

# Automated Visualised Translation from English to British Sign Language



Nicolaos Moscholios  
Pembroke College  
University of Oxford

A thesis submitted for the degree of  
*Master of Computer Science*  
Trinity 2016

## **Abstract**

A large number of people in the world today are born deaf and many rely on British Sign Language (BSL), the most widely used method of signed communication in the UK. BSL is structured in a completely different way to English and, like any language, it has its own grammar. In order to create a communication bridge between English speakers and individuals affected by deafness there have been attempts at building a formal model of translation. ...

# Acknowledgements

I would like to thank...

## Notes

The work described in this thesis is available online at [nicmosc.com/bsltranslate](http://nicmosc.com/bsltranslate). Examples discussed throughout the report marked by an asterisk (\*) can be viewed on the website. For demonstrative purposes it is highly suggested that the Examiner try those examples ..

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Motivation . . . . .	1
1.2	Objectives . . . . .	2
1.3	Structure . . . . .	2
<b>2</b>	<b>Background</b>	<b>6</b>
2.1	British Sign Language . . . . .	6
2.1.1	Linguistics . . . . .	6
2.1.2	Online Resources . . . . .	7
2.2	Machine Translation . . . . .	7
2.2.1	Classical . . . . .	7
2.2.2	Statistical . . . . .	7
2.3	Existing Methods . . . . .	7
2.4	Personal Work . . . . .	7
2.5	Summary . . . . .	7
<b>3</b>	<b>Design</b>	<b>8</b>
3.1	Language Choice . . . . .	8
3.2	Translation . . . . .	8
3.3	User Interface . . . . .	8
3.3.1	User Interaction . . . . .	8
3.4	Summary . . . . .	8
<b>4</b>	<b>Implementation</b>	<b>9</b>
4.1	Rule-Based MT in Python . . . . .	10
4.1.1	Pipeline . . . . .	10
4.1.2	System Components . . . . .	10
4.1.2.1	Grammar Tree Transforms . . . . .	10
4.1.2.2	Direct Translation . . . . .	10

4.1.2.3	Special Cases . . . . .	10
4.1.2.4	Output . . . . .	10
4.2	Animation in ThreeJS . . . . .	10
4.2.1	Blender . . . . .	10
4.2.1.1	Model . . . . .	10
4.2.1.2	Skeletal Animation . . . . .	10
4.2.2	Data Format . . . . .	10
4.2.2.1	JSON Formatter . . . . .	10
4.2.3	Animation Engine . . . . .	10
4.2.3.1	Pipeline . . . . .	10
4.2.3.2	ThreeJS . . . . .	10
4.3	Interlingual Communication with Flask . . . . .	10
4.3.1	Python to JavaScript . . . . .	10
4.4	Summary . . . . .	10
<b>5</b>	<b>Evaluation</b>	<b>11</b>
5.1	Translation . . . . .	11
5.1.1	BLEU . . . . .	11
5.2	Animation . . . . .	11
5.3	Survey . . . . .	11
5.4	Feedback . . . . .	11
<b>6</b>	<b>Conclusion</b>	<b>12</b>
6.1	Improvements . . . . .	12
6.1.1	Handling of Agreement Verbs . . . . .	12
6.1.2	Classifiers . . . . .	12
6.2	Expansion . . . . .	12
<b>A</b>	<b>Extra code (appendix)</b>	<b>13</b>
	<b>References</b>	<b>13</b>
	<b>Background Reading</b>	<b>15</b>

# List of Figures

1.1	Conceptual overview of the system . . . . .	3
-----	---	---

# Chapter 1

## Introduction

For most people around the world, communication is achieved orally by speaking. Unfortunately some are born deaf or are affected by hearing impairment with time. It is then necessary to use another medium of communication. Today there are about 1 million "functionally deaf" UK individuals [5], that is, that require the use of sign language to converse. Additionally there are around 11 million people affected by some degree of hearing loss and while many benefit from hearing aids, sign language bypasses the need to speak, making it easy for everyone to understand each other.

### 1.1 Motivation

The problem arises when hearing and Deaf individuals need to communicate. Deaf individuals are taught to read and write English from a young age, but it was found that they have difficulties understanding text with a reading level above that of primary school students [3]. Thus it is not enough for hearing individuals to rely on written text to communicate with their community. More and more people are learning BSL even though they have perfectly fine hearing. There are certificates that can be obtained to work with Deaf individuals [6]. Taking lessons from BSL teachers and practising with the community helps to learn the language.

Online resources such as UCL's BSL Sign Bank [7] and SignBSL.com [1] offer clips of signers showing words and phrases in BSL for learners and curious people?. The main issue is that they are highly static. Analogously to an English dictionary, it is only useful for looking up individual signs and not *translating* phrases. Automated translation has been an ongoing challenge in the field of computational linguistics, and we are finally seeing very positive results thanks to the recent developments in machine learning. Since spoken (written) languages are heavily dependent on their syntactic components, they are relatively easy to formalise in such a way that a



machine can interpret a sentence and perform operations on it to transition from one language to another. More recently, there have also been attempts at doing so with signed languages such as ASL (American Sign Language) and BSL. Given that there is no formally typed grammar for BSL, it is not easy to find a model that encapsulates all key elements involved, such as facial expressions and eye gaze. In addition, since the language is only signed, the only way to see if an interpretation is correct, is through visual output. While some past implementations have been successful, due to the then high computational power necessary to run these systems, most of them are now outdated or have been left at a prototype stage. In 2006, IBM created a fully working system [2] that allowed users to speak and see the translation from English to BSL in real time; however it has been disregarded and is not available any more.

## 1.2 Objectives

This project will build upon previous work and attempt to solve the interlingual translation from English to British Sign Language by implementing a web application where signs are visualised through a virtual avatar. Behaviour will closely follow that of other established translation systems such as Google Translate where users can type a sentence and get a result in real-time. Through rule-based translation methods (discussed in section 2.2) and 3D animation techniques the system will allow users to not only find out what a particular sentence corresponds to in BSL, but also learn and hopefully practice their skills. Figure 1.1 shows a conceptual overview of the system pipeline; this figure will be references multiple times throughout the report.

## 1.3 Structure

The report will read as follows: in chapter 2 we will give a brief introduction to the linguistics British Sign Language and its differences from written English, as well as existing methods of translation from written to written and from written to signed languages. Chapter 3 will cover the design choices for the system, that is, the development environment with the programming languages, the conceptual structure of the pipeline and the end-user interaction. Following up in chapter 4 we explain in detail the implementation of both the translation methods and the animation techniques utilised, as well as the communication between the two modules. Finally chapter 5 will discuss the evaluation of the system both in terms of translation

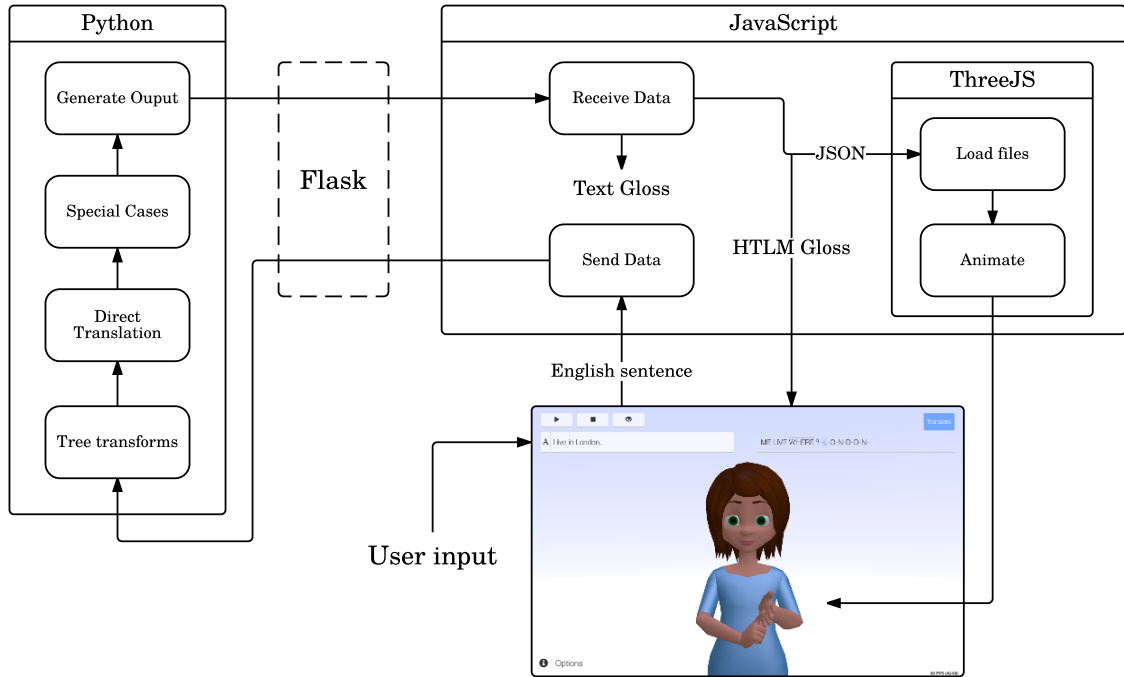


Figure 1.1: Conceptual overview of the system

accuracy and feedback from the user survey, while chapter 6 concludes the report along with project achievements, personal remarks and future work.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper

vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi

quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

# Chapter 2

## Background

### 2.1 British Sign Language

British Sign Language, often shortened to BSL, has been an officially recognised language since 2003 [6]. Like English, it has its own grammar [4] and its own lexicon. While not as large as its written counterpart, there are enough signs to convey the same ideas in sign language, as many can be combined (*compounds*, see section 2.1.1) to create new meanings. However BSL is not the only signed language; each country has their own with different dialects by region. ...

#### 2.1.1 Linguistics

This section will give a short introduction to the linguistics of British Sign Language, including common grammar rules, its morphology and how it differs from written English. Please note that only the most general information is described here, that is enough to follow concepts described in section 2.3 and the implementation of the system (section 4).

### **2.1.2 Online Resources**

## **2.2 Machine Translation**

### **2.2.1 Classical**

### **2.2.2 Statistical**

## **2.3 Existing Methods**

## **2.4 Personal Work**

## **2.5 Summary**

# Chapter 3

## Design

### 3.1 Language Choice

### 3.2 Translation

### 3.3 User Interface

#### 3.3.1 User Interaction

### 3.4 Summary





# Chapter 4

## Implementation

### 4.1 Rule-Based MT in Python

#### 4.1.1 Pipeline

#### 4.1.2 System Components

##### 4.1.2.1 Grammar Tree Transforms

##### 4.1.2.2 Direct Translation

##### 4.1.2.3 Special Cases

##### 4.1.2.4 Output

### 4.2 Animation in ThreeJS

#### 4.2.1 Blender

##### 4.2.1.1 Model

##### 4.2.1.2 Skeletal Animation

#### 4.2.2 Data Format

##### 4.2.2.1 JSON Formatter

#### 4.2.3 Animation Engine

##### 4.2.3.1 Pipeline

##### 4.2.3.2 ThreeJS

### 4.3 Interlingual Communication with Flask

#### 4.3.1 Python to JavaScript

### 4.4 Summary

# Chapter 5

## Evaluation

### 5.1 Translation

#### 5.1.1 BLEU

### 5.2 Animation

### 5.3 Survey

### 5.4 Feedback

# Chapter 6

## Conclusion

### 6.1 Improvements

#### 6.1.1 Handling of Agreement Verbs

#### 6.1.2 Classifiers

### 6.2 Expansion

# Appendix A

## Extra code (appendix)

# References

- [1] Sign BSL. Bsl sign language dictionary. [Online; accessed 30-July-2016]. URL: <http://www.signbsl.com>.
- [2] IBM. Say it sign it, 2007. [Online; accessed 14-February-2016]. URL: <https://www-03.ibm.com/press/us/en/pressrelease/22316.wss>.
- [3] Sue Lewis. Supporting reading within an auditory oral approach. In *International Conference on Deaf Education*. University of Edimburgh, 1997. URL: <http://threejs.org>.
- [4] Action on Hearing Loss. Deafness. [Online; accessed 14-February-2016]. URL: <http://www.actiononhearingloss.org.uk/your-hearing/about-deafness-and-hearing-loss/deafness/myths-about-deafness.aspx>.
- [5] Action on Hearing Loss. Statistics. [Online; accessed 20-April-2016]. URL: <https://www.actiononhearingloss.org.uk/your-hearing/about-deafness-and-hearing-loss/statistics.aspx>.
- [6] Signature. British sign language. [Online; accessed 30-July-2016]. URL: <http://www.signature.org.uk/british-sign-language>.
- [7] UCL. Bsl sign bank. [Online; accessed 30-July-2016]. URL: <http://bslsignbank.ucl.ac.uk/>.

# Background Reading

Rachel Sutton-Spence and Bencie Woll. *The Linguistics of British Sign Language: An Introduction*. Cambridge University Press, The Edinburgh Building, Cambridge, 1999.