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Speech-to-Text Hybrid English to Yoruba SMS Translator

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ABSTRACT The necessity for quick translation from English to regional languages, such as Yoruba language arises from the fact that it is imperative for the widespread dissemination of knowledge and information. A speech-to-text enabled translation on Android devices and text-to-speech synthesizer (TTS) capable to deliver real-time translation of Yoruba language is presented. It increases the naturalness of oral communications, eases the communication, and furthers the understanding and use of Yoruba language among people of different backgrounds. This speech-to-text enabled translation system uses NLP on one hand and a TTS interpretation technique on the other. It uses an Android Google translation API synthesizer and a recognizer for English and Yoruba translation. The current study attempted to develop an English to Yoruba SMS translator with built-in text-to-speech and speech-to-text features. The Android Studio Integrated Development Environment was used to create the system (IDE). Whereas, a statistical machine translation algorithm was adopted for the implementation of Google API translation for English speech to text, TTS conversions, and Yoruba translations. About 100 computational rules were formulated for the Yoruba voice translation process. For the translation processes, a questionnaire was also created and circulated to 350 people. Approximately, 96% of those who responded provided input. The responses were subjected to SPSS statistical analysis. The results suggested that the translation system has a 92% accuracy which is comparable to that of a human (expert).

INDEX TERMS Google translator, machine translation, natural language processing, speech synthesizer, translation, Yoruba language

I. INTRODUCTION

Any means or technique of communication can be referred to as a language. From the waving of hands to the wink of an eye, to spoken words, and so on can be considered as a language. A language is a notation or structured means used by a particular person, community, state, or country for effective communication [1]–[3]. It is a system of conventionally spoken signs or symbols through which people express themselves and communicate successfully within a culture [4], [5]. There are three (3) major common languages spoken by the people of Nigeria, for instance Hausa, Igbo, and Yoruba with the other sub-languages taking from these 3 major ones. English, which is now considered as a global lingua franca, is a West Germanic language and dates back to the early Middle Ages. Regardless of which country's language one is fortunate enough to be fluent in, English is one of the world's most widely used modes of communication, with over 2 billion people worldwide influenced by it [6]–[8].

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The Yoruba language is the language of Yoruba people who are predominantly settled in the Southwestern part of Nigeria and is one of the three major languages amid Nigerians' four hundred languages [6], [9]–[11]. Yorùbá is a Western African language spoken by around 50 million people [12]–[14]. It is a member of the Niger-Congo language family and is spoken in Nigeria, Togo, Benin, and parts of Brazil, Ghana, Sierra Leone (where it is known as Oku), and Cuba among other places (where it is referred to as Nago). The indigenous languages of Nigeria have struggled for their survival against the English language as it is the means of formal communication due to the widespread use of the Internet [15]. The widespread usage of mobile devices, which are frequently linked with paper instruments in English, adds to the rivalry [9]. The Internet provides many valuable documents in English that are not usable for most Yoruba speakers since they do not understand English language [8]. For these valuable online documents to be available locally, the translation of these documents to Yoruba is therefore, needed [8]. In reality, the world has become a global village and there is a need for rapid translation from English to local languages, such as Yoruba [8]. The global, political, technical, and cultural relationships between individuals, societies, enterprises, and governments around the world are also increasing rapidly [16]. It is also worth noting that the main problem of communication is language bias between communicators due to different translations and interpretations [17].

Translation is the process of understanding the meaning of a text and then producing an equivalent text in another language that expresses the same message [18], [19]. The source language is referred to as the source text, whilst the target language is referred to as the target language (target text). A correct translation, which may be very difficult due to cultural and gesture differences, is performed by human beings or programs most of the times called as 'language translators' [8], [20]. Natural Language Processing (NLP) is a field that allows machines to read and understand human languages [10]. It is a modern method of translation through which computer assistance is provided to bail the indigenous languages in the country out from extinction [14], [21]. Machine translation can be approached in three different ways. When machine translation employs a method based on linguistic rules, words are translated in a linguistic style, with the most relevant terms from the target language replacing those from the source language, this is called the 'rule-based method'. The second one is known as the statistical model which generates translations using statistical models whose parameters are determined from the analysis of bilingual text corpora. While the third one, known as the hybrid approach, combines the strengths of statistical and rule-based approaches [22]–[25] although, the power of Neural Machine Translation (NMT) and deep learning has emerged as the most powerful algorithm to perform these tasks lately. However, it is now widely accepted that the development of fully automatic and high-quality machine translation systems is a very difficult problem that needs special attention [24], [26]. Automatic or machine translation is perhaps one of the most challenging Artificial Intelligence (AI) tasks given the rate at which several human languages are freely flowing [26]. Multilingual translation has become increasingly significant as a result of globalization, trend, and knowledge boost in the second millennium [14].

Numerous authors have contributed to machine translation research and have also developed various types of translation systems in various languages to include Yoruba translators [8]. The most previous and current Machine Technology (MT) has been developed for web-based systems. This technology can be quite helpful to extract some of the keywords and phrases from one language to another, making it difficult for the level of their translation transparency to be properly measured as they may contain several errors. Additionally, there is a need for the development of translation systems that address the semantic gap in most Yoruba translation systems [8], [14]. This has made the researchers to advocate the improved MT applications that are likely to improve basic MT performance, automatically extracting meanings, and performing summarization [27], [28]. It is against this background that the current study presented the development of an Android-based English to Yoruba SMS translator with an integrated TTS and speech-to-text functionality. The translator is implemented by hybridizing the statistical application approach for the implementation of the Google API translator and the Rule-based method that was used for the design and implementation of the local Yoruba voice database.

The current study is based on six sections. The related works on Yoruba to English language translation systems have been presented in Section 2. Sections 3 and 4 present the technique and testing with a description of outcomes. Section 5 contains the conclusion, while section 6 discusses the study's shortcomings and future problems.

II. LITERATURE REVIEW

This section provides an overview of some selected works reported in literature in the last fifteen (15) years.

Author in [29] presented the sociolinguistic research conducted on SMS text messages in Yoruba language by advocating the interconnectedness in other tongues. The study looked into interconnection in different tongues as a sociolinguistic phenomenon since communication is the most symbolic function of every language. The Yoruba language is the primary language spoken here with English as the secondary language. The study provided compelling case studies and analysis with a critical perspective that are useful to get deeper insights into why interconnection as a linguistic reality is an unavoidable ornament in the process of language learning's beautifying. Author in [30] proposed a method to construct Yoruba text message forms and functions in Nigeria. The implications of SMS are used for communication purposes, English teaching and learning, interpersonal relationships, and indigenous language development. The report focused on issues and developments in using SMS text messages in Nigeria. In Nigeria, as in the rest of the globe, SMS messaging is gaining popularity as a means of communication.

Authors in [14] reported the development of a doctor-patient mobile chat application for Yoruba speakers. Mobile application is rapidly gaining popularity since it provides a diverse set of capabilities for long-distance communication which is the foundation for its widespread acceptance. The project uses JAVA's mobile programming technology to construct and simulate an instant message exchanger and language mapping that enables the patients to connect with doctors and acquire healthcare services. A working model was constructed for a mobile chat application using a mobile client terminal, the Internet, and a server among other components. JAVA 2 Micro Edition (J2ME) and JAVA 2 Enterprise Edition (J2EE) were used to replicate the model (J2EE). The method is useful in providing healthcare services to semiliterate (those who cannot speak in the official language) in a rural setting without requiring personal interaction with doctors. For nationwide use of this approach, ethical and legal procedures are being worked out. Authors in [27] worked on a multilingual chat system for English-to-Russia translation. The system's goal was to assess the intelligibility and accuracy of real-time chat messages that were automatically translated by translation bots installed in Google Talk. According to the findings, Google Translate (a free service) is an effective tool for translating instant messaging between Yoruba and English. Recent advances in machine translation have sparked hope for communication without language barriers, as real-time inter-lingual chats aided by automatic translation are now available using mobile apps.

The Authors in [30] developed an English to Yoruba machine translation web-based system. With today's globalization and over 40 million Yoruba speakers in the south-western half of the country, as well as sections of the Benin Republic, the evolution of this system seems unavoidable. The current study examined rule-based technique to translate English text into Yoruba language. Twenty-two (22) rules were developed for translation which were stated using type 2 grammar (context-free grammar). A bilingual dictionary dataset was employed that included English words and their Yoruba translations. The study model was created using the computer languages, that is, ASP.net and C#. Authors in [31] further proposed the creation of a digital Yoruba phrasebook on a mobile Android platform that would provide Yoruba translations of useful English words and phrases. It is highly handy for travelers in regions where both English and Yoruba are spoken because it can translate in Yoruba. It is comparable to an English-Yorùbá multilingual dictionary. It was built on a mobile platform to make it more accessible, convenient, and portable. Rough Set Theory (RST) is a mathematical method for decision assistance and data analysis to translate words or phrases. It is used to make comparisons between the query, that is, the word or phrase to be translated and the produced corpus. The project delivers benefits of information technology to non-Yorùbá tourists or learners who want to talk with Yorùbá people, make friends with them, or conduct business with Yorùbá indigenes who are illiterate. It was discovered after deployment that Yoruba language was understandable and accurate, with few errors. A great number of new terms and expressions have been generated that are appropriate for situations, legislation, science, engineering, business, computing, mass communication, and other areas of life.

The Authors in [23] worked on the creation of an English to Yorùbá machine translator thoroughly. The technology was used to convert English sentences (Source Language) into Yorùbá sentences (Target Language). When some English verbs are translated to Yorùbá, the tone shifts from low to mid-tone in the bilingual dictionary. They are known as tone shift verbs. These tone-changing verbs present considerable difficulties for Yorùbá machine translation in English; most of the time, the meaning of the sentence is altered. The locations of the nouns and pronouns in the sentences usually determine these modifications. The verbs in this category were collected in the current study and certain re-writing guidelines for the two languages were devised. These re-written rules were tested using JFLAP. Other grammatical rules were also considered in addition to the rewritten rules and the rules influenced the Yorùbá translation. Unified Modeling Language (UML) was used to create the software. A rule-based method was employed for the translation. The Python programming language was utilized for software development since it comprises natural language toolkits for phrase parsing. The algorithm accepts an English sentence and then searches for a pattern for the statements. In [32], the Authors designed and implemented a Yoruba language mobile tutor. The current study attempted to show how to build and deploy an interactive mobile application with basic tutorials to learn Yoruba on handheld devices. The system has tools that help users perform basic English to Yoruba translations as well as to learn basic lessons that would help people learn, write, read, and speak Yoruba fluently. The application was created using HTML5, JavaScript, and CSS and was designed and modeled using UML. The program works effortlessly on handheld devices in Nigeria where it has a high degree of penetration and adoption. In [33] a TTS synthesizer for English, Hausa, Yoruba, Ibo, and Arabic texts that helps the uneducated farmers with reading and writing disabilities to listen to a real-time agricultural update on Android devices was developed. The speech recognition and TTS are done using public Android APIs. Google's speech recognizer and synthesizer, available in both online and offline versions, were used.

Authors in [14] demonstrated an offline English to Yoruba SMS text and speech translation tool based on Android. The program accepts English sentences and converts them to Yoruba using word selections from a locally constructed dictionary (database). In the current study, the developed system was designed and tested in the Android studio Integrated Development Environment (IDE) before being packaged as an APK file that can be installed on a range of Android phones and versions. Both words and sentences were translated from English to Yoruba using this method (one to one mapping and one to many mapping). The study was conducted in phases with primary focus on the application's strategy and the second on the accuracy of translations to user expectations. For translations, a questionnaire was designed and distributed among one hundred (100) people, with eighty-one (81) of them providing input. SPSS was performed on the responses. In terms of exactness and persuasiveness, which are decided by the eminence and extent of the calculation guidelines produced, human conversion did best.

Reviewed literatures show that rule-based machine translation systems provide extensive control over output, however, the cost to formalize linguistic knowledge is higher. Statistical machine translation systems, which learn to translate from examples, can be limited in their ability to learn from external information. On the other hand, NMT models require high-quality large-scale parallel corpora, making them challenging to use in Yoruba language and other low resource languages. To address these limitations, a hybridized approach can improve the practicality of restricted translation to incorporate prior human knowledge into translation by imposing constraints on the decoding process. Additionally, a hybrid system has been proposed that combines the strengths of statistical machine translation and rule-based machine translation to overcome the limitations of existing systems and to achieve higher accuracy and speed.

III.METHODOLOGY

Four (4) techniques, that is, four types of machine translation are employed in the development of any form of automation in language translation. These techniques include rule-based machine translation, statistical machine translation, neural machine translation, and hybrid translation. The current study employed hybrid approach. Rule-based technique, the most realistic of the four (4) approaches [22], [30], [34], [35] alongside a statistical technique, was used in the development of application.

The designed and developed application here is a native android-based mobile application sectioned into three (3) modules. Figure 1 depicts the theoretical structure for the proposed application which can be thought of as an English to Yoruba automated system with five (5) primary actors. These primary actors are as follows:

1. A person is too busy to send an SMS at a specific moment and has to connect with someone who can or cannot read, write, or understand English.
2. A non-Yoruba or a Yoruba speaker who is unable to answer calls in a certain area at a precise period and requires to send vital information to somebody who can or cannot recite, inscribe, or interpret English (for instance, his mama in his hometown).
3. A system to convert language to text as well as TTS.
4. A mechanism for translation.
5. A Yoruba man or woman who is unable to communicate in English.

   Resultantly, the fourth (4th) actor acts as a mediator between the other performers (the liaison officer).

As mentioned earlier, the newly developed application is a hybrid application; the system uses two different approaches during its design stage. The first approach used in the current study was the statistical application approach for the implementation of Google API translator. In this study, the adopted statistical approach is presented in [35]. The second approach employed was rule-based method to design and implement the local Yoruba voice database. The manually created local Yoruba voice database stores five thousand (5,000) English texts, phrases, or sentences and their Yoruba translation. Mp3 files were, however, created for each of the five thousand (5, 000) recorded sentences and stored for the application. This was used to implement the English text to the Yoruba speech module of the application.

About 100 computational rules were constructed for the English and Yoruba languages’ constructions in the rule-based technique employed in Yoruba speech module, with the left-hand side (LHS) being replaced with the right-hand side (RHS) until the terminuses were arrived at. This is founded on Type 2 (context-free) sentence structure. The sample processing guidelines have been presented in Table I.

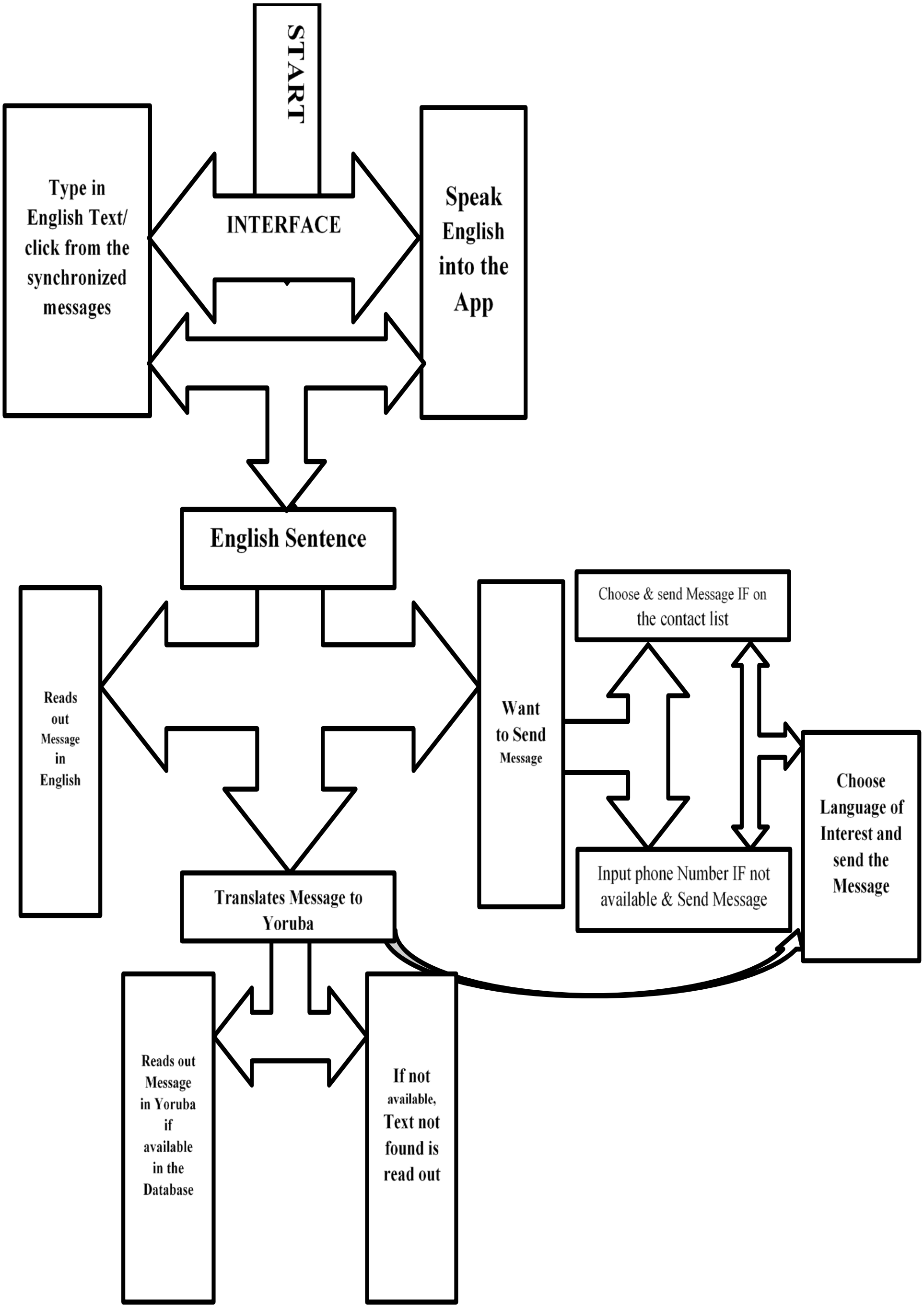

FIGURE 1. DFD for the Translation System

TABLE I

ESTABLISHED COMPUTATIONAL RULES

	ENGLISH RULES		YORUBA ARRANGEMENT OF RULES	
	SCHEMA	SCHEMA'S BREAKDOWN	SCHEMA	SCHEMA'S BREAKDOWN
R_{1}	S=NP + VP	NP=N +FT. VP= V	S=NP + ADV + VP	NP= (N+FT). ADV. VP=V
R_{2}	S=VP+ ADVP + PP+NP	VP=V. ADVP=ADV. PP=P. NP=N	S=VP + PP +NP	VP= V. PP=P. NP=N
R_{3}	AdjP= Det + Adj +N		AdjP= N + Adj +Det	
R_{4}	S=NP + VP	NP= N + FT. VP=V + (NP= N)	S=NP + VP	NP= N + FT. VP=V + (NP= N)
R_{5}	S=VP + PP + NP	VP= V. PP=P. NP=N	S=VP + NP + PP + NP	VP=V. NP=N. PP=P. NP=N
R_{6}	S=NP + VP + PP + NP	NP= N. VP=V. NP= N. PP =P. NP = Det + N	S=NP + VP + PP + NP	NP= N. VP=V. PP =P + (NP = N + Det)
R_{7}	S=NP + Aux + NP	NP= N. NP=N.	S= NP+ VP + NP	NP=N. VP= V. NP=N
R_{8}	S= NP + Aux + VP + PP + NP + Adv	NP=N. VP=V. PP=P. NP=N	S= NP + Aux + VP + PP + NP + Adv	NP=N. VP=V. PP=P. NP=N
R_{9}	S=NP + Aux+ Neg +NP	NP= N. (NP= Det + N)	S= Neg + NP + VP + NP	NP= N. VP=V. NP=N
R_{10}	S= NP + Aux + VP	NP= Det +N. VP=LV	S= NP + TNS + VP	NP= N +Det. VP=V
R_{11}	S=NP + Aux + NP + PP + NP + PP + VP + PP	NP=N. NP=P. PP=P. NP=N.PP=P. VP=V. PP=P	S=NP + TNS + NP + PP + VP + PP	NP=N. NP=P. PP=P. VP=V. PP=P
R_{12}	S= Adj + Aux + Neg + NP	NP=Det + N + (PP =P) + (NP= Det + N)	S= Adj + Neg +Aux + NP	NP= N
R_{13}	S=NP + Aux + ADVP	NP= N. ADVP=Adv + AdJ	S=Aux + NP + ADVP	NP= N. ADVP=ADV
R_{14}	S=NP	NP= N + Aux + Adj	S=NP + VP + ADJP	NP=N. VP=V. ADJP=Adj
R_{15}	S=NP + VP + PP + NP	NP= N + TNS. VP=V. PP=P. NP=N	S=NP + VP + PP + NP	NP= V+ FT. VP=V. PP=P. NP=N
R_{16}	S= VP + NP	VP= V. NP= N + Adv	S=VP +NP+PP	VP= V. NP=N. PP= P + Adv
R_{17}	S=ADVP + NP + VP	ADVP= Adv. NP=N. VP=V + Adv	S= ADVP + NP + VP +PP	ADVP= Adv. NP= N. VP= V. PP=P + Adv
R_{18}	S=NP + VP + AdjP	NP= Det + N. VP= Aux. AdjP=Adj	S=NP + Aux + AdjP	NP= N + Det. AdjP=Adj
R_{19}	S= NP + VP +NP	NP=N + FT. VP=V. NP=N	S= NP + VP + NP	NP= N + FT. VP =V. NP=N
R_{20}	S=NP + Neg + VP + PP + NP	NP= N + Aux. VP=V. PP= P. NP=N	S=NP + Neg + VP + PP + NP	NP= N. VP=V. PP= P. NP=N
R_{21}	S= FT + NP + VP + NP	NP=N. VP= V. NP=N	S=QM + NP	QM=Q. NP=N + FT
R_{22}	S= ADVP+ NP + VP + PP	ADVP= Adv + Aux. NP=N. VP=V. PP=P	S= Adv +Aux + NP + Aux + TNS + VP	NP=N. VP=V
R_{26}	S= VP + AdjP + NP	VP= V. AdjP= Det + Adj. NP=N	S= VP + NP + AdjP	VP= V. NP=N. AdjP= Adj + Det
R_{27}	S=ADVP+ NP+ VP + NP	ADVP=Adv. NP=N. VP=V. NP=N	S=ADVP + NP + VP + NP	ADVP = Adv + Adj. NP=N+ Adv. VP= N. NP=N
R_{28}	S= VP + PP + NP	VP=V. PP=P. NP= Det + N	S= VP + PP + NP	VP=V. PP=P. NP= N + Det
R_{29}	S= ADVP + NP + VP+ NP + PP +NP	ADVP= Adv. NP=N. VP=V. PP=P. NP= Det + N	S= ADVP + NP + VP+ NP + PP +NP	ADVP= Adv. NP=N. VP=V. PP=P. NP= N + Det
R_{30}	S= NP + VP + NP + NP	NP= N. VP=V. NP=N + Aux. NP= Det + N	S= NP + VP + NP	NP= N. VP=V. NP=N + Aux.
R_{31}	S= NP + VP + NP	NP= N + FT. VP=V. NP= Det + N	S= NP + VP + NP	NP= N + FT. VP=V. NP= N + Det
R_{32}	S= NP + VP + NP + VP + NP	NP= N. VP= V. NP= N + Aux. VP= V. NP= N	S= NP + VP + NP + VP	NP= N. VP= V. NP= N + Aux. VP= V
R_{33}	S= NP + VP + NP + VP + NP	NP= N. VP= V. NP= N + Aux. VP= Conjc + V. NP=N	S= NP + VP + NP + VP + NP	NP= N. VP= V. NP= N + Aux. VP= Conjc + V. NP=N
R_{34}	S=NP + NP +VP	NP= N + Aux + Adj. NP= N + Aux. VP= Neg + V	S=NP + NP +VP	NP= N + Aux. NP= N + Aux. VP= Neg + V
R_{35}	S= NP + VP + AdjP	NP= N. VP= V. AdjP= Art + Adj+ (NP= N)	S= NP + VP + AdjP	NP= N. VP= V. NP= N + Adj
R_{36}	S=NP + VP + NP + NP	NP= N. VP= V. NP= Det + N. NP= Det + N	S=NP + VP + NP	NP= N. VP= V. NP= Det + N
R_{37}	S= VP + ADJP + NP	VP= V. ADJP= Det + Adj. NP=N	S= VP + ADJP + NP	VP= V. ADJP= Adj. NP=N + Det
R_{38}	S= NP + VP + AdjP	NP= Det +N. VP= V. AdjP= Adj	S= NP + AdjP	NP= N + Det. AdjP= Adj
R_{39}	S= VP + NP + VP + NP	VP= V. NP= N. VP= V. NP= N	S= NP + VP + NP	NP= N. VP= V. NP= N
R_{40}	S= NP + VP + NP	NP= N. VP=V. NP=Det + N	S= NP + VP + NP	NP= N. VP=V. NP=Det + N
R_{41}	S= NP + VP + NP	NP=N + Aux. VP=V. NP= Det + N	S= NP + VP + NP + VP	NP=N + Aux. VP=V. NP= Det + N. VP=V
R_{42}	S= VP + PP + NP	VP=V. PP=P. NP= Det + N.	S= VP + PP + NP	VP=V. PP=P. NP=N + Det
R_{43}	S= NP + VP + N + Neg + VP + NP	NP=N. VP= V. VP=V. NP= N	S= NP + VP + Neg + NP	NP=N. VP= V. NP= N
R_{44}	S= NP + Adj	NP= N + Aux	S= NP + Adj	NP= N + Aux
R_{45}	S= NP + ADJP + ADVP	NP= N + Aux. ADJP= Adj. ADVP=Adv	S= NP + ADJP	NP= N + Aux. ADJP= Adj
R_{46}	S= VP + NP	VP= P. NP= Det + N	S= VP + NP	VP=P. NP= N + Det
R_{47}	S= NP + VP + NP	NP= N. VP= V. NP=N	S= NP + VP + NP	NP= N. VP= V. NP=N

R_{89}	S= NP + VP + NP	NP= N. VP=V. NP= Det + N	S= NP + VP + NP	NP= N. VP=V. NP= N + Det
R_{90}	S= VP + NP	VP= V. NP= N	S= VP + NP	VP= V. NP= Aux + N
R_{91}	S= VP + NP	VP= V. NP= N + Det + N	S= VP + NP	VP= V. NP= N + Det + N
R_{92}	S= NP + ADJP	NP= N + Aux. ADJP= Adj	S= NP + ADJP	NP= Aux + N. ADJP= Adj
R_{93}	S= ADVP + ADJP + NP	ADVP= Adv + Aux. ADJP= Det + Adj. NP=N	S= ADVP + ADJP + NP	ADVP= Aux + Adv. ADJP= Det + Adj. NP=Det + N
R_{94}	S= Adj + FT + VP + NP	VP= V. NP= N	S= Adj + FT + VP + NP	VP= V. NP= N
R_{95}	S= Adj + Aux + Adj		S= Adj + Aux + Adj	
R_{96}	S= NP + VP +NP	NP =N. VP=V. NP=N	S= NP + VP +NP	NP =N. VP=V. NP=Aux + N
R_{97}	S= NP + VP + NP +VP + NP	NP= N. VP=V. NP= N + Aux. VP=V. NP=N	S= NP + VP + NP +VP + NP	NP= Det + N. VP=V. NP= Aux + N. VP=V. NP=Det + N
R_{98}	S=NP + VP + PP + VP + NP	NP=N. VP=V. PP=P. VP=V. NP=N	S=NP + VP + PP + VP + NP	NP=Det + N. VP=V. PP=P. VP=V. NP=N
R_{99}	S=NP + VP + NP	NP= N + FT. VP= V. NP=N	S=NP + VP + NP	NP= FT + N. VP= V. NP=Aux + N
R_{100}	S=NP + Aux+ ADJP+ ADVP	NP=N. ADJP=ADJ. ADVP=ADV	S=NP + ADVP + ADJP	NP=Aux + N. ADVP=ADV. ADJP=ADJ

Rules for the Production of English Structures are as follows:

S → <NP> <VP> (<NP> <ADJP> <PP> <ADVP>) *

NP → <N> <FT> | <N> | <N><PP> | <DET><N> |<DET><N><PP> | <N><AUX> | <N><TNS>

VP → <V><NP> | <V> | <AUX> | <LV> |<V> <CONJC>

ADJP → <DET> <ADJ> <N> | <ADJ> | <DET><ADJ> | <ART><ADJ><NP>

PP → <P>

ADVP → <ADV><AUX> | <ADV>

Production Rules for the Yoruba Structures are as follows:

S → <NP> <VP> (<NP> <ADJP> <PP><ADVP><QM>) *

NP → <N> <FT> | <N> | <N><DET> | <DET><N><PP> | <N><ADJ>| <N><M>

VP → <V><NP> |<V> <CONJC>|<V> <NEG>| <V>

ADJP → <N> <ADJ> <DET> | <ADJ> | <ADJ><DET>

PP → <P> | <P><ADV>

ADVP → <ADV> <AUX> | <ADV>

QM → <Q>

S stands for starting symbol, while letters NP, VP, ADJP, PP, ADVP, and (*) stand for noun phrase, verb phrase, adjectival phrase, prepositional phrase, adverbial phrase, and optional, respectively. N represents noun, FT represents future tense, DET represents determinant, TNS represents tense, AUX represents auxiliary, ADJ represents adjective, QM represents question marker, ADV represents adverb, LV represents lexical verb, P represents preposition, V represents verb, and ART represents article.

The stages for rule-based approach used in the current study can be represented with the following data flow analysis as shown in Figure 2. However, the procedure of natural language processing component of TTS synthesizer and vice versa was reported in [36].

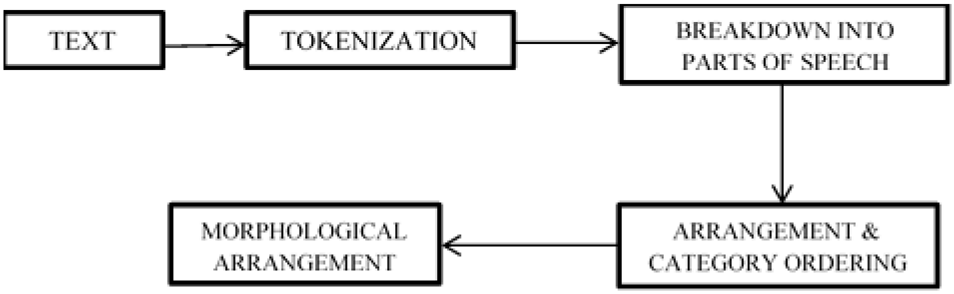

FIGURE 2. Data Flow Diagram for the Rule-based Approach

The Android Studio Integrated Development Environment was used to construct the system (IDE), which is a tool to create native Android applications. The interface of the mobile application was designed using Extensible Markup Language (XML), a subdivision of standard generation markup language (SGML) which represents the data. The backend of the system was developed using JAVA programming language and object-oriented, High-level language (HLL). Java programming language was used to control the dynamic contents on the system, to carry out the translation operations, to carry out the speech-to-text, and vice versa functions. Java programming language is known for its various functionalities in developing applications for the Android operating system.

Following steps are included in the process of using the produced application:

1. Install the application after downloading or receiving it.
2. Go to settings on your Android phone, pick App, select the translator, and set all permissions to allow to turn on the microphone, contact list, phone, and SMS.
3. Install the app on your Android phone.
4. On the user interface:

   a. Use microphone for speech-to-text.

   b. Type a message in the message box.

   c. Select a message from the synced messages to convert it to Yoruba or use the app's speech capability to read it out in English or Yoruba after translation.

5. Text message in English sentence is now:

   a. Readout as a text message in English.

   b. Translated to Yoruba if available in the created database.

   c. Sent out as a message to a recipient in the English sentence or Yoruba after translation.

For the Yoruba speech translation process, the produced system is an online application which was constructed using an Android Studio IDE and a bilingual voice database that was developed locally (thesaurus) as shown in Figure 3. The manually generated database, on the other hand, was created to contain mp3 files for each of the five thousand (5,000) sentences that were recorded and kept for the program. Figure 3 shows some of the Yoruba recordings in the voice database. All the recordings are in MP3 format and are kept inside a folder. The folder is embedded and built together with the mobile application which makes it much easier for the recordings to play locally on the device.

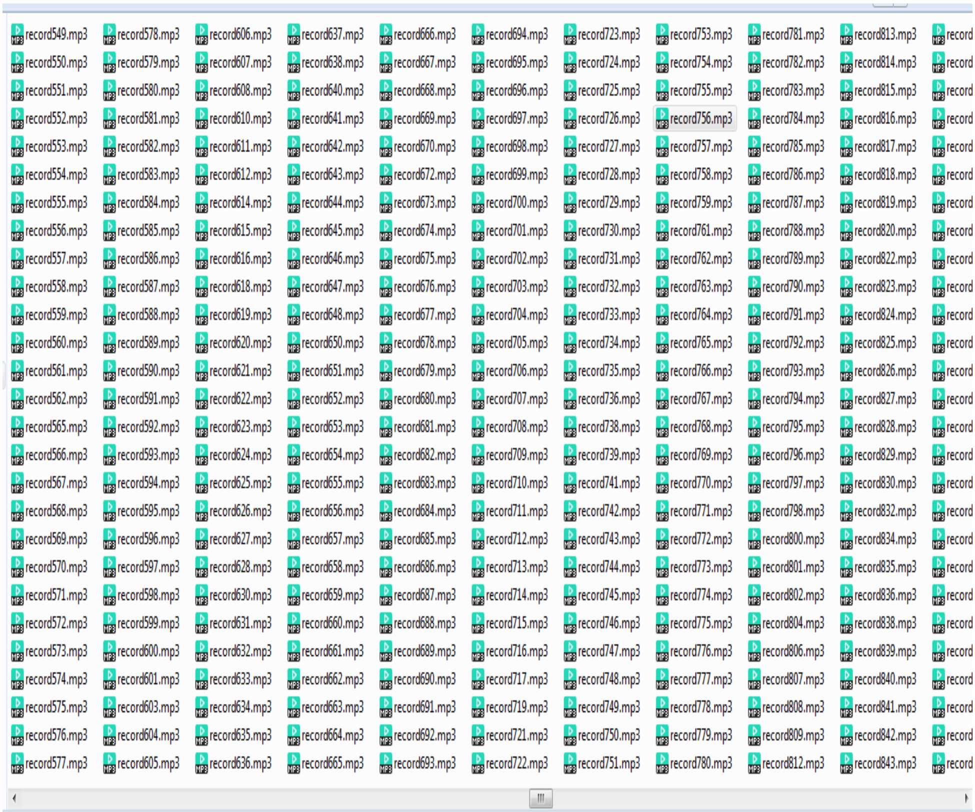

FIGURE 3. Sample Recorded Voice Database

Figure 4 shows the translating system's flowchart. It represents the sequence of events that occur in the application, from the launching of the application to sending speech into it via the microphone, to messages being translated into Yoruba or communicated as speech in English or Yoruba. To avoid mistakes, the program was created and tested on system using an aper (an Android gadget on the system) and the code for the installable was developed. The program is distributed as an APK file that can be installed and operated on any Android device, regardless of the operating system's version.

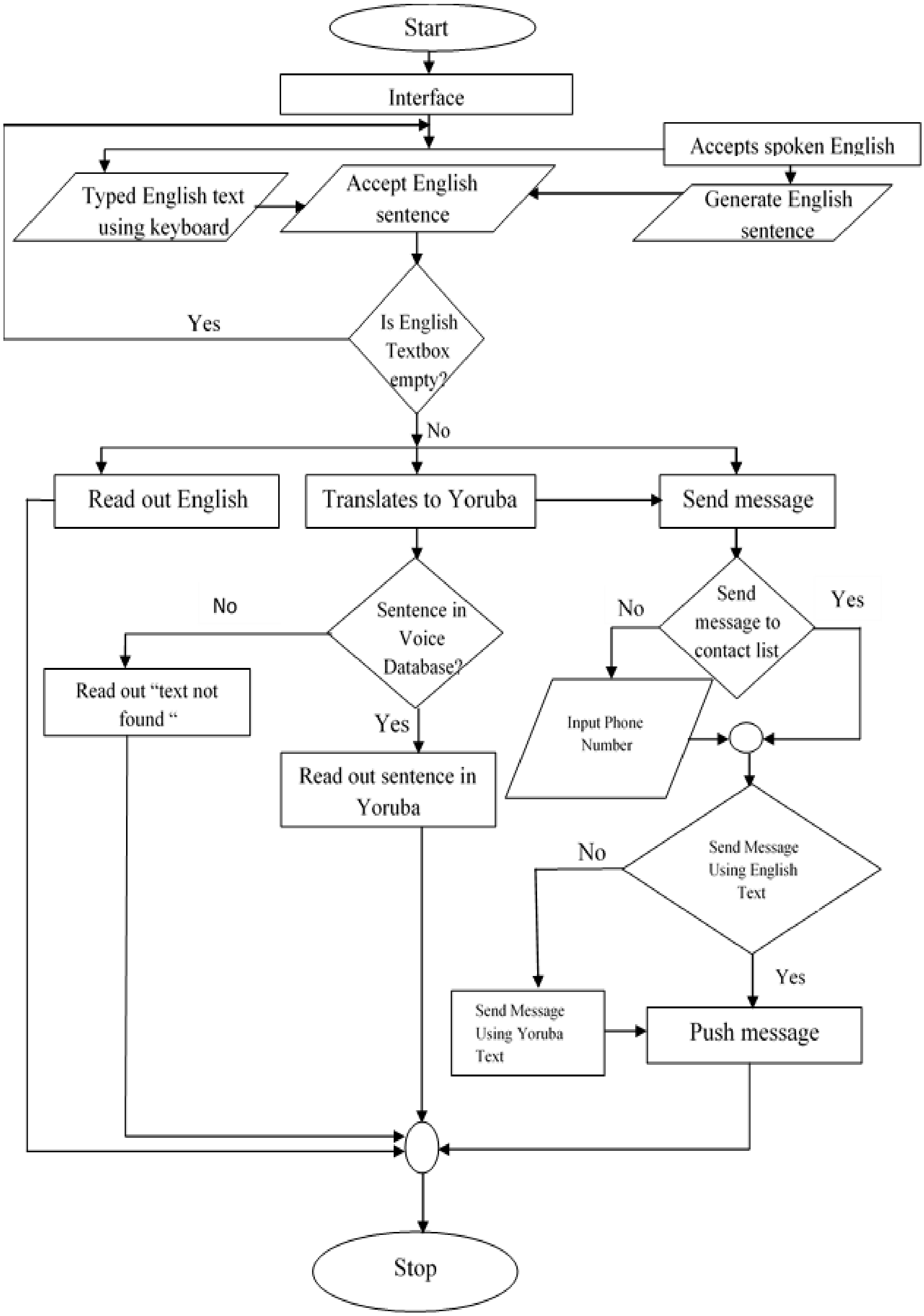

FIGURE 4. System Flowchart of the Application

IV. TESTING, EVALUATION, AND DISCUSSION OF FINDINGS

The designs exhibited and discussed in the previous section were created in this section using the Android Studio Integrated Development Environment (IDE) which is used to create native Android applications. The mobile application's user interface was created using Extensible Markup Language (XML), a subset of the standard generation markup language (SGML) that is mostly used for data representation. The system's backend was built with the JAVA programming language and an object-oriented, high-level language (HLL). To avoid mistakes, the software was produced and tested on the system using an emulator and the cipher was generated to create the installable Android Application Package (APK) file so that the program may be mounted and executed on any Android device, regardless of the operating system version. Afterwards, the application was tested and sample screenshots with discussions were presented in the sub-section for testing while in the sub-section for evaluation and an adequate report on the evaluation was reported.

A. TESTING AND DISCUSSION

The interface, as shown in Figure 5, is displayed once the software is successfully loaded. This interface contains all the basic functionalities of the app. The speech-to-text Android section is designed with an interface where the user's speech in English is captured by the Android-based microphone. Additionally, the speech is converted into equivalent text by the app. The interface contains two different text boxes for data input as displayed in the Figure. The first text box is for English sentences and the second one is for Yoruba sentences. The interface of the mobile application is sectioned into three different phases, the first interface contains both textboxes. The remaining two interfaces include local phone message inbox and details of the system developer. This interface has five different buttons which perform five distinct functionalities. The functionalities of all the buttons would be further discussed in the Figures that follow.

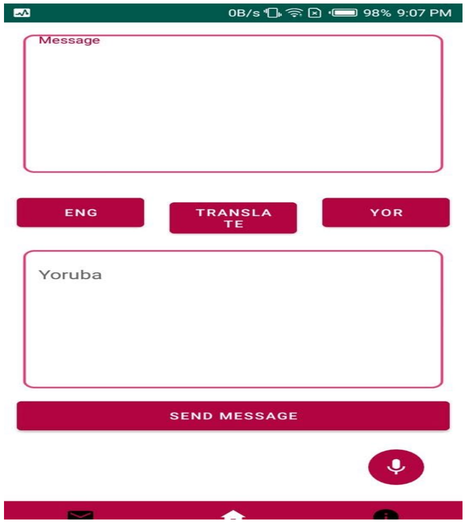

FIGURE 5. System Interface

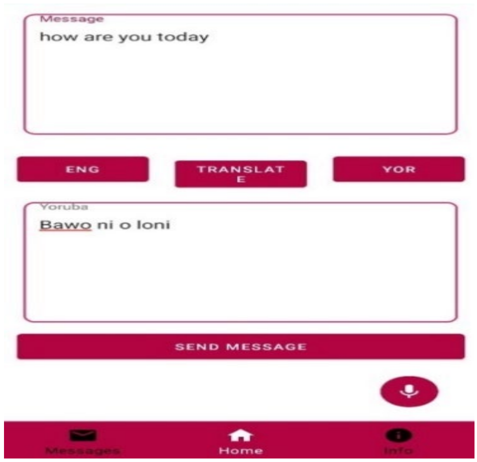

FIGURE 6. System Interface (Translation)

Figure 6 presents a sample translation process of the application from the English language to the Yoruba language. The middle button on the system interface which is the "translate" button would be clicked to translate any English sentence(s) inside the English language textbox to its Yoruba language equivalent. After the successful translation of the English text, the Yoruba equivalent of that sentence is displayed in the second textbox. The English language textbox can accept input through two different methods. By using the first method, sentences are typed through a user's mobile device's QWERTY keyboard. While the second method uses the English language speech-to-text functionality which is made possible through the use of microphone button on the interface. To achieve this, users would have to press down the microphone and speak into the application through the phone. By doing this, the system accepts the input and generates equivalent English text of the spoken sentences. The English and Yoruba buttons are used to read out the English and Yoruba sentences from their respective text boxes.

The TTS functionality is implemented by using Android OS API for English language TTS. Whereas, the Yoruba TTS functionality uses the designed local voice database. Any translated text in Yoruba would be searched for in the local voice database and the equivalent recording would be played through the mobile device's speakers. Yoruba sentences with no corresponding recording in the local voice database give a default recording of "text not found" to the user. The last button on the interface is the "send message" button which is used to send a text message in either English or Yoruba language to a specified receiver.

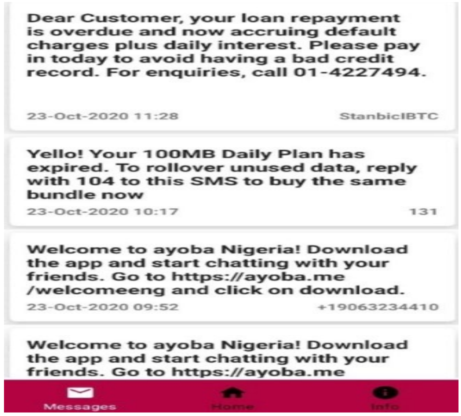

FIGURE 7. Synchronized SMS

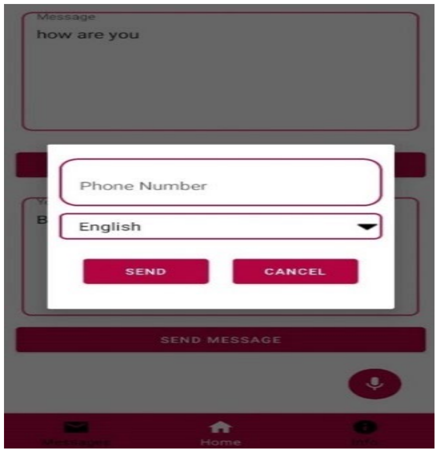

FIGURE 8. SMS Interface

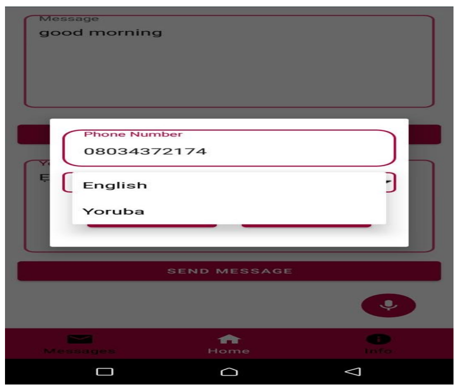

FIGURE 9. SMS Interface

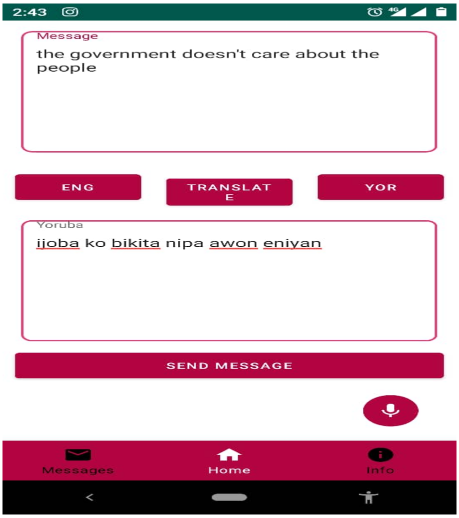

FIGURE 10. Sample of Screenshot

Figures 7, 8, 9, and 10 show a sample of the screenshot of the synchronized SMS, the activated SMS interfaces, and the translation interface, respectively. The SMS interface accepts two inputs, for instance, the phone number to send the message to and the language in which the message is to be sent. To input a phone number on the application, two (2) methods can be employed. One method is to input the phone number directly into the application, whereas another method is to choose a recipient from contact list. Figure 9 shows the selection of language to send the text message. The message is dynamically sent and can be sent either in English or the Yoruba language.

B. EVALUATION

The evaluation process began with the compilation of a questionnaire that outlined the profiles of the subject respondents who were largely university students. Respondents were asked to speak in English to the mobile app's microphone using 30 different sentences of their choice in section B of the questionnaire. The 30 sentences converted into the text were subsequently translated into their equivalent sentences in the Yoruba language. The respondents were then required to compare the translation from the mobile app translations with their translations. The respondents were required to test the accuracy of the text-speech pertaining to the capability of the mobile app. The respondents were required to use the mobile app to convert the translated text in Yoruba into speech. About 30 sentences translated in Section B were used and evaluated based on the respondent's observation of speech correctness. The final phase was dedicated to gather the information about the app's applicability and simplicity of use. The questionnaire was designed using three criteria, that is, accurate sentence syntax when converting speech-to-text, correct sentence syntax when translating, and the accuracy of the translated speech in Yoruba. The speech-to-text mobile app translator was tested with 350 individuals, however, only 337 people submitted the questionnaires.

1)PARTICIPANTS' DEMOGRAPHIC CHARACTERISTICS (N=337)

Table 2 represents the demographic characteristics of participants. Males accounted for 64.7% of responders, while females accounted for 35.3%. About 14.8% of respondents were under the age of 20, 13.6% were between the ages of 21 and 25. Moreover, 32.6% were between the ages of 31 and 35, 22.0% were between the ages of 36 and 40, and 16.9% were over the age of 41. Approximately, 15.4% of respondents are undergraduates, 44.5% had a bachelor's degree, 30.6% had a Master's degree, and 9.5% had a doctorate degree. The respondents spoke three native languages: 24.6% spoke English, 16% spoke Hausa, and 59.3% spoke Yoruba. The study also determined the respondents' speaking fluency, finding that 21% of the participants had poor fluency, 13.9% had average fluency, and 65% of the respondents were strongly fluent.

TABLE II
PARTICIPANTS' DEMOGRAPHIC CHARACTERISTICS (N=337)

Variable	Frequency (n)	%
Gender		
Male	218	64.7
Female	119	35.3
Age		
Under Age 20	50	14.8
21 to 25 years' old	46	13.6
31 to 35 years' old	110	32.6
36 to 40 years 'old	74	22.0
Above the age of 41	57	16.9
Level of Education		
Undergraduate	52	15.4
Bachelor Degree	150	44.5
Master	103	30.6
PhD	32	9.5
Language of Origin		
English	83	24.6
Hausa	54	16.0
Yoruba	200	59.3
Fluency of Native Language		
Poor	71	21.0
Average	47	13.9
Good	219	65.0

2) SENTENCE SYNTAX CORRECTNESS EVALUATION

The proposed system was established by considering the distinct respondent's translations as well as the translations of the mobile app by looking at the sentences in the questionnaire. Both the respondent and the mobile app translation were given a score for each phrase. The target language's sentence structure was used to assess the consistency of the sentence syntax. Figure 11 shows the syntax correctness findings for 30 sentences in the questionnaire. This is because the sentences were respondent particular, the mobile app translator ratings were found to match the human expert results for several sentences. The respondents' average ratings were initiated to be lower than the mobile app conversions.

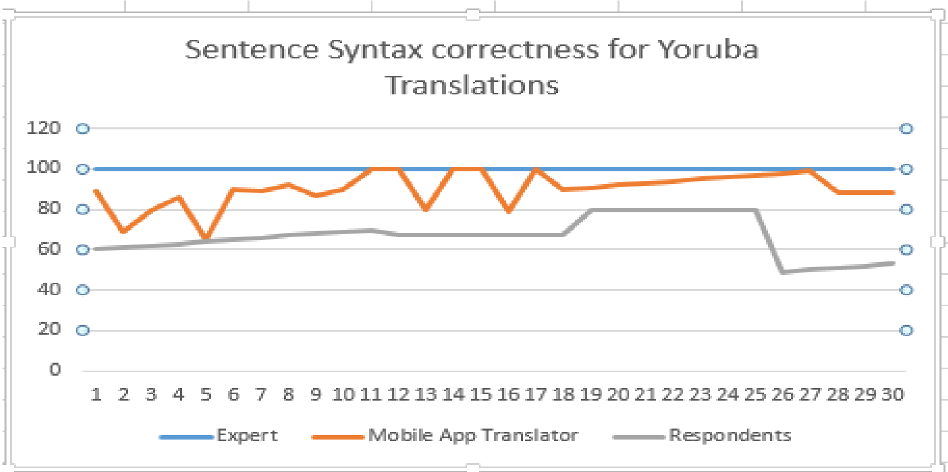

FIGURE 11. Sentence Syntax Graph

C. RESPONDENT ASSESSMENT OF THE MOBILE APPLICATION

Table 3 shows the user responses. About 298 of 337 respondents or 88.4% rated the program as above average in terms of simplicity of use (excellent or very good). The simplicity of utilization referred to how simple it was to utilize the translation software on a mobile device. On this basis, only two people (2 out of 337) gave the app a negative or very low rating.

TABLE III

RESULTS OF THE USER/RESPONDENTS' ASSESSMENT

Assessment Ratings	Ease of Use	App Translations accuracy
Exceptional (5)	234	225
Excellent (4)	64	93
Very Good (3)	19	10
unbiased (2)	15	3
dreadful (1)	3	6
Exceptionally poor (0)	2	4

V. THREATS TO VALIDITY

One fault in this technique is that it was implemented using the Java programming language, therefore it may not be representative of other languages. Java, on the other hand, is a widely-used programming language [37] that is employed in a wide range of applications. The method described in the current study is expected to be expanded to other programming languages in the future. The quality of synchronized messages and the local Yoruba voice database are also among the threats to validity. The study gathered an authentic Yoruba voice database that was personally made and recorded in mp3 format. Manual Yoruba voice messages, on the other hand, may not contain all of the information that should be included in a language translation message. Moreover, programmers are notorious for being lazy and producing subpar messages [38]–[40]. The human study also poses a threat to validity due to small number of participants. It cannot be ensured that each generated evaluation's final score is accurate. This threat was attempted to be counteracted by employing as many experienced programmers and researchers as possible.

VI.CONCLUSION

Since language is evolutionary, it is impossible to assume that one method would be enough to manage a translation project. Linguistic anomalies, ambiguities, lack of grammatical universality, and lexicon are some of the reasons for the failure of machine translation systems to reach 100% accuracy. Yoruba is one of Nigeria's most widely spoken languages. However, the fact that it is a lingua franca, it is gradually expanding since people do not speak it regularly. Various approaches in machine translations, involving English to Yoruba, have been postulated in literature, however, the entire approach has its advantages and disadvantages. In the course of developing this system, the problems associated with communicating in Yoruba language were firstly recognized. Various pieces of literature have been reviewed to get an in-depth knowledge as to how previous systems have worked. Google translator API was adopted in this system for the translation of English sentences to Yoruba sentences accurately. A local voice database was developed to achieve the Yoruba TTS functionality. A local database was used because google speech cannot correctly recite Yoruba sentences with the correct intonation, although the number of recorded sentences in the local database is limited (five thousand sentences). The

Android studio integrated development environment was used to design the system (IDE) which uses XML for the frontend and Java for the backend. The developed app can be extended for language learning and TTS facility can be used for the accessibility of disabled learners. Lastly, in healthcare scenarios, it can also be used to bridge the communication gap between healthcare professionals and a patient who speaks different languages.

A. SUGGESTIONS FOR FUTURE WORKS

Even though, the study met its stated goals and objectives, the research is still limited to several Yoruba sentences for speech based on the available voice translations in the database and thus have the following limitations:

i. The work integrated into it the Google API for English to Yoruba text translation and thus the application requires Internet access for its translation. The use of API became imperative due to the use of compound words in English.

ii. Sentences were built into the local voice database and were saved with their English meanings. This is because no functionality could concatenate the words in mp3 together.

iii. Additionally, Yoruba speech to Yoruba text could not be implemented in the work because the Yoruba language is not fully supported by Google.

iv. Future developers should consider developing a more efficient hybrid mobile application that could be used by any mobile operating system.

v. A more complex algorithm should be modeled to support the concatenation of more than one MP3 file to support TTS for multiple sentences.

vi. Incorporating contextual understanding to aid the understanding of context and idiomatic expressions. Potential enhancement with NMT to improve accuracy.

CONFLICT OF INTEREST

The author of the manuscript has no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

DATA AVALIABILITY STATEMENT

The data associated with this study will be provided by the corresponding author upon request.

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