a concept that involves the process of creating texts from speech or voice using the software. O’Shaughnessy (2013), articulated that the voice recognition system carries out functions ranging from recording, processing and comparison of the analysed speech patterns with a collection of probable words and finally, production of the written text format. Subsequent to the increment in the access to speech recognition on mobile devices, it ceases to be a new concept with daily increases in its usage and application to human activities.

Today, there exists flexibility in the systems which allows for its application is not just the user-dependent domains but also for independent domains. User independent systems can be employed by all users without requiring special skill or training on the system for each individual user, while user-dependent systems require personalized training for individual speech patterns so as to follow the pattern of speech for each of its users (Durling and Lumsden, 2008).

Progressions in computing power have provided the current systems with the ability to process large amounts of speech data, hence ensuring a higher level of precision in recent speech recognition systems (Zhao, 2009). Additionally, Pentland and Choudhury (2000), opined that voice recognition has hitched a natural place in the next generation of "smart" environments and possess great potential for widespread application. Nevertheless, there exists challenges ranging from differences in speech styles, speech rates and voice characteristics (Furui, 2005).

The application of speech recognition has great potentials of redefining and simplifying the method of execution of the majority of management tasks. For example, the healthcare sector generates a large amount of text and documentation, which oftentimes requires swift access (Al-Aynati and Chorneyko, 2003). The traditional Healthcare documentation technique and its several handwritten records are time-consuming and also dictated records come with the attendant expenses of transcription services. Voice recognition is devoid of all these problems as it provides spontaneous transference of spoken words into text directly (Korn, 1998). The utilization of voice recognition systems in the healthcare sector enables the physician to dictate, edit and create electronic reports instantly; these created reports can readily be made available to other physicians immediately and can be added to the patients' records. This will ensure that the procedure requires reduced time consumption, resulting in the provision of improved service delivery at a reduced price.

3. Research Methods

Research methodology is the philosophical procedure of research that involves assumptions and values which importantly sets a standard for every person carrying out a study need to properly make use of in achieving a good outcome (Morenikeji, 2006; Olanrewaju, 2017). The main focus of this research is to establish a model that aids the key-in of building dimensions using voice recognition technology. This integrated approach of voice-assisted key-in building quantities estimation system combines three different domain areas which include: voice recognition, information technology, and building quantities estimation procedure.

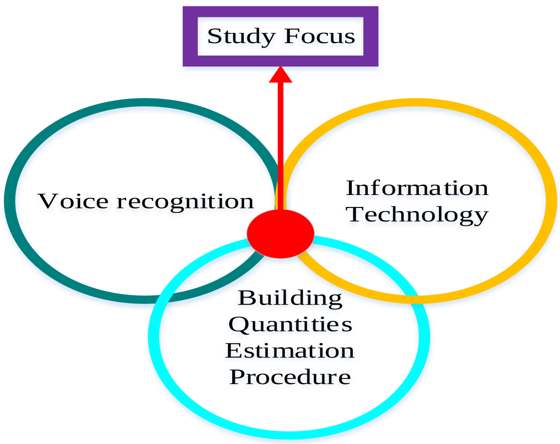

Fig. 1. Research domain areas

As indicated in Fig. 2, this research is divided into three distinct stages namely; problem identification and literature review, prototype development, and testing. The first stage includes an extensive literature review which was carried out to establish the current state of speech voice recognition applications and identify the problem to be solved. The second stage deals with programming infrastructure and the algorithm is coding. The Visual Basic programming language was used in conjunction with Google Speech Application Programming Interface (API) to design the prototype. The third stage is where the prototype is tested. The algorithm was tested using twenty–five (25) built environment professionals which consist of Quantity surveyors, Architects, Engineers, and Builders. At first, the participants were trained before using them to test the prototype. Their accuracy during training and testing was measured which was then subjected to further analysis. The formula below used to calculate the accuracy:

$$Accuracy = \frac{Correctly\ recognized\ words}{Total\ number\ of\ words} \times 100\% \qquad (1)$$

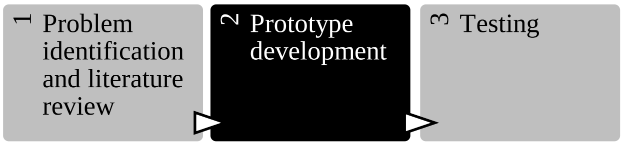

Fig. 2. Research stages

The data collected from the testing stage were analyzed using both descriptive and inferential statistics. The descriptive statistics consist of the usage of tables and charts to present data while inferential statistics include the use of independent-samples T-test. An independent-samples t-test was adopted in order to compare training and testing accuracy. The outcome of the test would indicate if there is a significant differential in the statistical mean scores between the groups (Pallant, 2013). There exist substantial modifications if the mean scores on the dependent variable for each of the two groups in the Sig. (2-tailed) column is equal or less than .05 (e.g. .03, .01, .001). Otherwise, no significant differences exist between the two groups if the value is above .05 (Pallant, 2013).

3.1. Software Prototype Architecture

This software prototype is based on modular software architecture. The software was designed with Visual Basic .NET using Visual Studio. The software requires Microsoft Office because documents associated with this software are created as Excel documents. Also, it requires Microsoft Net Framework (4.5 and above) and DotNetbar Framework (11.0 and above) for effective interface functioning. As shown in Fig. 3, the prototype has two major modules (interaction and task). Each module is independent of the others and has a corresponding function in conjunction with the project. The interaction module has five keywords while the task module has fourteen keywords. The keywords for the modules are incorporated into the speech database. When the user issues voice command to the computer it tries to link it to the database and performs the function based on the keywords. Fig. 4 and 5 shows the user interface of the software designed.

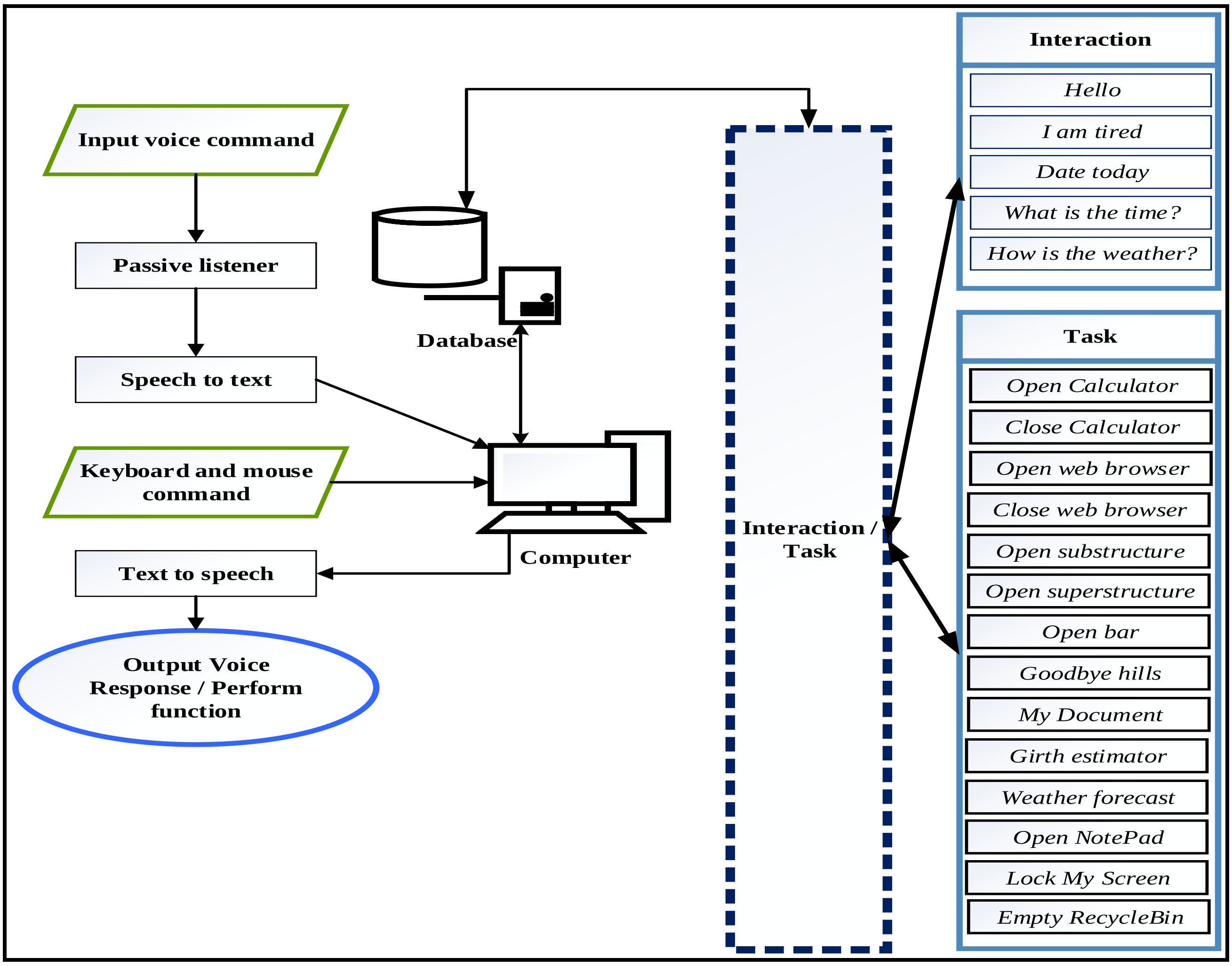

Fig. 3. System architecture

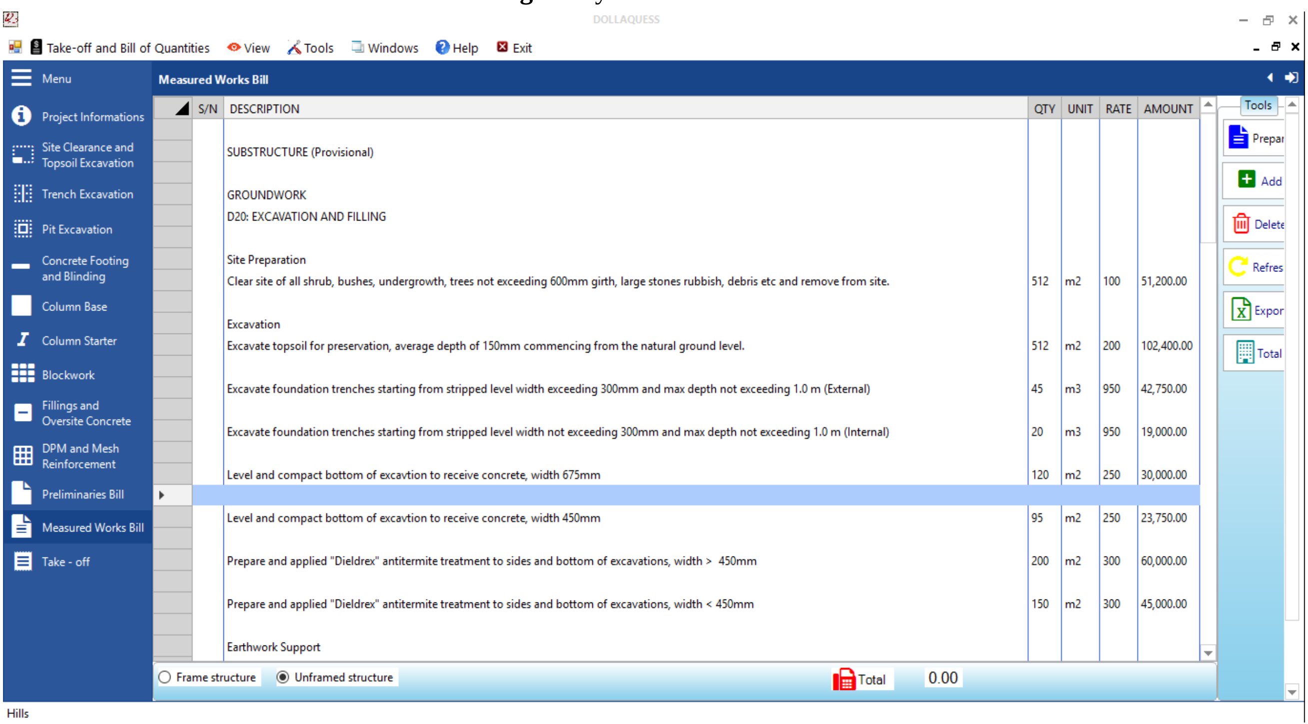

Fig. 4. Bill of quantities user interface

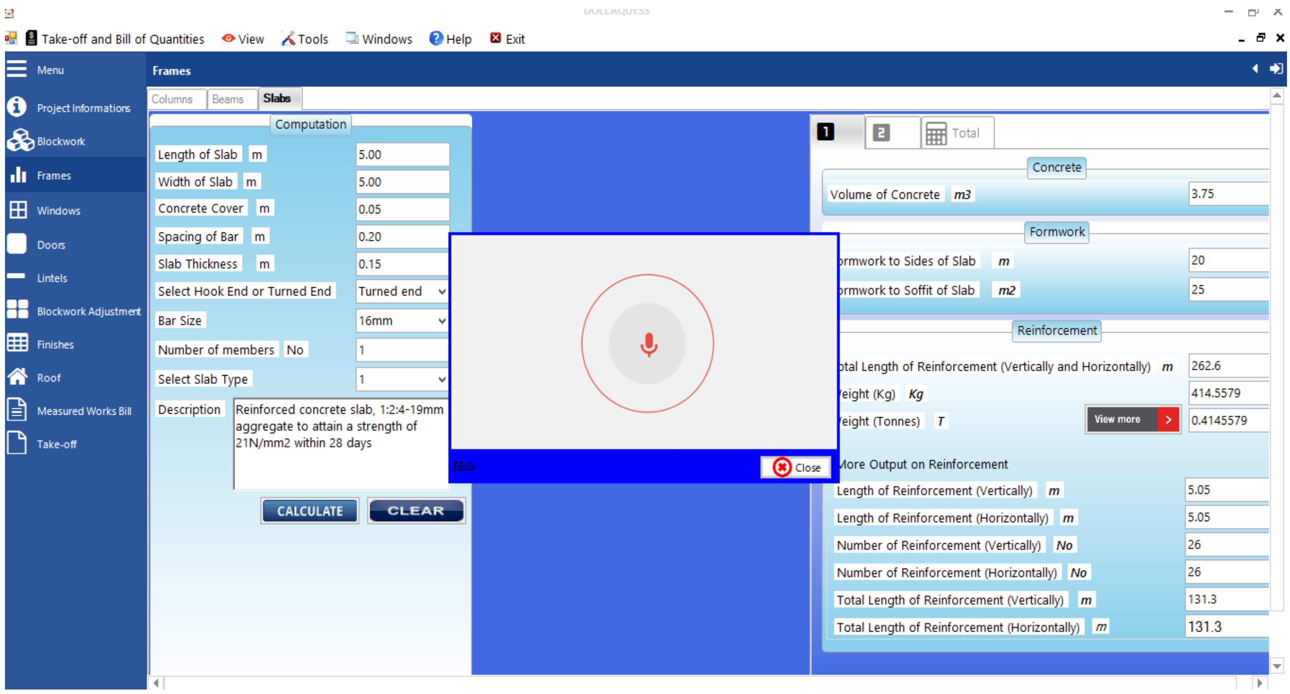

Fig. 5. Frame element and voice recognition interface

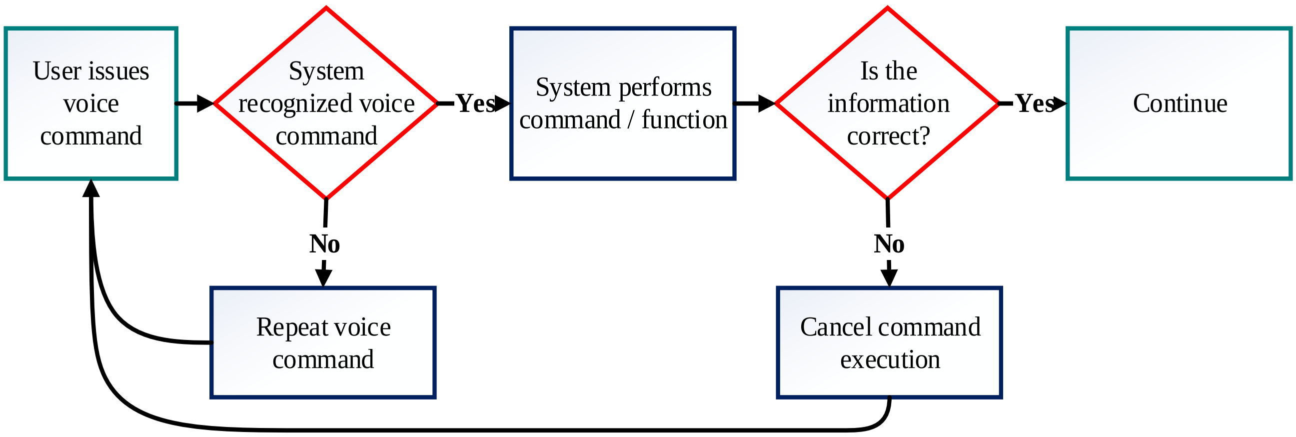

Fig. 6. The system processing a single command

3.2. Voice Recognition Algorithm Operation

Meanwhile, the users of the systems should not feel necessitated to look at the screen when working with this interface, audio feedback becomes the primary way of communicating information. The system is always listening and command detection is activated when the voice recognition interface is up. This impedes the system from trying to construe everything it hears when the voice command is not in use as the user can easily close the interface. The user can also use the keyword “Goodbye hills” to close the voice recognition interface. When the application detects the keywords, the system performs the task allocated to that keyword. Fig. 6 shows the process of the system executing a command while Table 1 shows the prototype module keywords and their functions.

4. Analysis and Discussion of Results

4.1. Descriptive Analysis of Data

Table 2 shows the descriptive analysis of data from the twenty–five selected built environment professionals which consist of Quantity surveyors (N = 9), Architects (N = 5), Engineers (N = 6), and Builders (N = 5). Quantity surveyors have the highest frequency because they are the main users of quantity estimation software packages. Also, the mean age of the professionals is 30 years and it ranged between 21 and 47 years. This is an indicator that the respondents are experienced to provide meaningful statistics for this research.

For training, the mean percentage of accuracy was 60.08% and it ranges between 25.00% and 94.00% with standard deviation and standard error of 17.50% and 3.50% respectively. Engineers have the highest accuracy percentage of 65.00%, followed by Architects (63.80%) and Quantity surveyors (58.00%). Builders have the least accuracy percentage of 54.20%.

For testing, the mean percentage of accuracy was 63.96% and it ranges between 27.00% and 96.00% with standard deviation and standard error of 17.40% and 3.48% respectively. Based on the mean accuracy of the participants, the voice recognition algorithm performs well above average with mean accuracy above 50%. Engineers have the highest accuracy percentage of 69.17%, followed by Architects (67.20%) and Quantity surveyors (61.89%). Builders have the least accuracy percentage of 58.20%.

Table 1. Module keywords and function

Keywords	Function
Interaction Module	
Hello	You get "Hello! How are you?"
I am tired	You get "Don't be tired! nothing good comes easy"
Date today	It tells you the date based on your computer time
What is the time?	It tells you the time based on your computer time
How is the weather?	It opens the web browser and navigates to google weather forecast
Task Module	
Open Calculator	It opens the calculator interface for the user
Close Calculator	It closes the calculator interface for the user
Open web browser	It opens the web browser interface of the software
Close web browser	It closes the web browser interface of the software
Open substructure	It opens the interface for building substructure quantities estimation
Open superstructure	It opens the interface for building superstructure quantities estimation
Open bar	It opens the interface for preparation of bar bending schedule
Goodbye hills	To close voice recognition interface
My Document	It opens the document section of file explorer
Girth estimator	It opens the girth estimator interface
Weather forecast	It opens a web browser and navigates to:https://www.google.com/webhp?sourceid=chrome-instant&ion=1&ie=UTF-8#output=search&sclient=psy-ab&q=weather&oq=&gs_l=&pbx=1&bav=on.2,or.r_cp.r_qf.&bvm=bv.47008514,d.eWU&fp=6c7f8a5fed4db490&biw=1366&bih=643&ion=1&pf=p&pdl=300
Open NotePad	It opens the notepad on your system
Lock My Screen	It locks the computer screen
Empty RecycleBin	It clears the recycle bin

On average, the mean percentage of accuracy was 62.02% and it ranges between 26.00% and 95.00% with standard deviation and standard error of 17.43% and 3.49% respectively. Engineers have the highest accuracy percentage of 67.08%, followed by Architects (65.50%) and Quantity surveyors (59.94%). Builders have the least accuracy percentage of 56.20%. This connotes that principal construction professionals are duly represented in this study with Engineers, Architects, and Quantity Surveyors being among the top three. Engineers perform best in using voice recognition for building quantities estimation whereas the innovation is more useful to Quantity Surveyors which will facilitate the rapid preparation of bills of quantities. Overall, this indicates that Engineers have a great tendency to adopt voice recognition technology due to their vastness and willingness to embrace emerging technologies. These findings corroborate with the findings of Olatunji et al. (2010) where it was said that Quantity Surveyors are usually slow in the adoption of new technologies.

4.2. Inferential Statistics

Table 3 shows the results of the T-test conducted on training and testing the accuracy of the algorithm. Two pair samples t-test was conducted to compare the accuracy of the voice recognition algorithm during training and testing stage. The analysis revealed that there is a significant difference between training and testing the accuracy of the algorithm. The magnitude of the differences in the means (mean difference = -3.880, 95% CI: -4.550 to -3.210) was large. This connotes that construction professional's performance in using voice recognition technology will improve rapidly if trained with voice technology. Conclusively, it can be said that proper training is central to the efficient performance of the voice recognition system during usage for building quantities estimation system. The research of Revathi et al. (2009) also indicated that there is a significant change in accuracy between training and testing stage.

5. Conclusions and Recommendations

This study identified different applications of voice recognition technology in different industries of an economy. It made a noteworthy contribution by integrating voice recognition technology into building quantities estimation software. The innovation will be of great benefit to construction professionals. Nevertheless, the algorithm still has some limitations. For instance, it cannot work efficiently in a noisy environment. Also, there is limited range of words the algorithm can recognize. The research revealed that Engineers are fast in the adoption of emerging technologies in the construction industry. The research also demonstrated the importance of training while using voice recognition technology as there were improvements in the participants' accuracy after training.

The study has implications for the future of building quantities estimation software, mainly on the acceptance of voice recognition technology. Employing technology fully could be more profitable for professionals as it reduces building quantities estimation time significantly. The technology is also essential to create an enabling environment for construction professionals and computers to interact. The innovation might stress users if used for complex projects, hence it is suitable for simple projects. Owing to the time used to key-in project dimensions during quantity take-off, voice recognition could reduce the amount of time the professional used in concentrating on computer screens which exposes them to computer-induced health dangers. With the effective integration of voice recognition technology with building information modeling (BIM), the time can be further reduced drastically.

This paper, therefore, recommends the following:

- Construction industry stakeholders should embrace the concept of voice technology.

- Construction professional bodies should team-up to educate members on the potentials of voice recognition technology.
- Government should fund research to explore the potentials that could be derived by the construction industry from voice recognition.

6. Study Limitations and Areas for Future Research

Although this research has revealed a pathway for future research on voice recognition technology applications, its design is not without shortcomings. Based on the limitation of not being able to use a large number of participants for training and testing. Also, the Visual Basic programming language was used for the coding aspect of the prototype. The acceptance of voice recognition technology by construction professionals was not determined in this study.

Future research may consider using a large number of participants to test the prototype. Also, more trending programming languages like Phyton, C#, F#, etc. should be used to enhance the user's experience. Future research can improve this innovation by introducing more languages and systematically improve the voice recognition algorithm to adapt to the noisy work environment. A study can also be conducted to determine the acceptance of voice recognition technology by construction professionals. Additionally, voice recognition technology can also be integrated with Building Information Modeling (BIM).

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Table 2. Descriptive Analysis of Data

Variables		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Age	Quantity Surveyor	9	30.56	8.31	2.77	24.17	36.94	24.00	47.00
	Architect	5	29.80	6.38	2.85	21.88	37.72	21.00	38.00
	Engineer	6	28.17	6.68	2.73	21.16	35.17	22.00	40.00
	Builder	5	30.80	8.79	3.93	19.89	41.71	21.00	41.00
	Total	**25**	**29.88**	**7.28**	**1.46**	**26.87**	**32.89**	**21.00**	**47.00**
Training Accuracy	Quantity Surveyor	9	58.00	10.81	3.60	49.69	66.31	42.00	81.00
	Architect	5	63.80	18.91	8.46	40.32	87.28	48.00	89.00
	Engineer	6	65.00	27.36	11.17	36.28	93.72	25.00	94.00
	Builder	5	54.20	14.27	6.38	36.48	71.92	36.00	75.00
	Total	**25**	**60.08**	**17.50**	**3.50**	**52.86**	**67.30**	**25.00**	**94.00**
Testing Accuracy	Quantity Surveyor	9	61.89	10.64	3.55	53.71	70.06	47.00	85.00
	Architect	5	67.20	18.58	8.31	44.13	90.27	52.00	92.00
	Engineer	6	69.17	27.48	11.22	40.33	98.00	27.00	96.00
	Builder	5	58.20	14.01	6.26	40.81	75.59	39.00	78.00
	Total	**25**	**63.96**	**17.40**	**3.48**	**56.78**	**71.14**	**27.00**	**96.00**
Overall Average Accuracy	Quantity Surveyor	9	59.94	10.67	3.56	51.74	68.15	44.50	83.00
	Architect	5	65.50	18.74	8.38	42.23	88.77	50.00	90.50
	Engineer	6	67.08	27.41	11.19	38.32	95.84	26.00	95.00
	Builder	5	56.20	14.12	6.32	38.66	73.74	37.50	76.50
	Total	**25**	**62.02**	**17.43**	**3.49**	**54.83**	**69.21**	**26.00**	**95.00**

Table 3. T-test on Training and Testing Accuracy

Variables	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Training Accuracy - Testing Accuracy	-3.880	1.620	0.320	-4.550	-3.210	-12.010	24	.000

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Oludolapo Ibrahim Olanrewaju is a young multitalented quantity surveyor, researcher and programmer. He attended the Federal University of Technology, Minna where he studied Bachelor of Technology in Quantity surveying and graduated in 2017. He graduated with a First Class and emerged as the best graduating student in the department of quantity surveying for the 2017 set. Oludolapo has a strong passion for ICT and he has been involved in a series of software projects like DOLLAQUESS (Quantity surveying software he

designed), decision support systems, inventory manager and others. He works with Dollasoft Technologies as a Freelance Software Developer, Data analyst and Researcher and Arbico Plc as a Graduate Trainee (Estimator). His research interests are on environmental health, green buildings, sustainability, building information modelling, knowledge management, conflict management, construction informatics, construction health and safety (H&S), construction management, construction emissions, etc. Oludolapo can be contacted on oludolapoolanrewaju2012@gmail.com.

Dr. Malindu Sandanayake is a lecturer in the Department of Building in the College of Engineering and Science. He completed his Ph.D. in construction management at RMIT University, Melbourne, Australia in 2016, following his Bachelor of Engineering (First Class with Distinction). Malindu is a certified professional engineer at the Institution of Engineers Australia. Prior to joining Victoria University, he worked as a post-doctoral research fellow at RMIT University. During this time, he delivered undergraduate and postgraduate units in construction management, risk and project management and AutoCAD for civil engineers. Currently, he is undertaking teaching responsibilities in the construction management field. His primary research interests include, but are not limited to, green buildings, Building Information Modelling (BIM), Life Cycle Assessment (LCA), construction management, the sustainable built environment and carbon-neutral construction. Dr. Sandanayake has published a number of Q1 journal papers and technical papers. He is also currently a visiting research fellow at RMIT University. Malindu can be contacted on Malindu.Sandanayake@vu.edu.au.

Sunday Ajiboye Babarinde is a resourceful Quantity surveyor and researcher. He attended Federal University of Technology, Minna where he studied Bachelor of Technology in Quantity surveying and graduated in 2017. His research interests are on building information modelling, risk management, lean construction, and IT applications to construction. Sunday can be contacted on spenpe196@gmail.com.