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Increasing the Usefulness of an NLP-Based Transportation Query System

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Abstract

BusTUC is a Natural Language Processing (NLP)-based system for bus information in Trondheim, Norway. This project reviews the theoretical background for BusTUC and relevant technology, with a focus on handling natural language. It then assesses the demand for various possible improvements to the system by conducting a survey, yielding both queries perceived as useful and a ranking of improvements. Through the findings of the literature review and an analysis of the survey's results, the research concludes with a collection of improvements that are valued highly by potential users, and that are reasonable to implement as part of the BusTUC system. The results of the report lay the groundwork for implementation to be done in a later project. This future work is also briefly outlined in the last chapter.

Preface

This report is the result of work done for *TDT4501 – Computer Science, Specialization Project* at the Norwegian University of Science and Technology in Trondheim, Norway. Everything took place during the autumn semester of 2014, with Rune Sætre as the supervisor.

Acknowledgements

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Erling Wishman Eeg-Henriksen
Trondheim, December 17, 2014

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Glossary

ASR Automatic Speech Recognition. 10

AtB Trondheim's main bus company.. 2, 7–9, 11, 24, 26, 31

BNF Backus-Naur form. 4

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CBR Case-based Reasoning. 10

CFG Context-Free Grammar. 4, 5

CWA Closed World Assumption. 6

DCG Definite Clause Grammar. 4, 5

FUIROS Future's Ultimate Intelligent Route-Organizing System. iv, 7, 9, 13, 26, 27, 29, 32

GPS Global Positioning System. 9, 10, 25, 26, 49, 50

IDI Department of Computer and Information Science. 8, 9

NLP Natural Language Processing. iii, 2–4, 10, 13, 25

NUST the Norwegian University of Science and Technology. 7, 10

SMS Short Message Service. 9

TABuss Tore Amble Buss. 9, 10, 25

TTS Text-To-Speech. 10

TUC The Understanding Computer. 7

XG Extraposition Grammar. 5

Chapter 1

Introduction

This report describes work done on a natural language processing system for bus-related queries. The goal is to discover how to best extend its current functionality in order to increase its usefulness. The system to be improved is BusTUC, a system allowing users to send natural language queries for information about bus routes in Trondheim, Norway.

1.1 Task text

> *What is the most natural way to get information about bus scedules or other well organised and structured data?*
>
> *The task will be to extend the functionality of the spoken natural language query system to include support for some other useful and possibly relevant information. Such information could be train routes (NSB), other train information, or possibly opening hours of for example Trondheim Torg or Studentersamfundet. If opening hours for popular destinations are included, one might extend the system to answer questions such as "first bus to Trondheim Torg" better: that is, the first bus that will drop you off by an open Trondheim Torg.*
>
> *One should look at different ways to include this functionality, as well as the consequences for the system as a whole. This could mean investigating user behavior and service quality. For example, what do users think of the system's usefulness and user-friendliness (with this extension)? And could one type of question be easily confused with another and damage the usefulness of the system? With a prototype in place one could then investigate the actual consequences, and see if any parts of the system could be changed to provide better service overall.*

1.2 Motivation

For many people, public transportation has become an essential part of daily life. The accessibility of information about the available public transportation is therefore very important to companies offering such services. Considering the often constant presence of mobile devices, and the availability of Internet connections, letting such information exist solely in the form of brochures and posters on public transportation stations is insufficient. Because of this, most companies offering such transportation also offer information through both websites and cell

phone applications (apps). In addition to these, privately developed applications with similar functionality often spring up as well.

This is also the case in Trondheim, Norway. The bus company AtB runs the buses and offers information in several forms. Numerous independent apps like *Bartebuss*[1] also exist.

One of the services offered by AtB, *Bussorakelet* (*the Bus oracle*) is powered by BusTUC's ability to answer queries in natural language, with natural language. Work has also been done to add spoken natural language support to the system, allowing users to query in a more conversation-like manner.

Much work has gone into BusTUC, but Trondheim's bus information services are still not perfect. If BusTUC is improved, it will improve the usefulness of every product offering BusTUC as part of its service. It would therefore be beneficial to discover which possible areas of improvement are most useful to users, and to plan an expansion of BusTUC's functionality based on this.

1.3 Goals

The overall goals for the project are briefly described below.

G1 *Discover how BusTUC can be made more useful*

The BusTUC system has numerous areas of improvement. In order to make BusTUC even more useful to its users, the improvements desired by users and potential users must be assessed. The structure of BusTUC must also be understood, as well as the concepts, tools and methods upon which it has been built.

G2 *Extend the BusTUC system to support additional useful information*

Based on what functionality users deem useful and the way in which BusTUC and associated technology works, extend the BusTUC's functionality to make it more useful.

1.4 Research questions

This section condenses what the research aims to answer into a few, simple questions.

Q1 *What additional information is it useful for Natural Language Processing (NLP)-based transportation query systems to support?*

Explore what information it would be useful to add support for. Examples could be supporting queries that specify time by a variable (such as opening hours) or possibly even queries about local train routes. As the usefulness of such information is decided by the users, it would be natural to ask for their opinions.

Q2 *How can the BusTUC system best be extended to support such queries?*

This question has two sides to it: The first is best answered by exploring published articles and other works on BusTUC and concepts and systems relevant to it, and combining the findings with the results of Q1. The second is answered by implementing the features found through the above and analyzing the results.

[1] Bartebuss, a bus information application for Trondheim. Available for both Android and iOS devices.

Chapter 2

Related work

This chapter delves into the relevant literature that exists on BusTUC, as well as its relevant systems, technology and NLP theory.

2.1 NLP concepts and methods

This section explores some areas of NLP that are relevant and useful to understand when studying BusTUC and similar systems.

2.1.1 Computational Semantics

"Computational semantics" refers to the study of how one can automate the construction of formal models describing the meaning of natural language phrases. This section gives an overview of some relevant concepts and procedures in this field of study. It functions as an introduction to the procedure of generating semantic representations usable by machines to understand statements (within their area of "expertise").

[Blackburn and Bos, 2003] gives an introduction to representation of natural language, as well as inference on such representations. They divide the field in two by asking how one can automate the creation of semantic representations of natural language, and how one can automate the inference with logical expressions.

Using first-order logic formulas in our models of natural language helps to ensure that the resulting models are both understandable for humans and relatively easily translated into code useful for NLP systems. In the creation of this type of model, one will typically define a *vocabulary*, with which one clearly states what relationships and constants are included in a model.

$$\{\ (\text{BUS66}, 0)\ ,\ (\text{SAMFUNDET}, 0)\ ,\ (\text{BUS}, 1)\ ,\ (\text{STATION}, 1)\ ,\ (\text{STOPSAT}, 2)\ \}$$

In the example vocabulary above, and `STOPSAT` is a relationship taking two arguments, for example `STOPSAT(BUS66,SAMFUNDET)` ("Bus 66" stops at "Samfundet"); while `BUS66` and `SAMFUNDET` are constants, shown by the fact that they take no (`0`) arguments. `BUS` and `STATION`,

being of arity `1`, can here be said to be properties, allowing us to describe single constants as being a bus or a station – for example `BUS(BUS66)` ("Bus 66" is a bus)[1].

The examples above give a peek of how models are defined. Below, a model is described using the vocabulary above, to show that "Bus 66" is a bus and stops at "Samfundet", which is a station. For this model, let the domain D of what the model describes be d_1, d_2. These correspond to the constants in the vocabulary. F is a function which specifies the semantic values of each element of D; in other words, what d_1 and d_2 actually *mean* (referred to as an *interpretation function* in [Blackburn and Bos, 2003, ch. 1]).

$F(BUS66) = d_1$
$F(SAMFUNDET) = d_2$
$F(BUS) = d_1$
$F(STATION) = d_2$
$F(STOPSAT) = d_1, d_2$

With vocabularies and models like the examples above, a "world" is described in a way that allows for a relatively easy transition into first-order logic. Adding rules and further complexity to the model of the world, one will lay the groundwork for first-order inference.

By following these procedures, one can design software capable of reasoning within its domain (for example, bus travel in Trondheim) when given statements or questions in first-order form. And sentences in natural language can be given this form – much like the transformation from meaning to model, the first steps of which were exemplified above.

2.1.2 Grammars

In the context of NLP, a *grammar* is a collection of rules for a given language, be it a natural language or not[2]. With the grammar, one can check whether given sentences are valid within the language to which the grammar belongs. Knowing this, the importance of grammars for NLP systems becomes apparent.

Definite clause grammars

A Definite Clause Grammar (DCG), as described in [Pereira and Warren, 1980], is a formalism in which one expresses grammars with first-order predicate logic, a method of language representation outlined in section 2.1.1 (and given a concrete, practical example in section 2.2.1's Listing 2.2). They are a special case of Colmerauer's *Metamorphosis grammars* [Colmerauer, 1978][3]. DCGs are descriptions of language, but being in first-order logic they can be written as Prolog code, and thus in themselves become usable parts in language computation.

A related category of grammars is the Context-Free Grammar (CFG). Also known as Backus-Naur form (BNF), the CFGs work with an *alphabet* containing *terminal* and *non-terminal* symbols. These are then used to represent words and phrases of the language, respectively. In CFGs, each rule is defined as a non-terminal equal to a certain sequence of symbols (both terminal and non-terminal), thus defining a valid form of non-terminals. The mentioned section 2.2.1's Listing 2.2 gives an example of a sentence analyzed in the context of a CFG, as such analysis produces a *parse tree* which visualizes the internal hierarchy of the sentence's parts.

Rules of CFGs can be expressed in logic, creating *definite clauses* (often called*Horn clauses*), making the connection to DCGs clear. DCG is the result of a generalization of the process of

[1] Note that one could alternatively let `BUS` and `STATION` be constants, and use a relation `(IS_A,2)` to describe "Bus 66" being a bus and "Samfundet" being a station.

[2] For example, a programming language

[3] This appears to be a translation of, and therefore published later than, the original.

creating definite clauses from CFGs. A collection of definite clauses of a CFG can form a program in Prolog that efficiently parses sentences, creating a parse tree from the top and down. With DCG, non-terminals may be compound terms, for example a noun phrase `np( X, S)` where `S` is a sentence. Furthermore, in the definition of a rule, one may also include procedure calls that create additional conditions for the rule to be valid. Implementing this in Prolog, a grammar can be made that, when used to analyze a sentence, classifies and creates a hierarchy for the sentence's parts. The result is easily visualized. Such analysis allows a program to decide whether a sentence makes sense, and if it does, use the result of the analysis to accomplish its goal (for example providing information corresponding to an input question).

Extraposition grammars

The BusTUC system's grammar, *Consensical Grammar*, is a version of the Extraposition Grammar (XG) [Pereira, 1981], which again is a generalization of the Definite Clause Grammar (DCG) described in section 2.1.2. With the background provided by that section, this one gives an introduction to XGs.

In natural language, one often encounters sentences containing an unknown, which in the sentence is replaced by for example *that*. An example is the sentence:

The man that Alice killed was a zombie.

For this sentence, one could say that there is a corresponding sentence *Alice killed [?]*, where one does not know who was killed from the previous sentence. In the first sentence, Alice's victim is extraposed (hence the name *extraposition grammar*) to the left , in the form of *that*, which represents the unknown victim. Pereira marks this with t for the trace, what replaces the unknown noun phrase (in this case, the victim); and with i, denoting the relationship between our unknown victim t and *that*, the representative of this missing part. This results in the following representation:

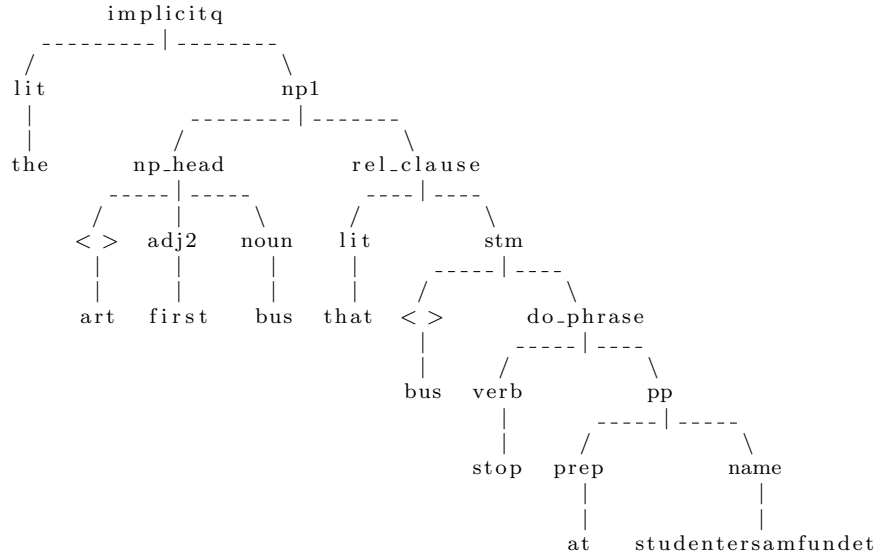
The man that$_i$ [Alice killed t_i] was a zombie.

Note how the hypothetical sentence involving t is included, and i marks t's relation to *that*. There are numerous other sides to this approach, such as the constraint that one for a given noun phrase cannot have a relative pronoun that is both outside the noun phrase, and referring to a relative clause inside the noun phrase. However, these are outside the scope of this report. To give an example of the important of this type of grammar in BusTUC, the following, similar input is given to the system:

"The first bus that stops at Samfundet"

By observing the tree BusTUC constructs for the query, one can locate the treatment of a relative clause in extraposition grammar as outlined above: see Listing 2.1's "`rel_clause`", with "`that`" representing the bus that stops at "*Studentersamfundet*" ("`bus`", "`stop`", "`at`", "`studentersamfundet`").

Listing 2.1: Output tree for "The first bus that stops at Samfundet"



2.1.3 Prolog

In section 2.1.1, parts of the area of computational semantics were outlined, and examples were given for vocabularies and models. Their purpose was to demonstrate the establishment of representations that may easily be used to create a system capable of reasoning within its domain. [Blackburn and Bos, 2003]'s descriptions of the implementation step involve using Prolog, a logical programming language excellent at this type of work. As BusTUC is written in SICStus Prolog[4] (which is an implementation of ISO-Prolog[5]) some examples are given below to show a glimpse of the structure of Prolog in practice.

Building on the examples in 2.1.1, the vocabulary would in Prolog look like this:

```
relation(stopsat,2).
relation(bus,1).
relation(station,1).
constant(buss66).
constant(samfundet).
```

Using the vocabulary defined in Prolog above, the model becomes:

```
[bus(bus66),station(samfundet),stopsat(bus66,samfundet)]
```

Note that with Prolog, one here follows the Closed World Assumption (CWA) [Reiter, 1978], meaning that what is not modeled as *true* is implicitly given as *false*. For example, it is not ambiguous whether Bus 66 is also a station – the absence of "`station(buss66).`" means that Bus 66 is (in Prolog's eyes) *not a station*.

A practical query example from BusTUC is given as:

```
[which(A):::(dragvoll isa station,B isa bus,A isa time,
             dob/leave/B/dragvoll/C,srel/in/time/A/C,event/real/C)]
```

[4]https://www.sics.se/projects/sicstus-prolog-leading-prolog-technology
[5]http://www.deransart.fr//prolog/docs.html

Here one sees that the initial question has been transformed into a form with which a model established as above (though obviously a far more complex model) can be queried. Prolog will go through its rules in order to find an `A` that fulfills the given conditions (being the time at which a bus `B`, leaves the `station` named `Dragvoll`).

2.2 FUIROS

This section explores the Future's Ultimate Intelligent Route-Organizing System (FUIROS) project, which aims to create the ultimate information system for bus routes in Trondheim, Norway. As BusTUC is a part of this project, this section provides it with both an explanation and a context.

2.2.1 BusTUC

The BusTUC system, described in [Amble, 2000], is the heart of the FUIROS project. It is built as a special application of the more general The Understanding Computer (TUC) system for language comprehension. TUC is described (along with a brief introduction to BusTUC) in [Amble, 2004], and was built to carry on the results of even earlier projects at the Norwegian University of Science and Technology (NUST) that could easily be adapted to more specialized use.

BusTUC's application of TUC is made to process and answer queries about the bus routes in Trondheim. In 1999 it became a part of the services offered by AtB, and its service is used in several other applications as well. The functionality of BusTUC is achieved through a large number of rules, implemented in Prolog (section 2.1.3), which the system churns through to provide an answer to each query. Given a question in one of its supported languages (Norwegian and English), it will go through its grammar rules in order to understand what information is required. By breaking down the query to comprehend it in this way, BusTUC lets users submit questions without any requirements for how the question is phrased. This allows users to write their question the way they feel is natural, and despite the large number of possible ways to phrase a question, the system will handle the rest.

BusTUC accomplishes the above through its three main components:

1. A parser system for natural language input

   The parser system contains a dictionary, a grammar, a lexical processor and a parser.

2. A knowledge base

   The knowledge base has two parts: one for semantics and one for the application.

3. A query processor

   The query processor contains a database and a logic system for routing.

As section 2.1.2 explains, BusTUC uses a variant of Extraposition Grammar called Consensical Grammar – "CONtext SENSItive CompositionAL Grammar". With Compositional Grammars, the semantics of a phrase is gained from the semantics of the phrase's sub-phrases. BusTUC's parser system uses this grammar for statements, and converts questions into a statement-based form. For example, a question like "Which bus stops at Lade?" would become closer to "For which X is it true that X is a bus that stops at Lade?". The statement is in this case "X is a bus that stops at Lade". BusTUC then analyzes the statement to find out what fits the

statement about "X". To accomplish disambiguation of the meaning of input, the parser discards semantically wrong parses early, prioritizes long (and semantically correct) interpretations of phrases, and is forced to make some committed choices along the way[6].

The rules necessary for BusTUC to understand its copies of AtB's bus routes, such as for example definitions of bus stops, form one of the most important parts of the system. The semantic knowledge base contains information on the meaning of words and how they work, and is the source of most of the logic of BusTUC's "world". It is also the place changes are made, while the dictionary and grammar are kept constant.

Much of the work performed by the query processor is to identify requested information about a certain event, such as the time of a departure. Below are some examples of queries that the resulting system can answer, along with the returned information. "Q" and "A" mark questions and their answers, respectively. When only one location is given, the other place (destination or origin) is assumed to be Trondheim's city center.

Q: *When does the bus leave Dragvoll?*

> **A:** Bus 9 passes by Dragvoll at 1:05 pm and at 1:25 pm and arrives at Sentrumsterminalen, 24-31 minutes later. Bus 5 passes by Dragvoll at 1:12 pm and arrives at Kongens gate K1, 18 minutes later. Bus 5 passes by NTNU Dragvoll at 1:13 pm and arrives at Kongens gate K1, 17 minutes later. Bus 36 passes by NTNU Dragvoll at 1:16 pm and arrives at Sentrumsterminalen, 14-18 minutes later. Bus 66 passes by NTNU Dragvoll at 1:17 pm and arrives at Munkegata M1, 32 minutes later. The hours indicate the earliest passing times.

Q: *From Nardo to City Syd*

> **A:** The station nearest to Nardo is Nardosenteret. Bus 8 goes from Nardosenteret at 1:16 pm to Prof. Brochs gate at 1:23 pm and bus 46 goes from Prof. Brochs gate at 1:41 pm to John Aaes veg at 1:49 pm. The hours indicate the earliest passing times.

Q: *What is the cheapest bus to Oslo?*

> **A:** I have only routes for buses in Trondheim.

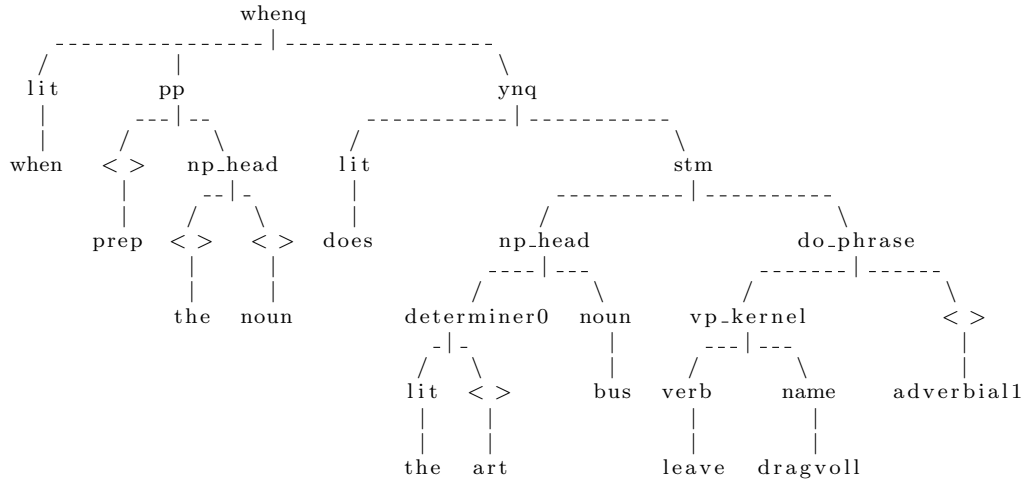
The questions above were asked and answered through the "Bus Oracle" feature on AtB's web pages[7], which use BusTUC for this feature. However, to get a more visual demonstration of BusTUC's query breakdown, one can use BusTUC's website[8] at Department of Computer and Information Science (IDI) and select the *tree* option. The tree in listing 2.2 shows the output given when we request query breakdown information in the manner above, for the query *When does the bus leave Dragvoll?* from the table above. This gives a decent illustration of the way BusTUC understands queries.

[6] Such "cuts" are made at certain places in the grammar, blocking backtracking past the cut, but is a necessity. One cannot expect infinite backtracking ability.

[7] https://www.atb.no/ (as of December 17, 2014)

[8] http://busstuc.idi.ntnu.no/ (as of November 2014)

Listing 2.2: Output tree for "When does the bus leave Dragvoll?"




```
[which(A):::(dragvoll isa station,B isa bus,A isa time,
             dob/leave/B/dragvoll/C,srel/in/time/A/C,event/real/C)]
```

Below the tree in listing 2.2, we also see the resulting logical expression that is generated from the query. This is the form in which the question is handled when BusTUC attempts to produce the necessary information for the user, through rules established as described in sections 2.1.1 and 2.1.3.

2.2.2 Applications of BusTUC

As mentioned, there are several other services using BusTUC as well. This section introduces some extensions to and applications of BusTUC, both within and outside the FUIROS project. The interfaces offered through AtB and IDI's web pages[9] have already been mentioned, and as a consequence of their simplicity, they require no further explanation. The same "bus oracle" functionality is also included in the popular Bartebuss[10] application for mobile devices. Another relatively simple side of BusTUC is the Short Message Service (SMS) interface it offers. This works just like the "normal" BusTUC, but gives shorter answers to avoid making lengthy (or numerous) SMS messages necessary. Some applications that require longer descriptions are outlined below.

TABuss

Tore Amble Buss (TABuss) [Marcussen and Eliassen, 2011] is a mobile application for the Android[11] platform, and provides helpful information to bus travellers. It is based on the work done in [Raaum, 2010], which created an Android application capable of taking real-time bus data, user Global Positioning System (GPS) location and bus stop GPS locations into account and use this to provide helpful information through BusTUC. Marcussen and Eliassen expanded and tested this to produce an improved result which is available on Google Play[12][13].

[9] AtB: https://www.atb.no/ , IDI: http://busstuc.idi.ntnu.no/ (as of December 17, 2014)
[10] https://play.google.com/store/apps/details?id=com.runemartin.bartebuss (as of December 17, 2014)
[11] https://www.android.com/ (as of December 17, 2014)
[12] Google Play: https://play.google.com/store/ (as of December 17, 2014)
[13] TABuss: https://play.google.com/store/apps/details?id=test.BusTUC (as of December 17, 2014)

Raaum's application provides a field for query input, along with a map with the user and bus stops marked, and text output. TABuss displays a similar input field, lists input suggestions and has separate answer and map screens. Because their context awareness through GPS support allows automatic fetching of the user's location, both versions provide answers to destination-only input.

MultiBRIS

Made in parallel with TABuss, MultiBRIS ("A Multiple-platform approach to the Ultimate Bus Route Information System for Mobile Devices") [Andersstuen and Engell, 2011] is a context-aware multi-platform system for mobile devices, outputting bus route information in much the same way as TABuss. As with TABuss, the starting point for MultiBRIS was [Raaum, 2010], but unlike TABuss, its exists on Google Play as a prototype, not a complete application.

Speech-based BusTUC

TaleTUC is the result of the combined work of [Engell, 2012] and [Andersstuen and Marcussen, 2012]. They designed TaleTUC as a proof-of-concept system where TABuss was extended to act as a client in a client-server architecture allowing TABuss to support voice-based querying of TABuss and BusTUC. Like the systems above, this is a context-aware application, and combines Case-based Reasoning (CBR) and Automatic Speech Recognition (ASR) to recognize the names of bus stops in the speech input. With taletuc in TABuss, the input speech is sent to the server, along with device ID and its location. The server has three modules, one for translation between text and speech, and two for case based reasoning. These analyze the information and return the resulting interpretation to TABuss.

BusTUC also has a speech-to-speech system in Norwegian, where for the output of the BUSTER Text-To-Speech (TTS) system [Johnsen et al., 2003, p.125–131], the Norwegian speech engine "Nora" is used to answer the questions in synthesized speech [Engell, 2012]. BUSTER is also part of *Telebuster*, which has been used at NUST before, in a project to provide automatic dialogue-based visitors' guide, *Marvina* [Hartvigsen et al., 2007]. Just like Marvina, the corresponding system for BusTUC supports dialogue-like querying. This allows user to, for example, state where they want to travel *to*, at which point the system will ask them where they want to travel *from*. The reply is then added to the information and the answer is provided in "spoken" Norwegian[14].

2.3 Recent successes

In recent years, NLP-based services have experienced an increased popularity. Apple's[15] "Siri" may be largely to thank for this, as it started much of the attention such services now receive from the general public. Siri is a digital assistant, released for the iPhone[16] in 2011. It uses speech processing to interpret spoken requests, then retrieves and presents an answer to the input. Though Siri has received criticism for imprecise interpretation and slow results [Pogue, 2012], it quickly became a useful tool for many iPhone users. Siri is known to be context aware, adapting to its user over time [Geller, 2012], but Apple has not made much detailed information on Siri's technology available. With iPhones running iOS 8[17], Siri can function as a travel assistant[18] if

[14]This example assumes that all input is understood by the system.
[15]http://www.apple.com/ (as of December 17, 2014)
[16]http://www.apple.com/iphone/ (as of December 17, 2014)
[17]https://www.apple.com/ios/ (as of December 17, 2014)
[18]https://www.apple.com/ios/feature-availability/#siri-directions (as of December 17, 2014)

the user is in a supported area.

Google's[19] "Google Now"[20], unveiled in 2012 [Needleman, 2012], is Google's equivalent of Siri, and has received much praise, sometimes in contrast to Siri. It was named "Innovation of the Year" of 2012 by the magazine "Popular Science" and is also context aware. As Google Now works well with Google's other services, its quality as a route planner is not surprising. It can even detect the user's travel patterns and email topics, and use that to offer useful information [Manjunath, 2014]. Google Maps[21] already offers route planning for pedestrians and car drivers, and if data is available for the area it will work for public transportation as well. Google Maps already has some BusTUC-like functionality, allowing text-based queries like "from Moholt to Lade". However, Google Maps does not currently include data on AtB's buses. Should this change, it would introduce Google Maps as a major competitor of BusTUC.

[19] https://www.google.com/intl/en/about/ (as of December 17, 2014)
[20] http://www.google.com/landing/now/ (as of December 17, 2014)
[21] https://www.google.no/maps/ (as of December 17, 2014)

Chapter 3

Method

To answer the first research question, it is appropriate to ask users and potential users, as they are the ones who ultimately decide the usefulness of the system, rather than the system's designers. What do people expect from NLP-based query systems for bus route information? This chapter describes the creation and distribution of a survey with the purpose of assessing this.

3.1 Distribution

The first version of the survey was distributed through Facebook[1], a social network, and advice on timing[2] was followed. However, the number of participants gained was insufficient. This approach worked reasonably well for another FUIROS project done in parallel with this report, but Facebook's algorithm for spreading posts does not treat everything as equal, and people's enthusiasm for surveys while browsing Facebook is not necessarily high. That same project group had already tried personally cunducting surveys at bus stops, but they found that the limited time (before people leave by bus), limited willingness to answer surveys, and limited parallelism (one person at a time) made it far too inefficient.

The manner of distribution was therefore chosen to be *SampleSize*[3], a survey-focused section of Reddit[4], an extremely diversely multifaceted online discussion platform. Given that the purpose of *SampleSize* is to provide and answer surveys of all kinds, and its acceptable level of activity, it quickly yielded results that were sufficiantly numerous, but also few enough for the manual treatment performed below.

3.2 Creation

When people can choose whether or not to answer a survey, they are far more likely to answer if it seems easy to do so. This was even confirmed specifically for the *SampleSize* community in a survey it did on and about itself[5]. This project's survey was therefore made as simple as it could be while providing the desired information, and no questions were made mandatory. In the creation of the survey, advice from Kelley et al. [2003] on the style of a survey was also heeded.

[1] https://www.facebook.com/ (as of December 17, 2014)
[2] http://blog.surepayroll.com/post-pin-tweet-best-time-to-outreach/ (as of December 17, 2014)
[3] http://www.reddit.com/r/samplesize (as of December 17, 2014)
[4] http://www.reddit.com/
[5] http://www.reddit.com/r/SampleSize/comments/ticys/results_from_the_meta_survey_about_surveys/ (as of December 17, 2014)

The survey was created using Google Forms[6], a free online tool for conducting surveys.

3.3 Survey content

The survey is described below, and the "raw" survey can be seen in A.

SQ1 *Occupation*
This question gathered ensured a minimum of information about the participant, by asking if (s)he is primarily a student, working, retired or "unemployed / other".

SQ2 *Frequency*
The purpose of this question is to gain a measure of the extent to which the participant is similar to target market of BusTUC system and the services it supports.

SQ3 *Location*
As travelling in the countryside can be quite different from travel in a city, capturing this information could be useful. This question thus gathers more information on the "relevance" of the participant.

SQ4 *Information sources*
How does the participant *currently* get information about bus routes?

SQ5 *Query suggestions*
Participants are asked to suggest a few questions for the system, given what they know.

SQ6 *Improvements*
This question asks the participant which improvements seem the most useful, with references to BusTUC's current functionality for context. The alternatives were:

1. "Chronological list of stops for a bus (currently alphabetical)"
2. "Final stop for a given bus"
3. "Time variables, such as opening hour information" (support for this would allow queries like "from Moholt to Trondheim Torg at opening hour". Other variables could be requested in SQ7.)
4. "Support for train information"
5. "Support for the buses between Trondheim and its airport"
6. "Something else" (to be specified in the answer to SQ7)

SQ7 *Further Input*
Participants may enter further ideas here.

[6]Google Forms, http://www.google.com/forms/about/ (2014-11-03).

Chapter 4

Results

This chapter presents the results of the survey described in section 3.3 (see appendix A for the survey itself).

4.1 Participants

The survey received 62 responses in total, presumably[1] from 62 different individuals. This section shows the answers collected from the questions that were focused on establishing some basic background knowledge on the people who answered the survey.

4.1.1 Occupation (SQ1)

Of the 62 participants, 40 (65 %) were students and 22 (35 %) were workers. It is likely that some were both, but the participants were asked to choose that which best described them. None (0 %) described themselves as primarily retired, unemployed or "other". Figure 4.1 displays the distribution.

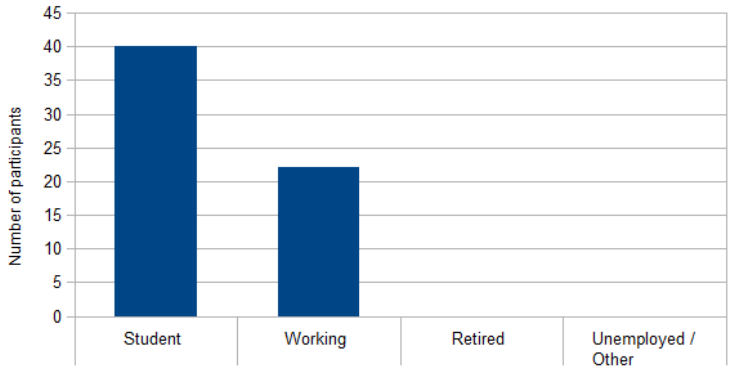


Figure 4.1: Answers to SQ1.

[1] No guard against multiple responses was added, as it would require logging in with a Google account, which might discourage some participants.

4.1.2 Frequency (SQ2)

Eight (13 %) participants do not use any kind of public transportation, while five (8 %) of them use some, but not buses. Twelve (19 %) use buses less than once a week, nine (15 %) use them one to four times a week, fourteen (23 %) use them five to eight times, and nine (15 %) use them nine to twelve times a week. Five (8 %) of the participants travel by bus more than twelve times during an average week. Figure 4.2 provides a visual comparison of the numbers.

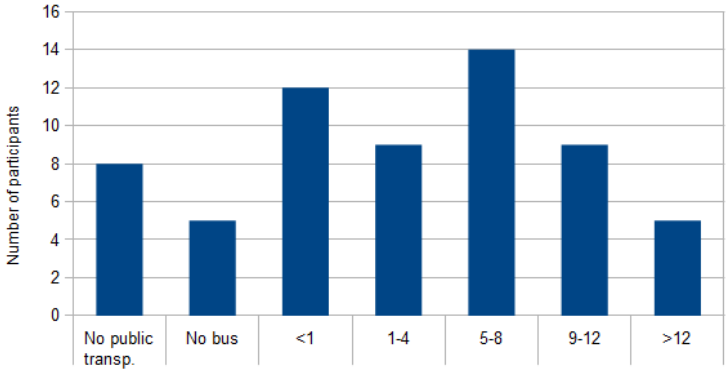


Figure 4.2: Answers to SQ2.

4.1.3 Location (SQ3)

When asked about their primary location for bus travel, 45 (73 %) answered that they travel in a city, while 5 (8 %) travel outside of cities and 12 (19 %) do not travel by bus (Figure 4.3).

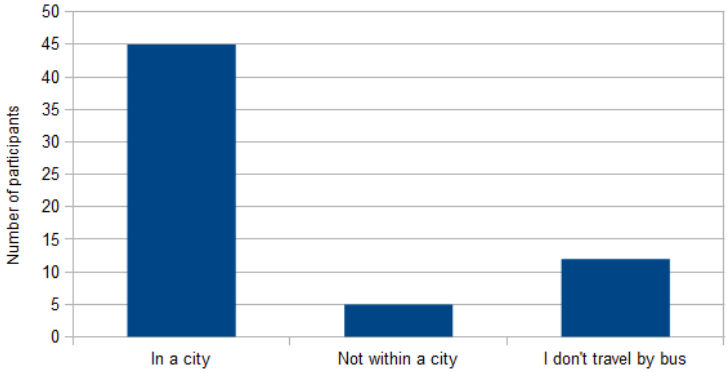


Figure 4.3: Answers to SQ3.

4.1.4 Information sources (SQ4)

This question asked how participants obtain information about bus (or other public transportation) routes. Multiple answers were possible. The results (Figure 4.4) were: 40 (65 %) use

websites, 32 (52 %) use information at the station or stop, 31 (50 %) use applications on mobile devices, 10 (16 %) do not seek information, and 1 (2 %) used something else ("other").

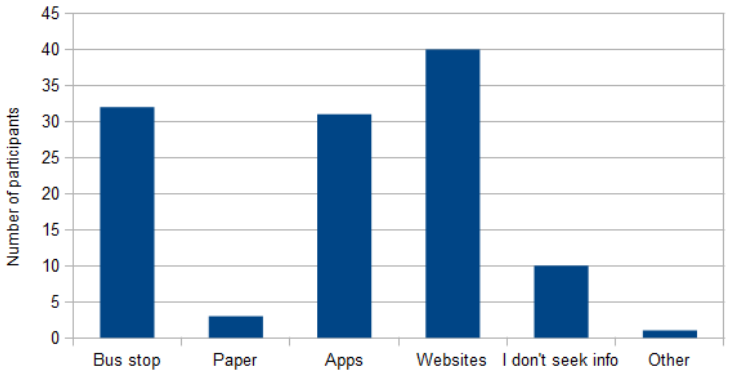


Figure 4.4: Answers to SQ4.

4.2 Demand

This section contains the results of questions SQ6 and SQ7.

4.2.1 Improvements (SQ6)

Participants were asked to select at least three improvements they thought would be useful, among five suggestions and the option to add their own suggestion instead of one of the provided ones. Those that had their own suggestions did this as their answer to the final question (SQ7). The results are shown in Figure 4.5 and are, in descending order of popularity: 51 (85 %) participants voted for changing lists of bus stops from alphabetical to chronological, 39 (63 %) requested support for train information, 37 (60 %) desired support for useful time variables[2], 36 (58 %) asked for "final stop" queries for buses, 27 (44 %) for airport bus support, and 8 (13 %) provided their own suggestion in question SQ7.

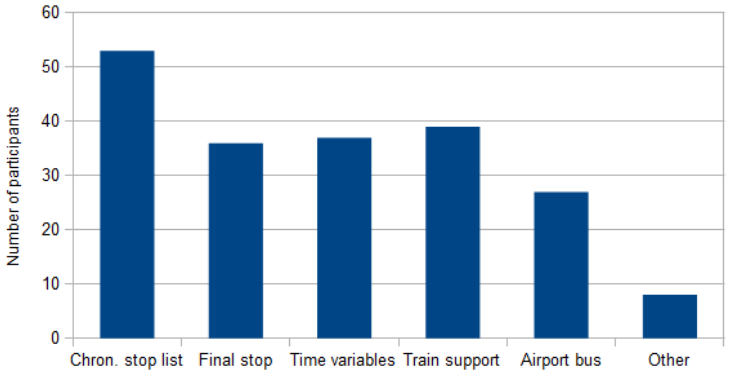


Figure 4.5: Answers to SQ6.

[2]For example opening hour: "from Lade to *[shopping center]* at opening hour".

4.2.2 Further input (SQ7)

The last question let participants provide further notes on information they felt would be important for a system like BusTUC[3] to support. This question also received the "something else" answers from the previous question.

The feedback received in this question was about the following subjects:

1. Geolocation (nearest bus stop)
2. Data on how the interval between buses varies between peak and non-peak hours
3. More specific descriptions of where the buses pass (for visitors who do not know where places are)
4. Deviation from schedule caused by current traffic conditions
5. List of all stops
6. Information on how handicap friendly the buses are
7. Obtaining current location using mobile device location API.
8. Delay information
9. Display all routes that are "equal"

   The participant gives the following example:

   > Buses 1, 2 and 3 go from A to B. Bus 4 goes from A to C. Bus 5 goes from C to B.

   and writes that some applications would return only two options here, namely using bus 1 or using buses 4 and 5. The participant requests that buses like 2 and 3 are not ignored merely because they share bus stops A and B with bus 1.

4.3 Queries

In question SQ5, participants were asked to provide some questions for the system, based on the explanation given in the introduction.

4.3.1 Query suggestions (SQ5)

The participants provided 140 query suggestions in total. Some of these were plain questions, some were implied questions, and others were descriptions of types of questions. The style of language also varied. Some queries were written poorly, others well, and though many were of short or medium length, other queries were unnaturally long. All the suggestions can be seen in appendix C.

A few examples are listed below, exactly as received. (Note that participants were asked to use placeholders where place names were required, hence the "A", "B", "xyz" and similar oddities.)

- "how do i get from A to B?"

[3]Based on the survey introduction's description of the system.

- "When is the last bus today to xyz?"
- "How much does the ticket cost?"
- "How long would it take me to get to point A to B?"
- "On the number 123 bus, where should I get off if I am going to 12 Abcdefg Road?"
- "At what time of the day are the busses of line X full/empty?"

4.3.2 Running the queries

All the suggested queries were used to test BusTUC, by giving them as input[4]. To do this, the placeholder names mentioned in section 4.3.1 were replaced with actual place names in Trondheim. The same was done to placeholder addresses, bus route numbers, times of day and shopping centers. The replacements used are listed in appendix C along with the queries (both original and edited versions) and the results of using them as input.

The results of testing BusTUC with the suggested queries are given in Table 4.1. Dividing the number of good results by the total number of queries and multiplying by 100 to obtain the percentage, the portion of queries that yielded good results from BusTUC was found to be $(52/140) * 100 \approx 37.14$ %.

Result quality	**Number**
Good	52
Bad	88
Total	140

Table 4.1: Result quality of the suggested queries as input BusTUC.

[4]The testing was done through http://busstuc.idi.ntnu.no/

Chapter 5

Analysis and discussion

This chapter analyzes and discusses the results in chapter 4.

5.1 Participants

Questions SQ1 through SQ4 provided some background information on the participants.

5.1.1 Representativeness

One goal of these questions was to gain insight into whether the participants were relevant or not. For example, if a majority of the answers were submitted by people who never or very rarely travel by bus, then the answers might not be sufficiently representative of the needs of BusTUC's users. Likewise, had most participants traveled mostly outside of cities[1], their bus-related information needs might differ from those of Trondheim's inhabitants.

Thankfully, 79 % of the participants travel by bus, 73 % in a city. It is somewhat peculiar that while twelve participants stated that they do not travel by bus in SQ3, while the corresponding options in SQ2 revealed one more in this group. This is assumed to be an error on the part of a participant, and not too significant. Since a clear majority of the responses were from people travelling by bus within cities, the participants can be said to have habits and opinions that are relevant to Trondheim's bus services.

The first questions also gathered some information on participants' occupation and their usual methods of finding route information. As students were the majority at 65 %, with workers filling the last 35 % (and no participants being retired or "unemployed / other"), the distribution may be reasonably close to a significant portion of Trondheim's bus routes, given the city's large student population[2]. However, it is important to note that the retired and the unemployed are not represented in this study. This bias towards younger age groups is probably a result of the distribution method, which was Internet-based and did not focus on covering all age groups. The elderly can be expected to have wishes and expectations that may differ from those of younger customers. Due to their absence among the participants, it may be useful to conduct another survey, targeting elderly bus travellers, to let their needs be heard in the evaluation of

[1] It is worth mentioning that views of what a "city" is also differs between people. A person living in an area of Trondheim's population density, but somewhat close to Tokyo, might apply the term "city" to one but not the other. This adds some impreciseness to the survey.

[2] http://www.trondheim.kommune.no/content/1117713236/Byutvikling (and in Norwegian) (as of December 17, 2014)

useful improvements to BusTUC. They might also be more dependant on their needs than their younger counterparts, due to issues with health or technological ineptitude, so it is important not to forget them simply because they do not represent the majority of the market. Because of cases like this, one must note that the results do not provide a *complete* description of demand in BusTUC's market.

5.1.2 Information sources

The survey's fourth question revealed that the participants' main sources of information about bus routes were websites (65 %), the bus stop (52 %) and mobile applications (50 %). As BusTUC is used both on the web and in mobile applications, the participants appear to suit BusTUC's market in this respect as well.

5.2 Improvements

With the opening questions having established that the results of the survey can be seen as relevant to Trondheim's buses, the later questions can be used to establish an overview of the demand a service like BusTUC faces. This section studies the results of questions SQ6 and SQ7 and what they mean for the future of BusTUC.

The workload associated with each improvement varies, ranging from tweaks to existing functionality (though not necessarily as minor as they may seem[3]) to whole new domains[4] to support.

5.2.1 General popularity

The most popular alternative, by far, was the change from alphabetical to chronological bus stop lists, which 85 % voted for. It appears that, among the improvements suggested, the strongest demand is for such chronological lists. Final stop queries were fourth place, but still only narrowly lost to train support and time variables. Given that the implementation of chronological bus stop lists appears to be a part of a solution to final stops in BusTUC's Prolog code (introduced in chapter 2), it might be natural to prioritize both of them. The overwhelming support for chronological bus stops make it a clear choice for implementation, and with the final stop alternative at 58 %, it seems worth continuing in that direction.

The results for the second most popular alternative, train support, are analyzed and discussed in section 5.2.3. Ranking third was the "time variables" option, close behind train support and barely above final stop queries. Ranked among the most useful by 60 %, this seems to indicate a demand for this type of support.

5.2.2 Time variables

Despite its popularity, ranking third in the answers to question SQ6, the "time variables" option may have impractical side effects. For queries relying on information about opening hours (or similar time variables) to be useful, support for the opening hours of only a few places is not sufficient. The feature needs to be reliable, making a large number of supported time variables necessary. This in itself is not a problem. The problem becomes clear when one considers the fact that the time variables are, after all, *variable*; they may vary. And more importantly, they

[3] Chronological stop listing seems almost trivial at first glance, but in BusTUC's Prolog implementation, it appears to require some work.

[4] See section 2.1.1.

may vary independently. One would therefore have to maintain that BusTUC's opening hour for each supported establishment is correct. Two options immediately present themselves: one could check all of them at regular intervals, a method which scales badly and risks leaving some time variables incorrect for unacceptable amounts of time. Alternatively, one could arrange for the establishments to send their updated opening hour information themselves. However, this is likely to be forgotten regularly, and it would take a large amount of effort to promote the establishment of this procedure for the city's shopping centers, gyms and other points of interest. Unless a reliable and efficient arrangement can be found, this option may demand too much maintenance, or too many errors, to be a useful addition in the long term.

5.2.3 Trains

The second most popular option was train support. This might be the most demanding of the suggestions, as it shares the least with BusTUC's existing domain, but for the same reason it would be a major expansion of BusTUC's service. If successfully implemented, it could be expected to be of use, simply because the trains are in use.

However, when reading the queries submitted in answer to question SQ5, a problem becomes apparent. The queries that focus on trains appear to focus less on trains in and out of a city, and more on the "subway" type of train often found in major cities. This appears to be a major and problematic ambiguity in the survey. A subway system would indeed be a very natural inclusion in this type of route planner for a city, but while trains in and out of the city can be useful as well, it is a very different matter. As most participants of the survey on Reddit's *SampleSize* were probably unfamiliar with Trondheim, they would not know that the city has no subway, making subway support irrelevant.

Comparing surveys

To investigate this worry further, the following subsection studies a part of the first version of the survey, introduced in section 3.1. This version was not used because of its few responses (merely 16 in number), but if the popularity of the "train" option differs greatly from the one previously described, it *may* indicate that the ambiguity was an important factor in the *SampleSize* survey.

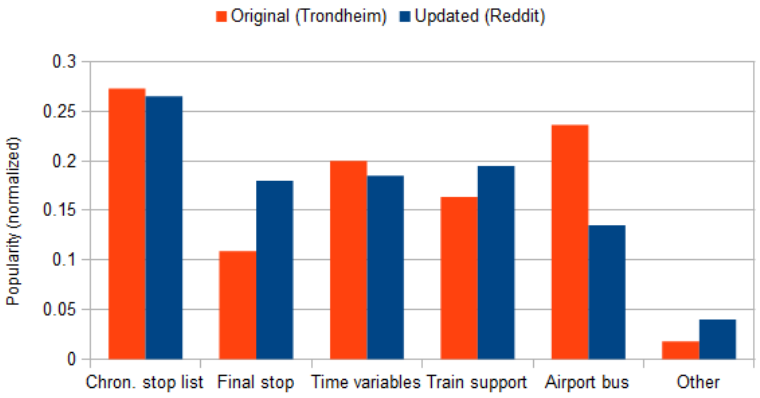


Figure 5.1: Answers to SQ6 and the original survey's equivalent of SQ6, both normalized.

Figure 5.1 displays the results of the original version's improvement suggestions alongside the results of the updated survey. Both have been normalized for the sake of easy comparison.

Observe that while train support was the second most popular option in the survey which was used, the original survey's (admittedly few) responses placed it in fourth place, below both time variables and airport bus support. This *could* indicate that the participants of the original survey, being mainly bus users in Trondheim (see Figure D.1 in Appendix D), rank train support lower because they know that there is no subway within the city.

Though the number of participants in the original survey is too low for any strong conclusions to be drawn, these are interesting and important observations to keep in mind.

Two other differences become immediately apparent. The updated survey shows a major rise in the relative popularity of final stop, and an even larger fall in the votes for airport bus support. It is common for buses to display their end stop on the front of the vehicle. This is the case in Trondheim as well, and perhaps the local participants were more aware of this. More interestingly, Figure 5.1 shows that airport bus support was far more popular among the participants in the original, locally conducted survey. The difference is large enough to go well beyond what one would expect in variation based on the lower number of participants. Trondheim's large population of students may be the explanation for this. Many students travel to their families' homes during the winter, summer and Easter holidays. As many do not own cars, this leads to visiting Trondheim's closest airport six times each year being reasonably common. For the participants in the updated survey, however, this might not be the case. It is therefore worth noting that the airport bus support might be more valuable to Trondheim's population than the main survey makes it seem. As the service the airport buses provide is very similar to that of AtB, adding support for these buses as well should not be a major challenge. The benefit might therefore be quite large compared to the workload. These buses are offered by different companies and have different prices, however. Some additional query types should also be supported to account for that.

5.2.4 Bias

Few participants chose the "other" option. As it requires more independent thought than the other alternatives, this is not surprising. Furthermore, simply by virtue of being shown to every participant, the improvements suggested through the five first options gain an advantage. If not among them, even a truly excellent idea would only be considered by those who happen to think of it; on the other hand, the improvement suggestions that were provided were considered by everyone. Question SQ6 thus naturally gained a bias towards the suggestions that were provided.

The question may also have created an advantage for the suggestions that were at the top of the list. One can assume that most participants read them in the order in which they were listed, and that many started choosing before having read them all. Having at first no competition, the sensible-sounding "chronological stop list" suggestion might make a participant think it an obvious choice. Subsequent suggestions would be presented with stronger competition in the mind of the participant, who could even have selected three options already and therefore be less motivated to select more. This might have been the case especially because the participants did not know the place in question. Had they known Trondheim, they might have stronger opinions on the subject, easily overpowering this tendency, as exemplified by the comparison in section 5.2.3.

5.3 Queries and further input

The survey's fifth question yielded another type of improvement suggestion. It requested questions for the system, based on the description given in the survey's introduction. These questions

show what the participants expect from the system, and can be seen as a practical set of descriptions of the demand on BusTUC and other NLP-based route planners. While the quality of the suggested queries varied, the results from SQ5 are not less important than those from the voting in SQ6. Due to their practical nature, they are of equal, or possibly greater importance. The queries indicate what functionality is perceived as useful, and can be used as input. This makes them useful both for deciding what is useful to implement, and for testing said implementation.

Like the one in section 5.2, this approach has its weaknesses. As the questions were left mostly untouched except for tweaks to make them relevant to Trondheim, some were useless because of overly convoluted language. This could be because participants were asked to create useful queries; this process is a creative one, and very different from the purposeful querying performed when one actually needs it. However, while it drags the success rate down, it also reveals some useful queries which were not supported. And with a success rate of 37.14 % (section 4.3.2), BusTUC handled it reasonably well, considering the circumstances.

5.3.1 Main topics

Among the topics that BusTUC was unable to provide answers for, the most popular ones are described below, each with an example from the queries received. They show which types of queries there is demand for in a practical situation[5].

Frequency: "How often do buses leave from A to B?"

There were numerous queries about the frequency of buses. Despite the apparent usefulness of the topic to the participants, BusTUC's typical response was "I have no information about frequency."

BusTUC's grammar can already handle such queries, so implementing this would require modifying the semantic knowledge base to support the handling of queries about frequency.

A natural answer to this type of query might be to specify the interval between buses, when the interval changes next, and what the interval is after the change.

Handicap: "Is this bus handicap accessible?"

There was only one question about the handicap friendliness of the buses, but to customers who need it, this information could be of the utmost importance. As section 5.1.1 mentions, one should be careful not to ignore needs merely because they belong to a minority.

As BusTUC appears to be unable to understand sentences about handicap accessibility, implementation would require the addition of not just the handling of such information, but also the definitions of the words involved. On the other hand, the output might be quite simple and apply for most or even all buses. The required additions to the semantic knowledge base should therefore be relatively small.

GPS: "The closest stop to your current position."

GPS is useful in many situations, including many related to public transportation. GPS support was therefore at the core of many of the submitted queries. However, from what the literature review in chapter 2 revealed, GPS is not really BusTUC's task. BusTUC's service is primarily a text-to-text NLP system for finding information related to bus travel in Trondheim, though it is used as part of the service of several applications that provide GPS-based assistance. For example, TABuss (section 2.2.2) uses GPS in combination with BusTUC, but this particular service is not part of BusTUC itself.

[5] At least practical compared to question SQ6, and as practical as a survey like this is likely to get without having participants use the system themselves.

Points of interest: "How can I get from Moholt to Bunnpris Lerkendal?"

Many of the suggested queries were about routes to or from supermarkets, and there were some about other points of interest. Though there are many places classifying as supermarkets, and people often know only the chain of supermarkets, not their individual names, there are similar points of interest it would make a lot of sense for BusTUC to recognize. For example, one does not necessarily know the name of the bus stop closest to a certain shopping center. As BusTUC can find bus stops based on street names, and knows *some* points of interest (such as Nidaros Cathedral), it would not be unreasonable to expand this to include Trondheim's major shopping centers and police station.

In this case, the queries would be mostly the same as ones BusTUC already supports, so one would mainly have to modify the knowledge base to include the names and positions of the points of interest.

Delay and traffic: "How much of a delay is there currently on route 5?"

Because buses easily can be hindered by traffic, it is not surprising that their customers are interested in information when a bus is delayed. While some delay statistics for a given day and time might be somewhat useful, BusTUC users would probably prefer more precise information.

As mentioned in section 2.2.1, BusTUC keeps its own copies of AtB's bus routes. This means it does not have to communicate with AtB servers to provide its service. Because of this, supporting information on current delay would require the construction of a module capable of communicating with AtB to retrieve such information from them. And sadly, the amount of such information that is available from AtB at this time is lacking. However, AtB has informed the FUIROS group that real-time GPS information is expected to become available within a year or so. If BusTUC were to be expanded to support such information, it would fulfill much of the demand that lies behind queries such as the example above. Alternatively, a separate service using BusTUC might be expanded to support it. It would in that case not benefit all applications of BusTUC, but it might still be the more natural option, similar to the GPS discussion above.

Length of time: "How long is the ride between Moholt and Studentersamfundet?"

Among the suggested questions for BusTUC were several that requested information about the time a bus trip takes, using the word "long". BusTUC, not realizing it was asked for a length of *time*, would simply answer "I have no information about lengths".

Because this type of query probably is more likely than questions about distance, it might be useful to the users if BusTUC's semantic knowledge base was altered to generally treat such questions as questions about time. Doing this might make the system mistakenly answer a query about distance with a length of time, but the mistake it currently makes seems both more likely and less useful.

There were no train specific questions suggested, further strengthening the hypothesis that ambiguity was a major factor in its popularity in the survey's voting on improvements (as discussed in 5.2.3).

The small amount of feedback (nine responses) received as "further input" (section 4.2.2) mostly reinforces the requests above, and does not add anything of significance.

5.3.2 Assumptions

The analysis and discussion above has revealed both useful information, and weaknesses in the survey. This section briefly describes the central assumptions included in the survey based part of the research.

To be able to use the queries as input for BusTUC, they were manually edited. This process replaced placeholders with actual place names, buses and times. It also included modification of suggestions that were descriptions of queries rather than queries themselves, or contained multiple queries. A consequence of this is that the results of the query testing depend on the interpretation of each query by its editor. The success rate is therefore the result of a process which is at least partially subjective. In addition to this, there might be alternative substitutions than the ones used for the placeholders, for which the results would have been different. Hence, the treatment of query suggestions in this research depends on the assumptions that this subjectivity does not skew the results significantly, and that the substitution done suits the queries as the participants intended them.

5.4 Approach and usefulness

There have been other BusTUC-related projects using questionnaires to gather the opinions of users [Andersstuen and Marcussen, 2012; Wollamo, 2013], but those surveys have focused on user testing of the result, rather than on establishing what is the best direction in which to *seek* results, when attempting to improve the services offered to users. For example, Wollamo also wrote about the usefulness of BusTUC to users, but the development was based on the assumption that users agreed with him on what would be useful; in this respect, the approach used in this project differs significantly from Wollamo's.

Furthermore: as the BusTUC part of the literature review revealed, a considerable number of both FUIROS applications (of varying degrees of completeness) and other services include BusTUC's functionality as a part of the service they provide. This project's approach, however, is to improve the usefulness of BusTUC itself, based on an assessment of what people expect and desire. A successful implementation of the findings will therefore become immediately available to end users through the numerous existing applications of BusTUC – thus providing useful improvements of the services available to users without having to struggle as a competitor *against* the existing applications.

Chapter 6

Conclusion

This chapter summarizes the conclusions reached with the analysis and discussion in chapter 5.

6.1 In general

The survey-based approach for discovering the most useful improvements, as described in this report, has yielded interesting results. The approach differs from that of previous FUIROS projects, and has resulted in increased knowledge about how BusTUC can be changed to increase its usefulness to users, regardless of which BusTUC-supporting service they use.

The survey itself was not without its faults, and eventual later use of this approach would do well to take the unforeseen ambiguities of this survey into account. One might also consider a more thorough evaluation stage for later surveys and their distribution, to avoid other problems of this type, and to gain insight into the needs of a broader spectrum of potential users. However, the survey results still provided a useful approximation of what users and potential users are likely to think of as good improvements to BusTUC's current service, as well as a significant number of queries with which one can measure how the system lives up to people's initial expectations. These queries may also be used to quantify the increase in usefulness caused by later expansion of BusTUC's service.

6.2 Research questions

This section offers a conclusion with a summary of the answers found to the first research question, Q1, and the first part of Q2 (section 1.4). This also corresponds to the first goal introduced in section 1.3.

Based on the research conducted on the structure of BusTUC, the grammars and concepts it relies on, and the responses to the survey, the following areas stand out as both useful and reasonable expansions of BusTUC:

Chronological stop lists: BusTUC should be modified to output bus stop lists chronologically. Not only was it shown to be a very popular improvement, it could also provide the groundwork for the support of end stop queries.

End stops: Building on the modifications done to accomplish chronological stop lists, BusTUC should be made able to answer questions about the last stop of a given bus.

Handicap information: At least some information about handicaps should be added to BusTUC's knowledge base, in order to support some simple questions about handicap friendliness.

Frequency: BusTUC should have its current knowledge extended to include frequencies, so that it may provide answers to how often a given bus line stops at a certain bus stop, and when this frequency changes next.

Airport bus: The main buses to the closest airport should be added to the buses currently supported. This is similar to the service already provided by BusTUC, but some more query types should also be supported, such as queries about airport bus prices.

Minor changes to interpretation: The query testing has proven that there are still reasonable queries that BusTUC misunderstands. Improving this would reduce the frequency with which users experience errors while using the system.

Trains: Though a significant amount of the perceived popularity of train support may stem from unintentional ambiguity in the survey, it has still been confirmed to be useful. Unlike the airport buses, it shares little with buses, and would therefore be a substantial undertaking, though it might prove valuable to those travelling in or out of the city by train.

The second part of Q2, covering the second goal (G2), is the implementation of this, and will be done and documented in a later report. It is outlined as part of chapter 7.

Chapter 7

Future work

This section explores the future work that emerges from the content of the report.

As this report researches and presents the most crucial parts of the demand BusTUC faces in terms of increased functionality, it naturally causes the implementation of these extensions to be the most relevant future work.

7.1 First improvements

Firstly, support for chronological stop lists should be implemented. As summarized in section 6, it was not only the most popular option by far, but it could provide part of a solution to supporting end stop queries.

The second task thus naturally becomes the implementation of end stop queries, allowing users to request and receive the last stop of any given bus. As lines can have different end stops depending on both direction, date and time of day, this will have to be taken into account.

After completing the above, AtB should be contacted, and using information gained from them, BusTUC should be made able to answer simple questions about the buses' handicap friendliness.

Minor changes to BusTUC's vocabulary can also be made as part of this step, to reduce the number of unnecessary errors. For example, questions about lengths of time should not be treated as questions about distance, as discussed in section 5.3.

7.2 Greater changes

Having implemented the relatively simple, but strongly requested improvements listed in section 7.1, one can move on to improvements that require more time. At least some of them should be implemented, as they together represent a sizable portion of the demand established in the report.

7.2.1 Frequency

Implementing support for queries about frequency would require either going through the bus tables manually and saving the patterns to BusTUC, or writing a program to automate this process. The latter option can be expected to save time in the long run, as bus schedules

change regularly. BusTUC must also be made able to understand and answer queries using that information.

7.2.2 Airport bus support

BusTUC should have Trondheim's airport buses added to its supported routes, and should be able to answer questions about them and related information such as price. The companies running the buses should be contacted and convinced to notify the FUIROS team whenever their schedules change.

7.2.3 Trains

A currently unfinished FUIROS project[1] has been working on a BusTUC system for Oslo[2]. As part of this work, some support for trains was created, though it is not part of the project's final product. If train support is to be added for Trondheim's BusTUC, the prototype for Oslo's trains should be evaluated, as much of it might translate relatively easily to Trondheim.

7.3 Dialogue

In combination with some or all of the planned implementations above, the user friendliness of BusTUC can be expected to improve greatly if one were to add dialogue support. As chapter 2 revealed, there exists a considerable amount of work done on both speech and dialogue for BusTUC. Implementing dialogue support into BusTUC itself would allow for a much more user friendly interaction with BusTUC. An evaluation of the code of the BUSTER [Johnsen et al., 2003, p.125–131] system and related projects such as [Engell, 2012] should be undertaken to determine what may be reused or minimally modified to work as a part of BusTUC itself, leading to an actual implementation. An example of a situation which would be improved by this is given below.

With current functionality:

User: "From Berg to Moholt"

BusTUC: "The place Berg is not unique. Please use a more specific name. Possible alternatives are: Berg Prestegård, Berg studentby, Østre Berg."

User: "From Berg studentby to Moholt"

BusTUC: "Bus 66 passes by Berg studentby at 1:24 pm, at 1:39 pm and at 1:54 pm and arrives at Moholt, 3 minutes later. Bus 5 passes by Berg studentby at 1:30 pm, at 1:40 pm and at 1:50 pm and arrives at Moholt, 4 minutes later. The hours indicate the earliest passing times."

The user experience could in this case clearly be better. The ambiguity causes BusTUC to force the user to submit the entire question again, with a modification. With dialogue support included in BusTUC, this would not be necessary, as shown in the following:

User: "From Berg to Moholt"

[1] Briefly described in Norwegian at https://www.ntnu.no/wiki/display/FUIROS/Espen+Jacobsson%2C+OsloTUC (as of December 17, 2014).

[2] The capital and largest city in Norway.

BusTUC: "Which "Berg" are you referring to? Possible alternatives are: Berg Prestegård, Berg studentby, Østre Berg."

User: "studentby"

BusTUC: "Bus 66 passes by Berg studentby at 1:24 pm, at 1:39 pm and at 1:54 pm and arrives at Moholt, 3 minutes later. Bus 5 passes by Berg studentby at 1:30 pm, at 1:40 pm and at 1:50 pm and arrives at Moholt, 4 minutes later. The hours indicate the earliest passing times."

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Appendix A

Survey questions

The complete survey is given here, in the same words as the version received by the participants. The headline for the survey on *SampleSize* (see 3.1) had to conform to the rules for such headlines, and was therefore chosen to be *[Academic] Quick survey about public transportation (Everyone)*. On Google Forms, the headline was *Short survey: Public transportation and information through language*.

One question requires at least three options to be selected. Where no such thing is mentioned, participants selected at most one option.

Introduction *Quick introduction:*

> The goal of this survey is to learn more about what people view as useful for information systems that understand natural language and answer questions about public transportation (primarily bus).
> The results will be used in a project at the Norwegian University of Science and Technology.
>
> We have a system for bus information, which understands English (and Norwegian) sentences.
> If asked a question about local bus routes in normal English (or Norwegian), it will interpret it and provide generate an answer (also in natural language).

Introduction *Examples:* (The "gibberish" words are just Norwegian place names.)

> Q: "When does bus 66 leave Høiset?"
> A: "Bus 66 passes by Høiset at 0:00 am and arrives at Munkegata M1 at 0:32 am.
> The hours indicate the earliest passing times."
>
> Q: "From Gløshaugen to Lade"
> A: "The station nearest to Gløshaugen is Gløshaugen Syd. Bus 22 goes from Gløshaugen Syd at 11:46 pm to Prinsens gate P2 at 11:52 pm and bus 4 goes from Munkegata M5 at 0:00 am to City Lade at 0:09 am. The hours indicate the earliest passing times."

SQ1 *Which of the following best describes you?*

1. Student
2. Working
3. Retired
4. Unemployed / other

SQ2 *How many times do you travel by bus during an average week?*

A rough estimate is fine.

1. I do not use any kind of public transportation
2. I never travel by bus (but sometimes other public transportation)
3. Less than 1 (on average)
4. 1-4
5. 5-8
6. 9-12
7. More than 12

SQ3 *Where do you travel by bus the most?*

1. In a city
2. Not within a city
3. I don't travel by bus

SQ4 *How do you get information about bus routes / other public transportation?*

1. Information at the bus(/other) stop
2. Information on paper
3. Application on mobile device
4. Websites
5. I don't seek out information
6. Other: [Input field]

SQ5 *Please think of a few questions for the information system to interpret and answer. They should be about public transportation. (Use A/B/etc as placeholders for place names.)*

Some example topics: getting from A to B, ending stop for a certain trip, the closest bus stop to place A. Two concrete examples of use can be found in the introduction above.

[Text input field]

SQ6 *What possible improvements do you think seem the most useful for this type of system? (As you probably do not have experience with our system, a "gut feeling" of usefulness is fine.)*

[Select at least 3]

1. Chronological list of stops for a bus (currently alphabetical)
2. Final stop for a given bus
3. Time variables, such as opening hour information (if something else, specify below) (ex.: "¡place¿ to ¡shopping center¿ at opening hour")
4. Support for train information
5. Support for the buses to/from airport (not currently supported)
6. Something else is important to support (specify below)

SQ7 *Any other notes on information you feel is important/useful for such a system to support?*

(If you chose "something else" above, please elaborate here)

[Text input field]

Appendix B

Answers from survey

B.1 Abbreviations

Because of the many and lengthy answer alternatives, the table below lists abbreviations used in order to increase readability.

Table B.1: Survey table abbreviations

Question	**Answer abbreviation**	**Answer text**
2	None	I do not use any kind of public transportation
2	No bus	I never travel by bus (but sometimes other public transportation)
2	<1	Less than 1 (on average)
2	>12	More than 12
4	Bus stop	Information at the bus(/other) stop
4	Paper	Information on paper
4	Apps	Application on mobile device
4	None	I don't seek out information
6	Chron stops	Chronological list of stops for a bus (currently alphabetical) ‘
6	Final stop	Final stop for a given bus
6	Time vars	Time variables, such as opening hour information (if something else, specify below) (ex.: ”<place>to <shopping center>at opening hour”)
6	Train support	Support for train information
6	Airport bus	Support for the buses to/from airport (not currently supported)
6	Other (next)	Something else is important to support (specify below)

B.2 Answers

Using the abbreviations given above, table B.2 lists the answers received.

Table B.2: Survey answers

Which of the following best describes you?	**How many times do you travel by bus during an average week?**	**Where do you travel by bus the most?**	**How do you get information about bus routes / other public transportation?**	**Please think of a few questions for the information system to interpret and answer. They should be about public transportation. (Use A/B/etc as placeholders for place names.)**	**What possible improvements do you think seem the most useful for this type of system? (As you probably do not have experience with our system, a "gut feeling" of usefulness is fine.)**	**Any other notes on information you feel is important/useful for such a system to support?**
Student	5-8	In a city	Apps, Websites		Chron stops, Time vars, Train support	
Student	9-12	In a city	Bus stop, Apps		Chron stops, Time vars, Train support	
Working	No bus	I don't travel by bus	None	How can I get from my house to the supermarket	Chron stops, Airport bus, Other (next)	Geolocaton, i.e. nearest bus stop.
Student	9-12	Not within a city	Apps	When is the next bus to Abcdefg due at the closest stop?On the number 123 bus, where should I get off if I am going to 12 Abcdefg Road?	Chron stops, Final stop, Airport bus	
Student	5-8	In a city	Bus stop, Paper, Websites	How many stops am I from A?How long will it take for me to get to A from B?How much will it cost for me to get to A from B?When does the next bus/train/etc. arrive at A?What is the best route to A from B?Which routes stop at station A?	Chron stops, Final stop, Train support, Airport bus	
Student	No bus	I don't travel by bus	None		Chron stops, Final stop, Time vars	
Working	1-4	In a city	Bus stop, Apps, Websites	how do i get from A to B? when will i be at C?Where does the line X stop?How do i get from A to B via C?At what time of the day are the busses of line X full/empty?	Chron stops, Time vars, Train support, Airport bus	

Student	5-8	In a city	Apps	The closest stop to your current position. Route planner from place a to b. Estimated time of trip.	Final stop, Time vars, Airport bus	
Working	9-12	In a city	Bus stop, Apps, Websites	"When will the next bus to [DESTINATION] get here?" - note: "here" being determined by location feature on mobile device while user is standing at the stop (and the busstop-display is broken or not present)."Where is the nearest [ROUTENAME] stop?" - again using location feature of mobile device and assuming user knows the route they want to use."How can I get home?" - location features are used to get current position and home is either pre-entered info or guessed like Google does it.	Chron stops, Final stop, Time vars, Train support, Other (next)	Obtaining current location using mobile device location API.
Student	<1	In a city	Bus stop, Apps, Websites, gmaps	When is the last bus today to xyz?	Chron stops, Final stop, Train support	
Student	1-4	In a city	Bus stop, Paper, Apps, Websites	Where do bus routes x and y intersect?	Chron stops, Final stop, Train support	
Working	1-4	In a city	Bus stop	Is there a night bus for this route?Where can I transfer to the subway?What is the stop before the one I want to get down at?What time is the last bus from A in Y direction?What time is the first bus from B in X direction?How much does the ticket cost?Can I use this transfer ticket from the subway?Does this bus go down C street?	Chron stops, Final stop, Other (next)	Please be more specific about where the buses pass. The vague list of neighborhoods does not help me very much, especially as a visitor.
Student	<1	In a city	Bus stop, Websites	How long would it take me to get to point A to B? What are the traffic conditions currently like or generally like at this time?	Chron stops, Time vars, Train support	

Student	No bus	I don't travel by bus	Bus stop, Websites	"which bus do i need to take to get to point b by <time>?"	Chron stops, Time vars, Train support, Airport bus	
Student	None	I don't travel by bus	None		Chron stops, Time vars, Airport bus	
Working	No bus	I don't travel by bus	Bus stop, Websites	How do I get to Denver by 18:30?When is the last bus out of Denver?	Chron stops, Time vars, Airport bus	
Working	1-4	In a city	Bus stop, Apps, Websites	What busses go from A to B (where a and b are places not necessarily bus stops)What stops does bus 123 go to	Chron stops, Final stop, Other (next)	Don't ignore additional bus numbers on the same route segment like certain apps do. eg if bus 1, 2, 3 all go direct from a to b, and you could also take bus 4 to c then change onto bus 5, some apps only list 2 options (bus 1 or bus 4+5).
Student	<1	Not within a city	Websites	When is the next bus?Does this bus (just arriving) go to station X?/Is this the right bus to go to station X?How much does it cost to go from here to station X?How much time does it take " " " ?	Chron stops, Final stop, Train support	
Student	5-8	In a city	Apps, Websites	How long a round trip will beHow long it takes for a bus to get from one stop to the next (factoring in traffic)Estimated arrival times for each stopEstimated leeway time for each stop (ex: differs day by day within a range of about 5 min)	Chron stops, Final stop, Time vars	
Student	None	I don't travel by bus	None	How long is the ride between A and B?When will the bus reach B?How much is bus fare?	Chron stops, Final stop, Airport bus	
Student	1-4	In a city	Bus stop, Websites	How much does the route cost?	Chron stops, Train support, Airport bus	

Student	5-8	In a city	Bus stop, Websites	What time will the 487 arrive?Approximately how long will it take me to get from stop 5522 to stop 5671?	Chron stops, Train support, Airport bus	
Student	5-8	In a city	Bus stop, Websites		Chron stops, Final stop, Time vars	
Student	1-4	In a city	Apps		Time vars, Train support, Airport bus	
Student	<1	In a city	Apps	Where is the closest bus stop for route A?What bus route will get me to place B?How long is the bus ride to Place C?Is D bus stop well-lit?	Chron stops, Final stop, Time vars	
Student	<1	In a city	Bus stop, Apps, Websites	How many transfers between A and B, Shortest travel time between A and B	Chron stops, Train support, Airport bus	
Working	5-8	In a city	Websites	How long until the next bus near A leaves for B?How many stops are between A and B?How many minutes from A to B?	Chron stops, Final stop, Time vars, Airport bus	
Working	9-12	In a city	Bus stop, Apps, Websites	What's the closest bus stop to Woodland Mall?	Time vars, Train support, Airport bus	
Working	None	I don't travel by bus	None	What lines would I use to travel round trip from point A making two stops at point B and C?Which is the fastest way to get from here to the mall?Which is the cheapest way to get from here to the stadium?	Chron stops, Time vars, Train support	
Student	9-12	In a city	Bus stop, Paper, Apps, Websites		Final stop, Time vars, Train support, Airport bus	
Student	1-4	Not within a city	Apps, Websites		Chron stops, Final stop, Train support	
Working	<1	In a city	Apps, Websites	How often does the #1 bus come?When is the last #1 bus?Which busses stop at B?	Final stop, Train support, Airport bus	

Student	None	I don't travel by bus	None	What time is the bus scheduled to pick up at A and drop off at B? How many bus stops are there near A? Do you have a crime rate for each bus stop?Is this bus handicap accessible? How do I get on a bus with a walker? Will I have assistance in getting on and off the bus if I should need it?	Final stop, Time vars, Airport bus, Other (next)	Handicapped riders, I struggled in Washington DC to get on and off the train, to find the handicap entrances and elevators in the station. There needs to be clear signs and perhaps people to assist. My wheelchair got caught between the platform and the train and other passengers had to pick me up to get me inside the train. It's scary taking public transit while disabled and not knowing how handicap friendly the system is.
Student	>12	In a city	Bus stop, Apps, Websites	What buses leave from A?How often do buses leave from A to B?What are possible routes from A to B?	Chron stops, Final stop, Time vars	
Student	>12	In a city	Bus stop, Apps	Closest station to AWhen does Line 123 arrive at B?From C to D at 12:34 PMArrive at E at 12:34 PMLast station Bus 123Stopovers Line 123 to F	Chron stops, Final stop, Train support, Other (next)	List of all stopovers from first to last station

Student	>12	In a city	Bus stop, Websites	1. What are my options for getting from A to B?2. What's the fastest way to get from A to B?3. What's the most convenient way to get from A to B (least transfers, closest bus stops)?4. If I miss a transfer on the way from A to B, what's the fastest way to continue to B?5. What's the earliest I can get to B, and the latest I can get back to A?	Final stop, Time vars, Train support	
Working	5-8	In a city	Bus stop, Websites	What time is the next bus to A from this stop?What time is the last bus to here from A?How long will it take to get to B from here?[when a bus is delayed] How far away is the (normal time) bus to A? - this might be confusing so I'll give an example. Bus to place A is scheduled to be at this stop at 9:00am, it is now 9:10am and it hasn't appeared, how far away/where is that bus now?	Chron stops, Final stop, Time vars	Time variability caused by current traffic conditions
Student	1-4	In a city	None	If I am at A at __:__ time, when would I get to point C after my transfer at point B?	Chron stops, Final stop, Train support	
Student	None	I don't travel by bus	None	When travelling by bus, do you talk to people also on one often?	Final stop, Train support, Other (next)	
Student	9-12	In a city	Apps	What is the fastest way to get to B from where I am?What is the last bus to B from A?	Chron stops, Final stop, Train support, Airport bus	
Working	5-8	In a city	Apps	When do i have to get on a bus to make a certain conenction	Chron stops, Final stop, Time vars	
Working	9-12	In a city	Bus stop, Apps	How long will it be for the bus to arrive at A?What is the stop before stop A?	Chron stops, Final stop, Time vars	
Working	<1	In a city	Bus stop, Apps, Websites	Next bus at A going to B, how do I get from A to B	Time vars, Train support, Airport bus	

Student	>12	In a city	Bus stop, Apps, Websites	What bus should I take to get to downtown Berkeley BART by 2:00?How long will it take for my bus to get here?	Chron stops, Time vars, Train support, Airport bus	
Working	5-8	In a city	Websites	How often does the bus run from A to B?When is the next bus from A to B?What bus goes from A to B after 12:20 PM?When does the last bus leave A?	Chron stops, Train support, Airport bus	
Working	>12	In a city	Websites	Which bus should I take to arrive in B by 9:00am? How long will it take to get from A to B? Is it cheaper to go from A to B or from A to C?	Chron stops, Time vars, Train support	
Student	5-8	In a city	Apps		Chron stops, Final stop, Time vars	
Student	1-4	In a city	Bus stop, Websites, None	When can I take the next bus from station A?From where can I take the next bus to A?I'm at A, where and when does the next bus to B leave?When does the last bus to A leave?How can I reach A quickest?	Chron stops, Final stop, Train support	
Student	<1	In a city	Bus stop, Websites	When does bus # arrive at A/B?When does bus # depart A/B?How long does the trip take?	Chron stops, Time vars, Airport bus	
Working	<1	In a city	Bus stop, Apps, Websites	When does a bus arrive at A?How long is a trip from A to B?How much money does a trip from A to B cost?	Chron stops, Time vars, Train support	
Student	<1	In a city	Bus stop, Websites	What's the fare? Where's the nearest toilets?	Chron stops, Train support, Airport bus	When will the bus arrive? What is the bus interval for peak and non-peak hours?
Working	None	I don't travel by bus	Apps, Websites	What bus should i take to get to the police station, town house, mall,....	Chron stops, Final stop, Time vars	
Student	None	I don't travel by bus	None		Chron stops, Time vars, Train support	

Student	5-8	Not within a city	Bus stop		Chron stops, Final stop, Train support	
Working	5-8	In a city	Apps	when is the bus coming, whats the quickest route from A to B	Chron stops, Final stop, Train support	
Student	None	I don't travel by bus	Websites		Chron stops, Time vars, Airport bus	
Working	<1	In a city	Bus stop, Apps, Websites	How to get from A to B? Alternate routes from A to B?How long is the trip to A?Closest stop to A?What time is the next bus/streetcar/-train coming to stop A?What time is the next bus/streetcar/-train on route A-B coming to stop A?How much of a delay is there currently on route A-B?	Chron stops, Final stop, Time vars, Train support, Other (next)	Delay information
Student	<1	Not within a city	Bus stop, Websites		Chron stops, Time vars, Airport bus	
Student	5-8	In a city	Apps, Websites	When will the next bus 66 stop at B?	Chron stops, Train support, Airport bus	
Working	No bus	In a city	Bus stop, Websites	When is the latest I can leave from A and get to B?What's the farthest I can go from A?	Chron stops, Final stop, Time vars, Train support	
Working	9-12	In a city	Apps, Websites	Directions from A to BWhat bus goes from A to BBuses stopping at both A and B	Chron stops, Final stop, Train support	
Student	9-12	In a city	Websites	getting from A to Bclosest stop from Alist of stops from A to Btime to get from A to B	Chron stops, Time vars, Train support	

Appendix C

Queries from survey

Table C.1 contains the query suggestions given in answer to the fifth survey question. There were 140 suggested queries. The first column contains the queries as they were received. The second column contains the queries after manual replacement of placeholders, so that they can be used in BusTUC (for example changing "from A to B" to "from Nardo to Moholt").

The marks for different types of results are as explained below:

Good An appropriate result was returned.

Wrong Incorrect or incomplete. A result was returned, but it did not contain the requested information.

Error BusTUC did not understand the query, or does not support the requested information.

Error(Shopping) The query requested travel to or from some point of interest, like a supermarket or police station. (See section 5.3.1)

Error(GPS) The query requested GPS information. (See section 5.3.1.)

Error(Sentence) BusTUC did not understand the sentence.

(Irrelevant) The question is in some way irrelevant.

The replacements used are as follows:

Moholt Primary area. Also used for "my house" (and similar) where GPS is not clearly mentioned (as one can expect people to know their home's closest bus stop well enough for it to be synonymous with "my home" in a bus context.

Samf Secondary area (abbreviation of "Studentersamfundet", understood by BusTUC).

Gløs Third area name, used for "via" queries.

Høgskoleringen 2 Primary address (used when a participant clearly wishes to use an exact address in the query).

Bus 5 Replaces bus numbers.

9 Replaces generic time in queries (for example "__:__").

Mercur As replacements for "the supermarket" and similar supermarket references, Mercur[1] was used. Tests with various other shopping centers were also run to make sure Mercur accurately represents BusTUC's treatment of shopping centers.

Some of the suggestions have been modified more than others. For example, some were not structured as a question for the system, but rather as a suggestion of what BusTUC should be able to answer. Furthermore, suggestions were not assumed to rely on GPS merely at the mention of a word like "here"; this assumption was made only when it was very clear that the user expects the system to know their current location.

Table C.1: Query suggestions

Query	**Usable query**	**Result**
How can I get from my house to the supermarket	How can I get from Moholt to Mercur	Error(Shopping)
When is the next bus to Moholt due at the closest stop?	When is the next bus to Moholt due at the closest stop?	Error(GPS)
On the number 123 bus, where should I get off if I am going to 12 Abcdefg Road?	On the number 5 bus, where should I get off if I am going to Høgskoleringen 2?	Error(Sentence)
How many stops am I from A?	How many stops is Samf from Moholt?	Error(Sentence)
How long will it take for me to get to A from B?	How long will it take for me to get to Moholt from Samf?	Good
How much will it cost for me to get to A from B?	How much will it cost for me to get to Moholt from Samf?	Good
When does the next bus/train/etc. arrive at A?	When does the next bus arrive at Moholt?	Error(Sentence)
What is the best route to A from B?	What is the best route to Moholt from Samf?	Error(Sentence)
Which routes stop at station A?	Which routes stop at station Moholt?	Good
how do i get from A to B?	how do i get from Moholt to Samf?	Good
when will i be at C?	when will i be at Moholt?	Good
Where does the line X stop?	Where does the line 5 stop?	Good
How do i get from A to B via C?	How do i get from Moholt to Samf via Gløs?	Error
At what time of the day are the busses of line X full/empty?	At what time of the day are the busses of line 5 full? At what time of the day are the busses of line 5 empty?	Error(Sentence), Error(Sentence)
The closest stop to your current position.	The closest stop to my current position.	Error(GPS)
Route planner from place a to b.	From Moholt to Samf.	Good

[1] http://www.mercursenteret.no/info/ (as of 2014)

Estimated time of trip. - note: here being determined by location feature on mobile device while user is standing at the stop (and the busstop-display is broken or not present).	Estimated time of trip [from current position] to Moholt.	Error(GPS)
Where is the nearest [ROUTE-NAME] stop? - again using location feature of mobile device and assuming user knows the route they want to use.	Where is the nearest [ROUTE-NAME] stop?	Error(GPS)
How can I get home? - location features are used to get current position and home is either pre-entered info or guessed like Google does it.	How can I get home?	Error(GPS)
When is the last bus today to xyz?	When is the last bus today to Moholt?	Good
Where do bus routes x and y intersect?	Where do bus routes 5 and 66 intersect?	Error(Sentence)
Is there a night bus for this route?	Is there a night bus for route 5?	Error(Sentence)
Where can I transfer to the subway?	Where can I transfer to the subway?	(Irrelevant)
What is the stop before the one I want to get down at?	What is the stop before Samf with bus 5?	Error(Sentence)
What time is the last bus from A in Y direction?	What time is the last bus from Moholt towards Samf?	Good
What time is the first bus from B in X direction?	What time is the first bus from Moholt towards Samf?	Good
How much does the ticket cost?	How much does the ticket cost?	Good
Can I use this transfer ticket from the subway?	Can I use this transfer ticket from the subway?	(Irrelevant)
Does this bus go down C street?	Does bus 5 go down Høgskoleringen?	Good
How long would it take me to get to point A to B?	How long would it take me to get from Moholt to Samf?	Error(Sentence)
What are the traffic conditions currently like or generally like at this time?	What are the traffic conditions like at this time?	Error
which bus do i need to take to get to point b by ¡time¿?	which bus do i need to take to get to Samf by 9?	Good
How do I get to Denver by 18:30?	How do I get to Moholt by 18:30?	Good
When is the last bus out of Denver?	When is the last bus out of Moholt?	Good
What busses go from A to B (where a and b are places not necessarily bus stops)	What busses go from Moholt to Høgskoleringen 2	Good
What stops does bus 123 go to	What stops does bus 5 go to	Error(Sentence)
When is the next bus?	When is the next bus from Moholt?	Good
Does this bus (just arriving) go to station X?	Does this bus go to station Moholt?	Error(GPS)(and realtime data)

Is this the right bus to go to station X?	Is this the right bus to go to Moholt?	Error(GPS)(and realtime data)
How much does it cost to go from here to station X?	How much does it cost to go from here to Moholt?	Error(GPS)
How much time does it take ” ” ” ?	How much time does it take to go from here to Moholt?	Error(GPS)
How long a round trip will be	How long is a round trip will be from Moholt through Samf?	Error(Sentence)
How long it takes for a bus to get from one stop to the next (factoring in traffic)	How long it takes for a bus to get from Moholt stop to Samf?	Error(Sentence)
Estimated arrival times for each stop	Estimated arrival times for Moholt	Error(Sentence)
Estimated leeway time for each stop (ex: differs day by day within a range of about 5 min)	Estimated leeway time for Moholt today	Error(Sentence)
How long is the ride between A and B?	How long is the ride between Moholt and Samf?	Wrong(assuming time is the desired output)
When will the bus reach B?	When will the bus reach Moholt?	Good
How much is bus fare?	How much is bus fare?	Good
How much does the route cost?	How much does the route cost?	Wrong
What time will the 487 arrive?	What time will bus 5 arrive at Moholt?	Good
Approximately how long will it take me to get from stop 5522 to stop 5671?	Approximately how long will it take me to get from Moholt to Samf?	Error(Sentence)
Where is the closest bus stop for route A?	Where is the closest bus stop for bus 5?	Error(GPS)
What bus route will get me to place B?	What bus route will get me to Moholt?	Error(Sentence)
How long is the bus ride to Place C?	How long is the bus ride to Moholt?	Wrong(assuming the length of time is desired)
Is D bus stop well-lit?	Is Moholt well-lit?	Error(Sentence)
How many transfers between A and B	How many transfers between Moholt and Samf	Error(Sentence)
Shortest travel time between A and B	Shortest travel time between Moholt and Samf	Error(Sentence)
How long until the next bus near A leaves for B?	How long until the next bus near Høyskoleringen 2 leaves for Moholt?	Error(Sentence)
How many stops are between A and B?	How many stops are between Moholt and Samf?	Error(Sentence)
How many minutes from A to B?	How many minutes from Moholt to Samf?	Error(Sentence)
What's the closest bus stop to Woodland Mall?	What's the closest bus stop to Mercur?	Error(Shopping)

What lines would I use to travel round trip from point A making two stops at point B and C?	What bus would I use to travel round trip from Moholt making two stops at Samf and Høyskoleringen 2?	Wrong
Which is the fastest way to get from here to the mall?	Which is the fastest way to get from here to Mercur?	Error(Shopping)
Which is the cheapest way to get from here to the stadium?	Which is the cheapest way to get from Moholt to Lerkendal Stadium?	Wrong
How often does the #1 bus come?	How often does the bus 5 come?	Error
When is the last #1 bus?	When is the last bus 5 from Moholt?	Good
Which busses stop at B?	Which busses stop at Moholt?	Good
What time is the bus scheduled to pick up at A and drop off at B?	What time is the bus scheduled to pick up at Moholt and drop off at Samf?	Error(Sentence)
How many bus stops are there near A?	How many bus stops are there near Trondheim Torg?	Wrong
Do you have a crime rate for each bus stop?	Do you have a crime rate for each bus stop?	Error
Is this bus handicap accessible?	Is bus 5 handicap accessible?	Error
How do I get on a bus with a walker?	How do I get on a bus with a walker?	Error
Will I have assistance in getting on and off the bus if I should need it?	Will I have assistance in getting on and off the bus if I should need it?	Error
What buses leave from A?	What buses leave from Moholt?	Good
How often do buses leave from A to B?	How often do buses leave from Moholt to Samf?	Error
What are possible routes from A to B?	What are possible routes from Moholt to Samf?	Good
Closest station to A	Closest station to Moholt	Error(Sentence)
When does Line 123 arrive at B?	When does Line 5 arrive at Moholt?	Good
From C to D at 12:34 PM	From Moholt to Samf at 12:34 PM	Good
Arrive at E at 12:34 PM	Arrive at Moholt at 12:34 PM	Good
Last station Bus 123	Error	
Stopovers Line 123 to F	Stopovers Line 5 to Moholt	Error(Sentence)
What are my options for getting from A to B?	What are my options for getting from Moholt to Samf?	Error(Sentence)
What's the fastest way to get from A to B?	What's the fastest way to get from Moholt to Samf?	Good
What's the most convenient way to get from A to B (least transfers, closest bus stops)?	What's the most convenient way to get from Moholt to Lade?	Error(Sentence)
If I miss a transfer on the way from A to B, what's the fastest way to continue to B?	If I miss a transfer on the way from Moholt to Samf, what's the fastest way to continue to Samf?	Error(Sentence)

What's the earliest I can get to B, and the latest I can get back to A?	What's the earliest I can get to Samf, and the latest I can get back to Moholt?	Error(Sentence)
What time is the next bus to A from this stop?	What time is the next bus to Moholt from Samf?	Good
What time is the last bus to here from A?	What time is the last bus to Moholt from Samf?	Good
How long will it take to get to B from here?	How long will it take to get to Moholt from Samf?	Error
[when a bus is delayed] How far away is the (normal time) bus to A? - this might be confusing so I'll give an example. Bus to place A is scheduled to be at this stop at 9:00am, it is now 9:10am and it hasn't appeared, how far away/where is that bus now?	How far away is the bus to Moholt?	Error(Sentence)
If I am at A at __:__ time, when would I get to point C after my transfer at point B?	If I am at Moholt at 9, when would I get to Lade after my transfer at point Samf?	Error(Sentence)
When travelling by bus, do you talk to people also on one often?	When travelling by bus, do you talk to people also on one often?	(Irrelevant)
What is the fastest way to get to B from where I am?	What is the fastest way to get to Moholt from where I am?	Error(GPS)
What is the last bus to B from A?	What is the last bus to Moholt from Samf?	Good
When do i have to get on a bus to make a certain conenction	When do i have to get bus 5 to change at Samf at 9?	Error
How long will it be for the bus to arrive at A?	How long will it be for the bus to arrive at Moholt?	Error(Sentence)
What is the stop before stop A?	What is the stop before Moholt for bus 5?	Error(Sentence)
Next bus at A going to B, how do I get from A to B	Next bus at Moholt going to Samf	Good
What bus should I take to get to downtown Berkeley BART by 2:00?	What bus should I take to get to Moholt by 2:00?	Error(Sentence)
How long will it take for my bus to get here?	How long will it take for bus 5 to get to Moholt?	Error(Sentence)
How often does the bus run from A to B?	How often does the bus run from Moholt to Samf?	Wrong
When is the next bus from A to B?	When is the next bus from Moholt to Samf?	Good
What bus goes from A to B after 12:20 PM?	What bus goes from Moholt to Samf after 12:20 PM?	Good
When does the last bus leave A?	When does the last bus leave Moholt?	Good
Which bus should I take to arrive in B by 9:00am?	Which bus should I take to arrive at Moholt by 9:00am?	Error(Sentence)

How long will it take to get from A to B?	How long will it take to get from Moholt to Samf?	Error
Is it cheaper to go from A to B or from A to C?	Is it cheaper to go from Moholt to Samf or from Moholt to Lade?	Good
When can I take the next bus from station A?	When can I take the next bus from Moholt?	Good
From where can I take the next bus to A?	From where can I take the next bus to Samf?	Error(GPS)
I'm at A, where and when does the next bus to B leave?	I'm at Moholt, where and when does the next bus to Samf leave?	Error(Sentence)
When does the last bus to A leave?	When does the last bus to Moholt leave?	Good
How can I reach A quickest?	How can I reach Moholt quickest?	Error(Sentence)
When does bus # arrive at A/B?	When does bus 5 arrive at Moholt?	Good
When does bus # depart A/B?	When does bus 5 depart Moholt?	Good
How long does the trip take?	How long does the trip from Moholt to Samf take?	Good
When does a bus arrive at A?	When does a bus arrive at Moholt?	Good
How long is a trip from A to B?	How long is a trip from Moholt to Samf?	Wrong
How much money does a trip from A to B cost?	How much money does a trip from Moholt to Samf cost?	Good
What's the fare?	What's the fare?	Good
Where's the nearest toilets?	Where's the nearest toilets?	Error
What bus should i take to get to the police station, town house, mall,....	What bus should i take to get to the police station? What bus should i take to get to the town house? What bus should i take to get to Mercur?	Error, Error, Error(Sentence)
when is the bus coming, whats the quickest route from A to B	whats the quickest route from Moholt to Samf	Good
How to get from A to B?	How to get from Moholt to Samf?	Good
Alternate routes from A to B?	Alternate routes from Moholt to Samf?	Error
How long is the trip to A?	How long is the trip to Moholt?	Error
Closest stop to A?	Closest stop to Moholt?	Error(Sentence)
What time is the next bus/streetcar/train coming to stop A?	What time is the next bus coming to Moholt?	Good
What time is the next bus/streetcar/train on route A-B coming to stop A?	What time is the next bus on route 5 coming to stop Moholt?	Good
How much of a delay is there currently on route A-B?	How much of a delay is there currently on route 5?	Error(Sentence)
When will the next bus 66 stop at B?	When will the next bus 5 stop at Moholt?	Good

When is the latest I can leave from A and get to B?	When is the latest I can leave from Moholt and get to Samf?	Error(Sentence)
What's the farthest I can go from A?	What's the farthest I can go from Moholt?	Error(Sentence)
Directions from A to B	Directions from Moholt to Samf	Good
What bus goes from A to B	What bus goes from Moholt to Samf	Good
Buses stopping at both A and B	Buses stopping at both Moholt and Samf	Wrong
getting from A to B	getting from Moholt to Samf	Good
closest stop from A	closest stop from Moholt	Error(Sentence)
list of stops from A to B	list of stops from Moholt to Samf	Error(Sentence)
time to get from A to B	time to get from Moholt to Samf	Error(Sentence)

Appendix D

Answers to the original survey

This appendix contains one of the answers to the original survey. This survey which was replaced by the updated version used on Reddit's *SampleSize* because of the few responses, but this particular question is used for comparison in the report.

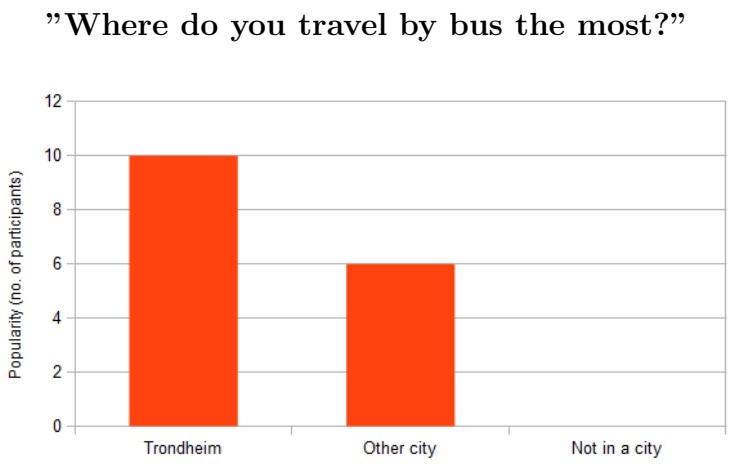

Figure D.1: Answers to the original survey's question about location.