Machine Translation Approach to Translate Amharic Text to Ethiopian Sign Language

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Abstract

Sign language is a communication system using gestures that are interpreted visually. Many people in deaf communities around the world use sign languages as their primary means of communication creating a strong sense of social and cultural identity. About 0.4% of the whole population of Ethiopia is deaf and out of this, more than half is illiterate because of the fact that there are very limited studies conducted on Ethiopian Sign Language. This research document presents a Machine Translation system to translate Amharic text to an equivalent Ethiopian Sign Language (ESL) by finger spelling representation with the help of a 2-dimensional animating avatar rendering the equivalent ESL finger translation. Animating an avatar for rendering Ethiopian finger spelling requires a dynamic and periodic switching of hand shapes and hand movements. Macromedia Flash 8.0 and ActionScript 2.0 are used as a tool to model and design the avatar, the hand shapes and the hand movement definitions. The translation system is tested by 10 deaf people and 66.6% of them responded that the overall performance is good and supportive.

Keywords: Ethiopian Sign Language, Ethiopian Finger Spelling, avatar based translation

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Introduction

According to Ethiopian National Association for Deaf (ENAD) referring Ethiopian national statistical agency's study, about 1.5 million deaf people lived in Ethiopia in 1994 E.C. and latter in 2000 E. C., the deaf

population raised to approximately 2.5 million. About 8% of the whole population of Ethiopia is disabled people. Out of these, 2% counts for deaf and hard of hearing people.

Deafness, characterized by visual communication, creates a strong sense of identity among the society of any country. Visual communication like sign language is the primary means of communication among the deaf. Except for parents of deaf people, teachers of deaf students and people interested on sign language; most of the hearing society does not know sign language. This created a huge communication gap between hearing people and the deaf. The researcher believes that a research attempt on translating either from the auditory language (Amharic) to that of sign language (ESL) or the vice versa eases the communication gap. There is either two-way translation (Bilingual translation) or one-way translation among natural language translation systems (Emiko, n.d.). Bilingual translations are commonly observed for languages of same nature (spoken/written languages). A translation made between sign languages and spoken/written languages like Amharic is more manageable if accompanied in one-way translation approach because of the nature of the two languages. In one-way translation, the translation direction is best identified based on previous research attempts, available resources and the worth of beneficiaries. In the case of Amharic and ESL, there are two directions of translation: from Amharic to ESL or from ESL to Amharic. Such translations are conducted considering that ESL is of the deaf side and Amharic is of the hearing society. Translating Amharic to ESL benefits the deaf because it helps the deaf understand what is stated in Amharic. It also helps the Amharic speakers express what they want to say to the deaf. Translating ESL to Amharic on the other hand, benefits the hearing people because it helps the hearing people understand what is said in ESL.

Scope and limitation

Sign languages all over the world including Ethiopian Sign Language make use of finger spelling and signing. Signing by itself include sign language, sign-spoken language, signed-spoken language. The intended system is supposed to take a text input, undergoes through a machine translation path and finally, delivers an animation output. On the input part, this study is specific to a Unicode Amharic text typed with the phonetic mode of Geez alphabet. Associated with the processes, an adoption of machine translation system adopts a multi-path machine translation approach takes part to analyze the internal process of the system. On the output part, this research is limited to only the application of Ethiopian finger spelling to convey meaning by ESL. The reason to select only the finger spelling ignoring the conceptual signs is that finger spelling is quite manageable to be presented by animation with some machine translation rule. Conceptual ESL words can of course be animated also; but no refined rule can be defined to generate animations for even a very specific corpus of words in a particular domain. The application of set of animations corresponding to some corpus of words in a specific domain would be no better than the correspondence of pre-recorded video sets corresponding to domain specific corpus of words, which is already studied on the context of hypermedia tool development for ESL (Endale, 2005).

Sign Structure in Sign Language

Sign Languages involve simultaneous manual and non-manual components for conveying meaning. Non-manual features are comprised of the posture of the upper torso, the orientation of the head and facial expressions. Manual features have been often been decomposed as hand-shape, hand orientation, hand position and motion (Stokoe, 1978). The Hamburg Notation System (HamNoSys) is an established phonetic transcription system for sign languages comprising more than 200 iconically

motivated symbols to describe these manual and non-manual features of signs (Prillwitz, Leven, Zienert, Hanke, Henning, et al, 1989).

Visual languages systems especially like sign language are expressed by combining different components of the sign. Signs have the following components (Daniel, 2006) (Kadous, 1995)

I. Hand shape

Hand shapes are usually used to represent finger alphabets of sign languages. Hand shapes are created by bending and stretching the finger and the palm. There are signs created using only one hand like Ethiopia, America and two hands like British.

II. Location

Location refers to the place where the signing is performed. The signing can be performed either by hand, eye or other body. There are signs that are the same with other components of sign and only defers in their location. For example, signing the word "mother" and the word "father" in ESL have the same hand shape except for the sign for "mother" is signed locating hand at the fore-head and that of "father" at the chin.

III. Movement

There are a wide variety of movements possible with sign language including arcs straight lines and wavy patterns. Hand movement is dominantly used to make the major component of ESL. Head movement, eye movement and the torso movement may also be applied in ESL.

IV. Orientation

There are three possible orientations of the hand: roll, pitch and yaw.

Finger Spelling

Finger spelling is a manual representation of written language, and it is used as a substitute for speech as a live, or face-to-face, medium of communication. It is a means of communication rather than spelling of any

spoken language words. It is used in combination with sign language for proper nouns, names and addresses and for words that have no specific sign (Riekehof, 1987). The term finger spelling stands for both sign language production and perception (Evans, 1982).

When finger spelling, people use their dominant hand to make hand shapes, one corresponding to each letter of the word. Fluency in sign language includes the ability to produce and recognize finger spelling at a rate of four characters per second (Wolfe, 2004).

Ethiopian Sign Language

Ethiopian Sign Language is used as the primary communication language among the Ethiopian deaf community. It is derived from American Sign Language since the first school for deaf people was established by American missionaries and it served as an instruction tool. The major differences that exist between American and Ethiopian sign languages are (Legesse, 2008):

- Ethiopian Sign Language has borrowed too some signs from Nordic countries Sign Languages, especially from the Finnish one.
- There are local signs created and used in some specific deaf schools in the country, later included into Ethiopian Sign Language.

E.g. **እቁላል ፤ ቀዳውጣ፤እጆራ፤አባሻ፤ራሳ፤ቁምጣ፤በጆት፤ደሞዝ፤ ቁማር**

- The finger alphabet used in Ethiopian Sign Language is constructed based on the shapes and orientations of Amharic alphabet as shown in Figure 1.

Very limited attempt has been made to find out the grammatical structure and rule of Ethiopian Sign Language, due to non-existence of local experts in the field of sign languages. However, there are fruitful attempts in the development of modern sign language dictionaries in Ethiopian local spoken languages (BERTAT, 1997)

Ethiopian Finger Spelling

ENAD (Ethiopian National Association for Deaf), has developed the Ethiopian Finger Spelling in 1971(Legesse, 2008). Latter, Ethiopian Finger Spelling was accepted and recognized by the Ministry of Education. Currently, it is used in all deaf schools along with the American finger spelling. The American Finger Spelling is used when we want to express words or concepts in English and local languages based on Latin alphabet, like Oromiffa, while Ethiopian finger spelling is used when we need to express words or concepts in languages that use Gee'z alphabet, like Amharic and Tigrigna (Legesse, 2008). Ethiopian Finger Spelling has 34 unique hand shapes to represent the first order Amharic alphabet, where 33 of them (except the Amharic letter '**ቨ**') have been used until 2009 (Legesse, 2008). The hand shape for letter '**ቨ**' (shown in Figure 2) is lately introduced as the 34th finger spelling of ESL by ENAD. Figure 1 shows the 33 Ethiopian finger spelling with the corresponding Gee'z alphabet except letter '**ቨ**' as found from ENAD.

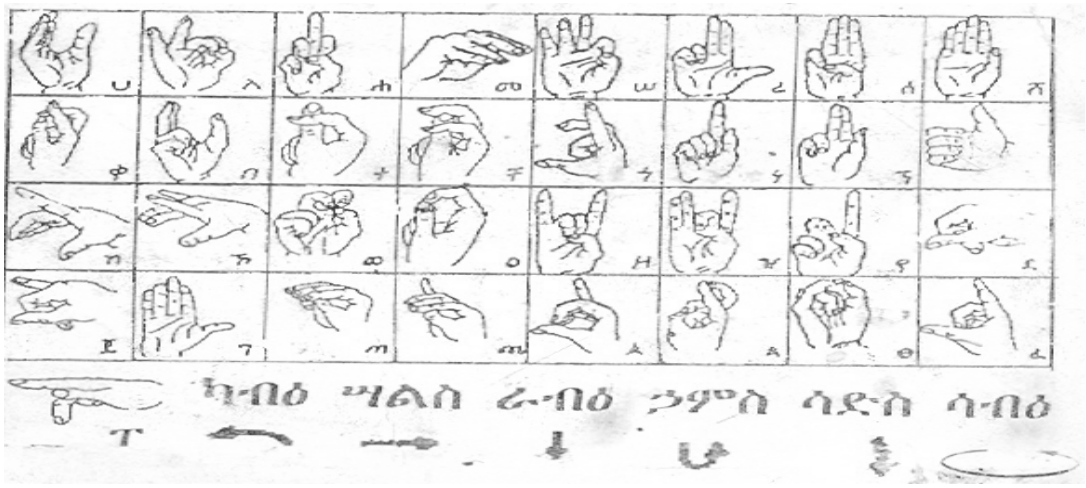


Figure 1: Ethiopian Finger Spelling

Figure 2: the lately introduced letter '**ቨ**' (v)

ESL Linguistic Issues

In ESL, several parts of the body convey meaning in parallel: hands (location, orientation, and shape), eye gaze, mouth shape, facial expression, head-tilt, and shoulder-tilt. Signers may also interleave lexical signing (LS) with classifier predicates (CP) during a performance (Legesse, 2008). During LS, a signer builds ESL sentences by syntactically combining ESL lexical items (arranging individual signs into sentences). The signer may also associate entities under discussion with locations in space around their body; these locations are used in pronominal reference (pointing to a location) or verb agreement (aiming the motion path of a verb sign to/from a location).

It is also necessary to remember that ESL is signed dominantly by the conceptual and conventional gestures, and body signs and ESL finger spelling assist in conveying nouns and pronouns. Commonly, these finger alphabets are applied together with ESL conceptual signing to convey some doubtful words by initialization (Legesse, 2008).

Gee'z alphabet on Power Ge'ez 2005

Amharic language use Gee'z alphabet as its scripting latter. According to Power Ge'ez 2005, there are a total of 44 base Gee'z letters in Amharic texts. Each of these Gee'z base latter is multiplied by 7. On the base letters, there is no vowel sound identified by the phonetic mode of power Gee'z. Therefore the 7 is to refer for 1 base letter and 6 different Amharic vowel sounds. Out of these letters, the Ethiopian Sign Language finger spelling uses only 34 base letters of Gee'z alphabet. The developer of power Gee'z software, Concepts Data Systems P.L.C., has provided different modes like phonetic (P), phonetic Unicode (PU), typewriter (T), typewriter Unicode (TU) and English (E) modes of using the power Gee'z. In this

research, the phonetic mode (P) is selected to take Amharic input from keyboard because the phonetic mode is the simplest and common for people who do not type Amharic frequently. The researcher believes that the simplicity may help both the deaf and hearing people in easing the application of this new study results.

Concepts Data Systems P.L.C presented the phonetic mode of Gee'z alphabet in such a way that it corresponds with the English sound of that letter by English alphabet, as presented in Table 1.

Grouping Gee'z alphabet

It appears manageable if the seven columns of Gee'z alphabet are grouped from one to seven on the basis of the 6 vowel group and the first consonant (base) group. In this study, the seven groups of Gee'z letters are used as indicated in table 1.

Table 1: Amharic vowels and their Groups

Consonant	u	I	A	y	e	o
ግዕዝ	**ክብዕ**	**ሣልስ**	**ራብእ**	**ኃምስ**	**ሳድስ**	**ሳብዕ**
Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7

As mentioned before, the ESL finger spelling uses only 34 consonant letters with 6 Amharic vowels for each. According to the above table, the 34 unique letters are under group 1 and the Amharic vowels generate the remaining groups (group 2 through group 7). ESL Finger spellings of group 1 letters (**ግዕዝ**) are signed without hand movements; whereas the remaining groups are signed by hand movements as shown by the arrows in figure 3.

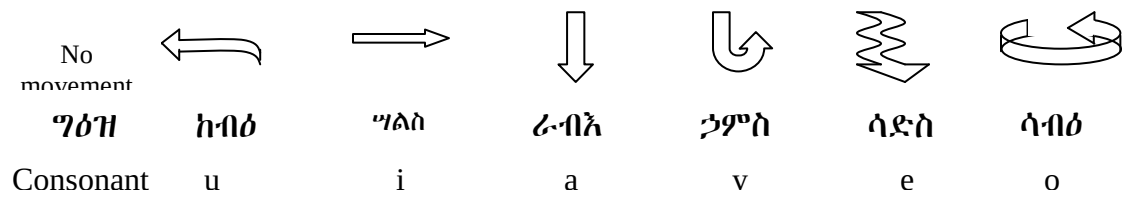


Figure 3: Amharic vowels associated with ESL finger spelling hand movement.

In all of the 33 selected consonants with their vowels, the phonetic mode of power Gee'z uses either one or two English letters. While typing a consonant Gee'z letter, the phonetic mode uses only one English letter (mostly that corresponds with the sound of the Gee'z letter). But while typing the combination of consonants and vowels, the phonetic mode of power Gee'z uses two letters of English alphabet. Should be mentioned that there are cases in ESL finger spelling associated with Gee'z letters that need the Caps Lock – On (**ኀ**,**ኸ**,**ሸ**, **ጸ**, and **ፀ**).

Translation architecture

This research investigates the conversion of Amharic text into the equivalent ESL finger spelling sign. ESL finger spelling translation needs an "heuristic" approach that can be mapped in the direct and transfer paths of Machine Translation architecture. These are defined in the experimentation part of this study as methods of hand-shape modeling and hand movement definitions. The pyramidal model of machine translation architecture is customized in this research as in Figure 4.

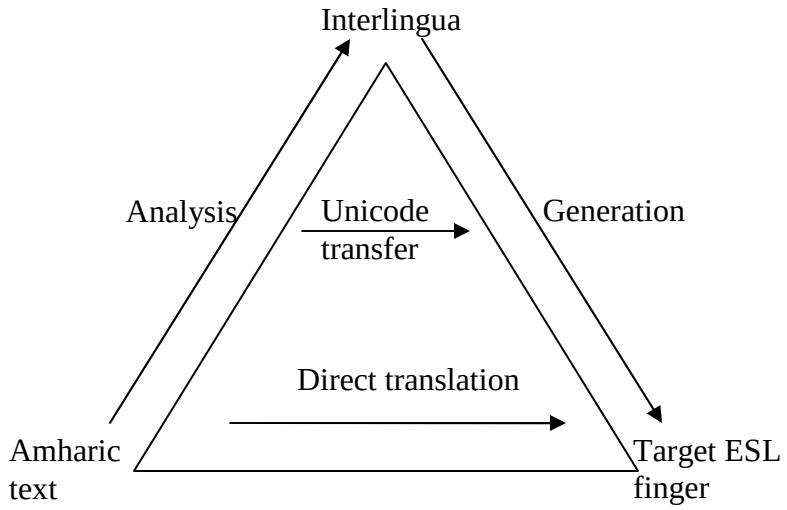
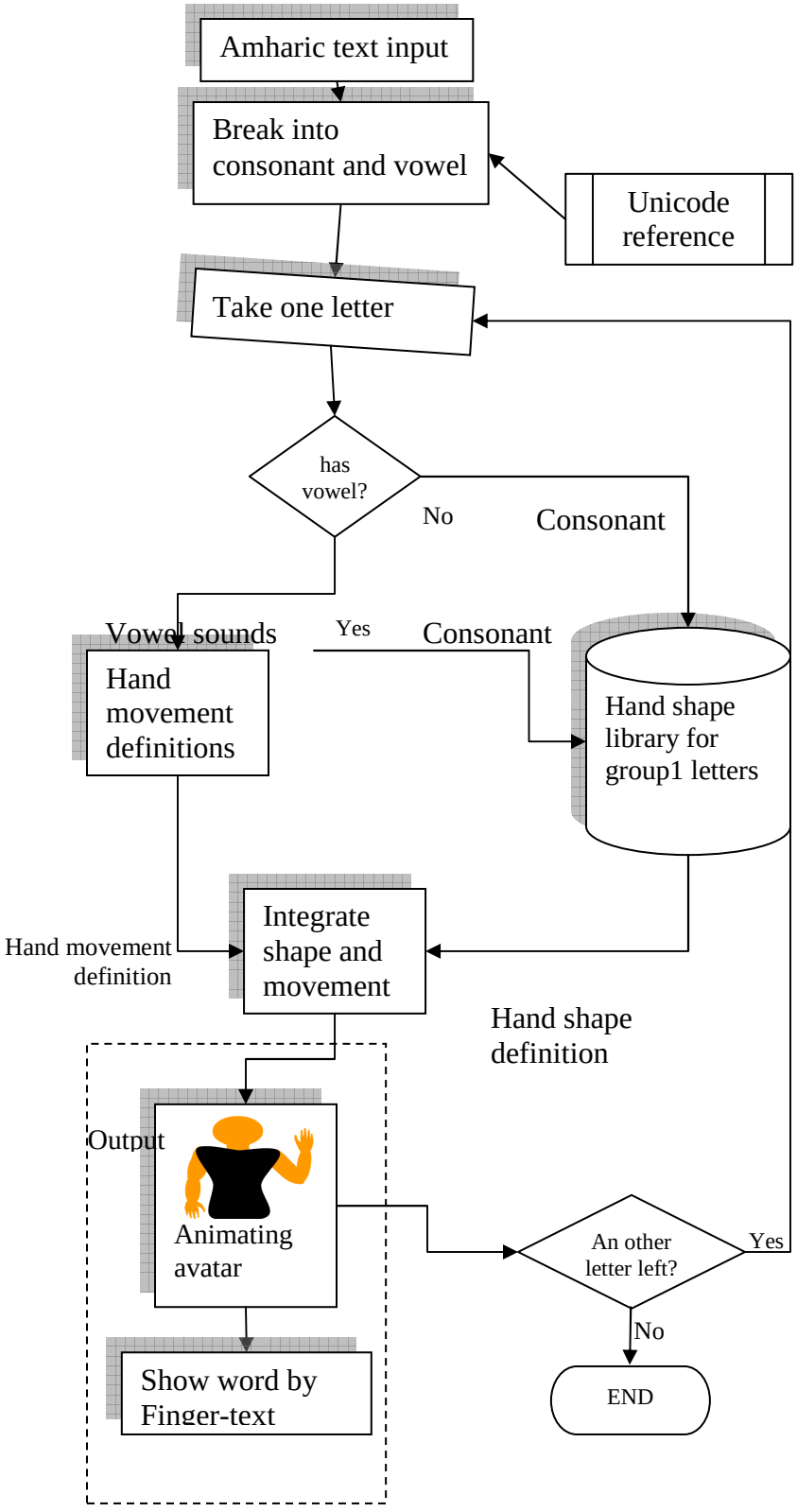


Figure 4: Machine translation architecture

The direct translation involves a simple mapping between the corpus of Amharic text and ESL finger spelling words. On the transfer level of the model, the mapping derives from the Unicode equivalent of the input Amharic text and the equivalent ESL finger spelling word. The Interlingua system incorporates the different intermediate rules of ESL finger spelling as a correspondence to the Unicode mapped word of Amharic text. The rules of ESL finger spelling considered in this level (Interlingua) are hand shapes and hand movements.

Modeling the system

The translation system has some basic components that are integrated to one other to show the right ESL finger spelling equivalent of an input Amharic text, Hand shape definitions library, Hand movement definitions library, Integrator and the avatar are the basic component of the translation system model. The following figure 5 shows these components with their interaction and the process flow of each component:


Amharic text input
Break into consonant and vowel
Unicode reference
Take one letter
has vowel?
No
Consonant
Vowel sounds
Yes
Consonant
Hand movement definitions
Hand shape library for group1 letters
Integrate shape and movement
Hand movement definition
Hand shape definition
Output
Animating avatar
An other letter left?
Yes
No
Show word by Finger-text
END

When an Amharic text is typed from the keyboard, the Unicode equivalent of each letter is collected from a module. Note that the Unicode equivalent of each base letter of Gee'z alphabet is defined in a module for the purpose of displaying the Amharic font at the input box. Each letter of the input text is then broken into a consonant (group1) and vowel-containing (Non-group1) category and stored in an array. Here, if a letter is categorized as vowel-containing, it is identified by the base letter and the following vowel. For example, in the word "ሞርካቶ", the phonetic mode key sequence becomes "m, re, ka, to". Only the first letter "ሞ" is characterized by a consonant category (group1). But the remaining letters are all characterized by a vowel-containing category (Non-group1). For instance, "ር" is phonetically typed as "re" where "r" represents the base letter "ረ" from group1 and the vowel "e" is appended to it. The following table illustrates the consonant / vowel category on the above example.

Table 2: Categorizing Individual Letters of an Input Text

Alphabet of the typed word	**Keyboard Equivalent**		**Category**
	Consonant	**Vowel**	
ሞ	m (**ሞ**)		Group1
ር	r (**ረ**)	E	Non-group1
ካ	k (**ከ**)	A	Non-group1
ቶ	t (**ተ**)	O	Non-group1

The system checks the category of each individual letter as consonant or vowel-containing. This is carried out just by deciding whether a letter has a vowel (Non-group1) or not. If a letter does not have a vowel, then it is a consonant which is directed to hand shape library to refer for the right hand shape from group1 set. But if the letter contains a vowel (Non-group1), the

letter is supposed to be directed to both hand movement definition set and hand shape library, so as to prepare the right input for the avatar. Hand movement definition is a set of defined rule that is directly associated with the 6 hand movements corresponding with the 6 vowels. These movement definitions are applied on the shoulder-joint and the elbow joint of the avatar's hand (see figure 6). The hand shape definition library is the set of pre-defined hand shape movie clip for each of the group1 letters of Geez alphabet as shown in Figure 1. These two components, the hand movement definition set and the hand shape library integrate their information and provide the right information to the avatar. This process is repeatedly iterated until there is no other letter is left in the queue to generate an ESL finger spelling word.

Translation algorithm

The translation algorithm shows a step-by-step transition of the translation process passing through each component.

Step 1: Enter an Amharic word by using the phonetic mode of power Gee'z.

Step 2: If unsigned character is available:

pick one character and identify the character's behavior based on the two categories, Group 1 letter or none group 1 letter.

Sub procedure:

If the input letter contains either of the 6 vowel sounds (a, u, i, a, y and o), then it is identified as vowel containing (none-group 1).

Otherwise, it is a group 1 letter.

Step 3: If the letter is group 1, then it picks the correct hand shape for the hand shape library. Otherwise, pick the correct hand shape for the hand shape library and refer the right type of hand movement corresponding with the attached vowel.

Step 4: Integrate the hand shape information and the hand movement definition and provide- input it to the avatar.

Step 5: Go to step 1.

Modeling the avatar

An avatar in this research is an animating object that resembles and acts as a human ESL finger spelling translator. The avatar is constructed with only a torso, and the upper torso limbs: two hands, and a head. Only the right hand of the avatar is dynamically associated with the different translation operations, and is by considering the avatar as a right-handed translator. The basic joints of the hand to determine hand motion are taken as the shoulder-joint and the elbow. Shoulder-joint connects the avatars shoulder with its upper-arm and an elbow connects the fore-arm with the upper arm.

The white point at the avatar's right shoulder is the shoulder joint and the dotted selection shows the rotational movement of its right hand from the shoulder.

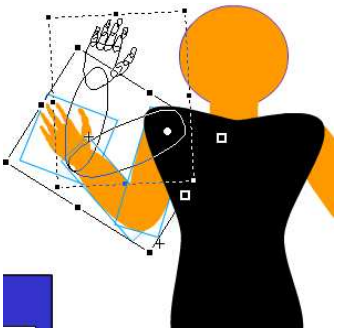


Figure 6: Shoulder joint hand movement of the avatar

As shown in the figure 6, Rotational operation is applied on the shoulder-joint and the elbow to generate the required hand movement on ESL finger spelling. The shoulder-joint rotation and the elbow joint rotation integrate to create a virtual realism to the 6 hand movements associated with the 6 vowels of the Geez alphabet. The hand shapes of the avatars right hand are carefully modeled having similar shape with the actual hand shape and stored in the library window of Macromedia Flash. Each of the 34 base letters are designed and stored in the library as a movie clip (one of

Macromedia Flash's symbol type that can be manipulated and called by an action script language). The resemblance sample between the avatar's hand at design mode and the real picture of the letter "ሀ" is shown in figure 7.

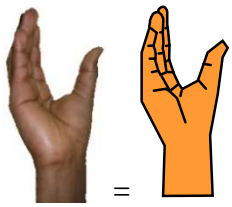


Figure 7: Design of avatar's hand shape as compared to real hand shape picture

Hand shape modeling needs to consider each of the five fingers independently in five different layers. And each finger consists three sections (knuckles). Here also, rotational operation is applied on each fingers and finger knuckles. Note that each finger is separately treated as a movie clip symbol and even the three knuckles of each finger are treated as movie clips. These components are converted to movie clips because movie clips are highly interactive with action script of Macromedia Flash.

Each of these components of the avatar are named and layered in Macromedia Flash 8. The following figure shows the snapshot of the avatar in Macromedia Flash 8.

Text matching analysis

Matching the Amharic text input with the hand shape library and associated with hand movement definitions of the system follows the procedure demonstrated in the machine translation model. But the internal text matching analysis passes through some technical steps. As mentioned in the model, texts are first broken into their individual constituents as consonant and vowel-containing. There is a method that identifies the category of each letter of the input text as consonant or vowel-containing by

returning Boolean information as True for Consonant (group1) input and false otherwise. This method identifies the category of each letter simply by referring the phonetic mode key-board input for each letter. If a letter is phonetically typed being accompanied by any of the 6 vowels (a, u, i, y, e and o), then this indicates that it contains a vowel. For instance, this module returns True if "ቨ" is typed and False if "ቩ" is typed. Note that we can use this module only by associating True with group1 alphabets and False with the remaining none-group1 alphabets. It is only the None-group1 elements (Vowels) that need hand movement definition. Any letter, group1 or none-group1 element, have its own hand shape definition. Hence, hand shape definition does not depend on this module but hand movements are referred only if this module returns False.

As mentioned earlier, hand shape definitions are designed by modeling the avatar's right hand as shown in figure 7 for the 34 base letters of ESL finger alphabet. Each of these hand shapes is stored in a library of Macromedia Flash 8.0 being compatible with action script operation. The action script code is responsible to switch between the different hand-shapes needed for each alphabet of the typed input text; 34 hand shapes are designed and stored in the macromedia flash library as movie clip. Switching between these hand shapes is done by taking different layering display levels that hides the image at the lower display level compared with the current display level. Note that hand shapes are changed only for different base letters (group1) or in other words, for different consonants. For example there is no hand shape change between "ሶሠ" and "ሶሧ" because they have common base letter "ሶሠ". Therefore the two letters have common hand shape. There is a module that can switch hand shapes by matching the Unicode of the input letter with that of the stored hand shape movie clip in the library associated with the input Unicode. This module returns a link to the right movie clip for a given Unicode input.

Hand movement definitions are defined based on the avatars two joints: the elbow (Hinge joint between the forearm and upper arm) and the shoulder joint (joint between upper arm and shoulder). Flexible rotational operations on these two joints suffice to show the 6 different hand movements for group2 though group7. First, a default rotational angle is set to 0^0 with a reference of the vertical avatars standing direction for both joints. Vertical and horizontal referencing is frequently applied to the rotational operation to result on the right hand movement. Additional operations like scaling and translation (movement) are slightly applied to create virtual realism.

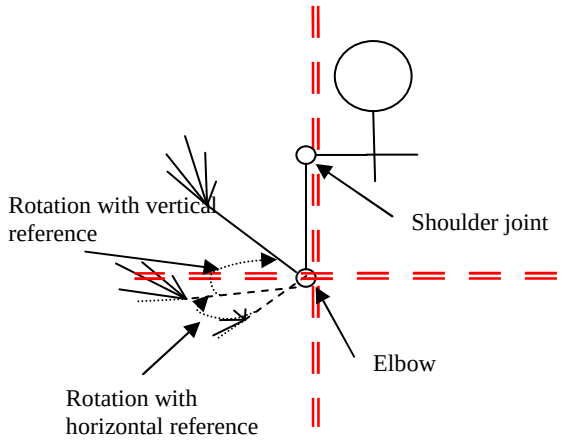


Figure 8: Rotational Movements

Stick picture shows the rotational operations applied on the elbow of the avatar's hand with respect to the vertical and the horizontal references.

Testing the avatar

Ethiopian Signs Language uses two basic approaches to communicate: conceptual signing and finger alphabet, but there is even a hybrid approach called 'initialization' that uses both finger spelling and conceptual signing (Legesse, 2008). As stated on the scope of this document,

this study is limited to ESL finger spelling only. Even if finger spelling is very crucial for the fluency of ESL and can convey meaning by itself, it is least frequently used in ESL. ESL most commonly uses the conceptual signing, so identification of the target group of this system is the first step of testing. Hence both deaf people and hearing people are identified. Testing this system obviously needs the involvement of deaf people who communicate by ESL and who can read and write Amharic text, so I tried to get as many of such people as possible. The avatar translation system is provided for 10 different criteria fitting people, with a questionnaire to evaluate the avatar where some of them have also repeatedly tested it (two of them responded twice for two different tests).

The testing parameters are identified as:

1. quality of rendering ESL finger alphabets by avatars hand shapes;
2. hand movement performance;
3. quality of animation transition from one ESL finger alphabet to the other;
4. general amount of Amharic sample texts correctly translated;
5. quality of rendering an accurate ESL finger alphabet word;

Based on these parameters, 12 different responses have been collected from 10 deaf people, where two of them responded twice.

Table 4: Statistical Illustration of the Respondent on the first 4 Objective Parameters

Parameter	**Options**	**Respondents**	
		Frequency	**Percentage**
Quality of hand shape for ESL finger alphabet	Was correct	6	50
	Medium	4	33.3
	Was not correct	2	16.67
Hand movement quality	Was correct	4	33.3
	Medium	4	33.3
	Was not correct	4	33.3
Was there Animation transition quality problem?	No problem	4	33.3
	Little problem	5	41.67
	Serious problem	3	25
Amount of Amharic sample texts correctly translated	More than half	7	58.33
	Half	-	0
	Less than half	4	33.33

Even if almost all respondents have appreciated the study mentioning that such studies are quite uncommon, they also pointed out some serious problems. These problems are observed on the hand movement quality and animation transition between two ESL finger spellings as shown in the above table. Such problems appeared because the avatar translates in a 2-dimensional plane. In fact 3-dimensional spaces are very crucial for rendering any sign language. Most of the respondents from the user satisfaction analysis, recommended a 3D animation technique to cover the failures of this system.

Conclusions

ESL lacks a standard writing system and besides very limited studies has been conducted on ESL finger spelling, despite the fact that it is quite

necessary to help the existing communication gap between hearing people and the deaf. Animating any character is a challenging task, especially when the animation is humanoid and intended to act as a human. Avatar construction is quite different from other animations because, avatars need to have some more heuristics of human operations.

In this research, an attempt is made to adopt a machine translation approach to translate Amharic text into ESL finger alphabet word. The machine translation architecture is adopted from Interlingua system of the three-level Machine Translation Architecture. The adopted architecture and the translation model are designed in such a way that it can be a good input for any researcher who want to improve this system or even to construct ones own avatar on other platforms or other media.

Recommendations

A number of shortcomings can be observed from this research that may initialize further similar studies. The following issues need to be considered to complement the study area.

- It is quite convincing to use avatar based machine translation especially for Sign language related researches. From the literatures reviewed in this research and performance analysis, it has been observed that using a 3D avatar can definitely better convey sign languages than 2D avatars.
- ESL is complete in both signing and finger spelling. Signing includes the conceptual sign expression which is dominantly applied to convey meaning in ESL. Hence, there is a need to study a Machine Translation of conceptual ESL expressions with a high level heuristic-based animation technique. It is even better if both, the finger spelling and the conceptual expression, could be incorporated together in a single application.

- This research reads only a single word to translate in to ESL finger alphabet expression which is not applicable for a phrase, sentence, or a document translation. Therefore it is necessary to extend the system so that it handles sentences or even a document.
- Identification and classification of nouns and action words (verbs) of ESL is worth studied issue because ESL or any sign language use finger spelling fully or partially for nouns and proper nouns. On the other side, sign languages use of conceptual expression for action words or verbs. This would ease the translation of Amharic text to ESL or other sign language.

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