**Faculty of Natural and Mathematical Sciences**
Department of Informatics

The Strand
Strand Campus
London WC2R 2LS
Telephone 020 7848 2145
Fax 020 7848 2851

**7CCSMPRJ**

**Preliminary Project Report**

| | |
|---|---|
| **Name:** | Sebastian Zillessen |
| **Student Number:** | #1564629 |
| **Degree Programme:** | MSc Web Intelligence MSc |
| **Project Title:** | Automated Small Datanalyst |
| **Supervisor:** | Jeroen Keppens |
| **Scientific Assistant:** | Isabel Sassoon |

**RELEASE OF PRODUCT**

Following the submission of your project, the Department would like to make it publicly available via the library electronic resources. You will retain copyright of the project.

☑ I **agree** to the release of my project

☐ I **do not** agree to the release of my project

**Signature:**

**Date:** April 24, 2016

Department of Informatics
King's College London
WC2R 2LS London
United Kingdom

# Automated Small Datanalyst

Preliminary Project Report

**Sebastian Zillessen**
Student Number: #1564629
Course: MSc Web Intelligence MSc

**Supervisor:** Jeroen Keppens

Thesis submitted as part of the requirements for the award of the MSc in Web Intelligence.
7CCSMPRJ - MSc Individual Project - 2016

# Contents

# List of Figures



# List of Tables

# 1 Introduction

Nowadays data collection is omnipresent. However, most of the research is done on the extraction of information from large data sets (so called Big Data Analysis). Therefore small data sets collected in day-to-day practice of professionals is often overlooked. Clinicians and hospitals collect for example a lot of data on their patients, the used therapies and the outcomes. Unfortunately this data is often not used to inform future practice. This project aims to implement an intelligent agent that provides statistical advice on the analysis of such data. The system will be based on the design described in the related paper by Sassoon *et al.* [1].

This preliminary report first clarifies the project aims and objectives in subsection 1.1. Second, the used methodologies and the general technical specification are explained (see subsection 1.2 and subsection 1.3). This is followed by a background research in section 2 providing a review of the theoretical aspects of argumentation frameworks and their extensions and the theory behind statistical model selection. A critical review of related literature and approaches is given. At the end of this preliminary report a detailed project plan is presented (see section 3) which depicts the planned progress of this thesis till the end of August 2016.

## 1.1 Project Aims and Objectives

The aims of this project can be divided into a list or primary and secondary goals. For a successful project progression the following primary objectives have to be reached:

- General explanation and summary of argumentation frameworks (AFs), extended argumentation frameworks (EAFs) and statistical model selection.
- Development of an *Ruby on Rails* web application that implements the requirements proposed in [1] including but not limited to:
  - An approach to instantiate and solve AFs and EAFs.
  - The ability to store, manage and reuse research questions, analysis, preferences for statistical models and data sets.
  - An easy to use user interface to upload clinical data and run analyses in an interactive way using the theory proposed by Sassoon *et al.*
  - The ability to deal with preferences between models on a meta-level using EAFs while taking into account global and personal (end user) preferences.
  - A user rights management to allow the system to be used by clinicians and statisticians.
  - A small set of statistical models and their assumptions integrated in the

  system (externally provided).
  - A comprehensive set of unit and integration tests of the system.
  - Hosting of this web application at a public accessible provider.
- The system should provide the end user with an explanation why a statistical model should be used, and why one model might be preferred over another one.

The secondary goals are desired to be achieved but do not influence the successful finalisation of the project. These objectives are the following:

- A documentation of the developed system providing information on how to use it and an overview over the key components of the application.
- A reusable implementation to solve standard AFs in Ruby as a `gem` including documentation and a comprehensive set of unit tests.
- A reusable implementation to solve EAFs in Ruby as a `gem` including documentation and a comprehensive set of unit tests.
- Extended sets of statistical models and their assumptions.
- A graphical representation of the arguments explaining the actual analysis outcome of the system.

## 1.2 Methodologies of the Project

This project will be developed in an agile way. To ensure that it meets the requirements described by Sassoon *et al.* ([1], see subsection 2.4), the main author of that paper is treated as a client during the requirements analysis and the testing phase. For the actual development process the Use-Case 2.0 approach by Jacobson *et al.* [2] is used as it provides a great way to communicate, specify and iterate over functional (independent) parts of the system. Due to its descriptive nature it does not require any knowledge about the actual process to be easy understandable. The key components of this approach are Use-Cases, Use-Case Flows, Use-Case Slices and Test Cases. The later will be used for the test- and behaviour-driven development approach employed in this project. These methodologies will be explained and introduced in detail later in this thesis.

As a project communication and management tool Trello[1] is utilized as it provides an easy-to-use and interactive way of dealing with cards (in our case use-cases and tasks) and to group them. As the final application will be developed in four release cycles (RC 1 - 4, see section 3), track of the already achieved intermediate steps and the actual progress of the development process can be recorded efficiently. Labels and different lists visualise the status and progress of each task and use-case (see Figure 1).

[1] http://www.trello.com

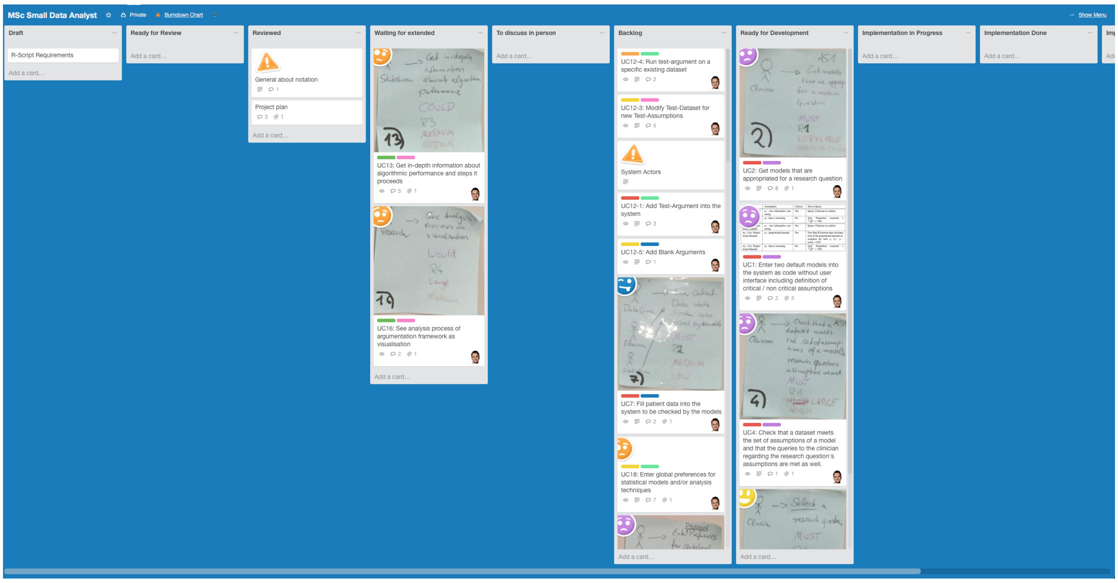



Figure 1: Screenshot of the used Trello board used as project management tool.

## 1.3 Technical Specification

As the system should be accessible by multiple users and from different departments (e.g. clinicians and statisticians), it will be developed as a web-application in `Ruby on Rails 4`[2] and will be hosted on `Heroku`[3].

The used datasets are anonymised, so data protection issues are reduced to a minimum and the datasets can be hosted in the cloud. `PostgreSQL`[4] will be used as a database, as it is well integrated on `Heroku` and provides high scalability.

Most of the assumption tests for the statistical models will be performed in `R`, as this is a common used language for statistical calculations and well known by statisticians. In addition many assumption-checks already exist in `R`. These scripts (provided by Sassoon) will be executed in the `Ruby on Rails` application with the help of third party gems.

To provide a responsive and clear user interface the `Bootstrap`[5] framework will be used to design and style the application.

[2] http://rubyonrails.org
[3] http://www.heroku.com
[4] http://www.postgresql.org
[5] http://getbootstrap.com

# 2 Background Research

The following section provides an introduction on argumentation frameworks (AFs) and extended argumentation frameworks (EAFs). The approach for a statistical model selection proposed in [1] is based on computational models of argumentation. Usually multiple assumptions have to be fulfilled for statistical models to be applicable on a dataset. These assumptions are defeasible and may lead to multiple possible models, which requires argumentation over assumptions and models to provide a reasonable statistical model selection. An introduction to AFs is given in subsection 2.1.

Non-monotonic argumentation (as proposed in [3, 4]) and monotonic (classic) logic (as proposed in [5]) are in general different approaches to deal with reasoning. However, recent research is focusing on dialogue based approaches which are mostly based on non-monotonic argumentation [6, 7]. Nevertheless Sassoon *et al.* propose to employ preferences by using EAFs to reason about the order of applicable models and to deliver a final statistical model which should be used.

To understand this approach, an extension to the standard framework to reason over preferences is presented later in this chapter (see subsection 2.2). Other possible solutions to argue over preferences are explained in subsection 2.3.

Finally, a summary of Sassoon *et al.* [1] on the problem of finding applicable and choosing preferred models by clinicians for a given research question is provided in subsection 2.4.

## 2.1 Argumentation Theory: General introduction

In the following section a general overview on AFs will be given. The notation and definitions are based on Dung's theory [4] as it is a widely used definition for argumentation frameworks.

**Definition 2.1.** An argumentation framework is a tuple $AF = \langle \mathcal{S}, \mathcal{R} \rangle$ where $\mathcal{S}$ is a set of arguments and $\mathcal{R} \subseteq \mathcal{S} \times \mathcal{S}$. $\mathcal{R}$ is a binary relation and called attack relation.

An (abstract) argumentation framework can be represented as a directed graph where nodes are arguments and an arrow from a node $A$ to a node $B$ represents an attack from argument $A$ against $B$.

**Example 2.1.** Figure 2 represents an AF with the definition $AF = \langle \{A, B, C, D, E\}, \{(A, B), (B, C), (B, E), (C, B), (D, C), (D, D)\} \rangle$. This framework will be used as an example for the following definitions.

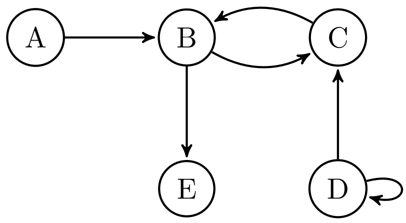



Figure 2: Small example argumentation framework

**Notation 2.2.** In this paper we use capital letters $\{A, B, ...\}$ to denote arguments. $AB$ or $(A, B)$ denotes an attack from $A$ to $B$ ($(A, B) \in \mathcal{R}$).

For the following definitions let $AF = \langle \mathcal{S}, \mathcal{R} \rangle, S' \subseteq \mathcal{S}$.

**Definition 2.3.** A subset $S'$ is **conflict-free** iff $\forall A, B \in S' : (A, B) \notin \mathcal{R}$ *(the subset has no attacks between its arguments).*

**Remark 2.4.** Conflict-free subsets are of interest, as these sets are not directly contradictory. In other words, a conflict-free subset of an argumentation framework does not contain any attacks between its members.

**Example 2.2.** Conflict-free subsets in the provided example are $\emptyset, \{A\}, \{B\}, \{C, E\}, ...$. The sets $\{D\}, \{A, B\}, \{B, C\}$ are not conflict-free.

**Definition 2.5.** $A$ is **acceptable** w.r.t. a subset $S'$ iff $\forall B \in \mathcal{S} : (B, A) \in \mathcal{R} \Rightarrow \exists C \in S' : (C, B) \in \mathcal{R}$ *(an argument $A$ is acceptable with respect to a subset $S'$ iff for each attacker $C$ of $A$ there is an argument in $S'$ that attacks this attacker of $A$).*

**Remark 2.6.** If an argument $A$ is acceptable w.r.t. a subset $S'$, then there exists no holding counter-argument in this AF causing the argument $A$ not to hold.

**Lemma 2.7.** $S'$ **defends** $X$, if and only if $X$ is acceptable with respect to $S'$.

**Example 2.3.** In Figure 2 $E$ is acceptable with respect to $\{A\}$. $A$ is acceptable with respect to $\emptyset$.

**Definition 2.8.** The **characteristic function** of an argumentation framework $AF$ (denoted as $F_{AF}$) is defined by the following:

$$F_{AF} : 2^{\mathcal{S}} \to 2^{\mathcal{S}}$$
$$F_{AF}(S') = \{A | A \text{ is acceptable with respect to } S'\}$$

**Notation 2.9.** If it is unambiguous, we often refer to $F_{AF}$ with $F$.

**Definition 2.10.** A conflict-free set $S' \subseteq \mathcal{S}$ is **admissible** iff $S'$ defends all of its arguments (*each argument in $S'$ is acceptable with respect to $S'$*) or $S' \subseteq F_{AF}(S')$.

**Example 2.4.** In the given example in Figure 2 sets $\{A\}, \{A, E\}$ are admissible, and $\{B\}$ is conflict-free but not admissible, since $B$ is not acceptable with respect to $\{B\}$.

**Definition 2.11.** $S'$ is a **complete extension** iff $S'$ is admissible and each argument that is acceptable with respect to $S'$ (which is defended by $S'$) belongs to $S'$.

**Remark 2.12.** A complete extension is a set of arguments that defends all members and includes all arguments that can be accepted regarding these members. In Figure 2 the set $S' = \{A\}$ is acceptable, but as this set defends as well $E$ (the only attacker $B$ is not acceptable w.r.t. $S'$), this argument must be included in $S'$ to make the set complete. Hence $S' = \{A, E\}$ is a complete extension.

**Example 2.5.** $X = \{A, E\}$ is a complete extension in Figure 2, since it is admissible and it defends $A$ and $E$. Note that $C$ is not defended by $X$ since it does not attack $D$ and $D$ cannot be defended. Complete extensions in Figure 3 are $\{A\}, \{A, C\}$ and $\{A, D\}$.

**Definition 2.13.** A grounded extension ($GE_{AF}$) of an argumentation framework $AF$ is the minimal (with respect to set inclusion) complete extension of $AF$. In other words $GE_{AF}$ is the least fixed point of $F_{AF}$. ($GE_{AF} = F_{AF}(\emptyset)$).

**Remark 2.14.** The grounded extension can be understand as the set of arguments an rational agent can accept without doubts, as it contains only the minimal acceptable arguments for an argumentation framework and does not require the agent to assume anything about any argument.

**Example 2.6.** The grounded extension of the example framework in Figure 2 is $\{A, E\}$. The grounded extension of the example framework in Figure 3 is $\{A\}$.

**Definition 2.15.** A preferred extension of an argumentation framework $AF$ is a maximised (with respect to set inclusion) admissible set of $AF$.

**Example 2.7.** The preferred extensions in Figure 3 are $\{A, C\}$ and $\{A, D\}$.

**Definition 2.16.** A conflict-free set of arguments $S' \subseteq \mathcal{S}$ is called a **stable extension** iff $S'$ directly attacks each argument which does not belong to $S'$.

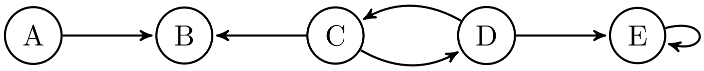



Figure 3: Example argumentation framework

**Example 2.8.** The $AF$ in Figure 3 has the stable extension $\{A, D\}$. $\{A, C\}$ is a preferred, but not a stable extension.

**Remark 2.17.** The different extensions of a $AF = \langle \mathcal{S}, \mathcal{R} \rangle$ have the following relations between each other [4]:

- Each preferred extension is as well a complete extension.
- Each stable extension is as well a preferred extension.
- The grounded extension is the least (with respect to set inclusion) complete extension and therefore unique for each $AF$.
- Preferred extensions are the most (with respect to set inclusion) complete extensions.
- Arguments accepted in the grounded extension are skeptically accepted in the $AF$.
- Every $AF$ has at least one preferred extension.
- A stable extension does not always exist.

**Definition 2.18.** An argument is regarded as **sceptically accepted under a semantic**, iff it is accepted in all extensions of this semantic (complete, grounded, preferred, stable). An argument is regarded as **credulously accepted under a semantic**, iff it accepted in at least one, but not all, extensions of this semantic.

**Example 2.9.** In Figure 3 $\{A\}$ is sceptically accepted under each semantic. $\{C, D\}$ are credulously accepted under a preferred semantic. $\{D\}$ is as well accepted sceptically under the stable semantic.

Furthermore [4] introduces *well-founded argumentation frameworks* (having exactly one extension which is grounded, preferred and stable), *uncontroversial argumentation frameworks* and *coherent argumentation frameworks* (each preferred extension of an $AF$ is stable). Regarding the problem we are looking at, defeasible argumentation is really important, as we are dealing with inconsistent statistical knowledge bases (SKBs). Hence these restricted argumentation frameworks will not be used in this project, therefore they are not discussed any further.

In extension to the discussed extension-based semantics, [3] introduces a so called *labelling-based approach* where there are usually three labels: `IN` (accepted argument), `OUT` (rejected argument) and `UNDEC` (undecided whether this argument is accepted or rejected) and a labelling function $\lambda : \mathcal{S} \rightarrow \{IN, OUT, UNDEC\}$.

By defining legally labelled arguments, definitions for *conflict-free labelings*, *admissible labelings* and *complete/grounded/preferred labelings* can be derived. As there exists a bijective projection, they can be easily transferred to the extension-based semantics already introduced in this section.

## 2.2 Extended Argumentation Framework - Working with Preferences in $AF$

A Dung's argumentation framework is based on logical theory which is transformed to arguments and a binary attack relation. By applying the different extensions on the created argumentation framework accepted arguments can be evaluated. However for practical reasons and in some applications only one unique set of accepted arguments has to be determined. In addition personal preferences, contextual requirements or additional information might result in some arguments having a higher priority than others. The order of preferences is often itself defeasible and conflicting and therefore subject to argumentation. These aspects have not been considered in Dung's approach [8].

In this thesis the EAF approach introduced by Modgil in [8] will be used, as it provides a useful meta-level on preferences between other arguments, by extending Dung's framework with a new attack relation between arguments and attacks. This overcomes the issues of defining orders over preferences (see subsection 2.3) or value-evaluation functions (see subsection 2.3) and enables us to argue about preferences regardless whether they are defeasible or conflicting. In addition it provides a really user-friendly way to consider preferences which will improve the understandability for clinicians, who will be the main actors (see **??**) in the final system. Figure 4, which is taken from [8], shows an example for a EAF representing the following arguments:

- $A$: "Today will be dry in London since the BBC forecast sunshine"
- $B$: "Today will be wet in London since CNN forecast rain"
- $C$: "But I think the BBC are more trustworthy than CNN"
- $D$: "However, statistically CNN are more accurate forecasters than the BBC"
- $E$: "Basing on a comparison on statistics is more rigorous and rational than basing a comparison on your instincts about their relative trustworthiness"

**Definition 2.19.** An extended argumentation framework (EAF) is a triple $\langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle$ with $\mathcal{S}$ being a set of arguments and:

- $\mathcal{R} \subseteq \mathcal{S} \times \mathcal{S}$: attack relation.
- $\mathcal{D} \subseteq \mathcal{S} \times \mathcal{R}$: new attack relation of arguments on attacks.
- $\{(A,(B,C)),(A',(C,B))\} \subseteq \mathcal{D} \rightarrow \{(A,A'),(A',A)\} \subseteq \mathcal{R}$ (any arguments expressing contradictory preferences must attack each other).

**Remark 2.20.** To be able to express a preference between $C$ and $B$ by an additional argument $A$ it is required, that the arguments $B, C$ express contradictory preferences. This can be achieved, if $A$ defines a preference of $C$ over $B$ and the EAF contains $\{(B,C),(C,B)\} \in \mathcal{R}$ and $(A,(B,C)) \in \mathcal{D}$.

Let $\Delta = \langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle$ be a EAF and $S' \subseteq \mathcal{S}$ for the following definitions.

**Definition 2.21.** $A$ **defeats**$_{S'}$ $B$ iff $(A,B) \in \mathcal{R}$ and $\nexists C \in S' : (C,(A,B)) \in \mathcal{D}$. If $A$ defeats$_{S'}$ $B$ and $B$ does not defeat$_{S'}$ $A$ then $A$ **strictly** defeats$_{S'}$ $B$.

**Notation 2.22.** For the rest of the document $A \rightarrow^{S'} B$ denotes that $A$ defeats$_{S'}$ B and $A \nrightarrow^{S'} B$ denotes that $A$ does not defeat$_{S'}$ $B$.

By using this definition, similar properties (e.g. conflict-free and admissible sets, acceptability of an argument, sceptically/credulously accepted arguments, extensions) as in Dung's argumentation framework can be introduced and defined.

**Definition 2.23.** $S'$ is **conflict free** iff $\forall A, B \in S' : (A,B) \in \mathcal{R} \Rightarrow (B,A) \notin \mathcal{R} \wedge \exists C \in S' : (C,(A,B)) \in \mathcal{D}$ *(a subset is only conflict free, if for every attack within the subset there is no counter attack and the attack itself is canceled out by an attack on this attack from an argument that is part of the subset as well).*

**Example 2.10.** The set $S' = \{A, B\}$ of the EAF in Figure 5 is not conflict-free. But the set $S' = \{A, B, C\}$ is conflict-free as $C$ attacks the attack between $A$ and $B$ and cancels it out.

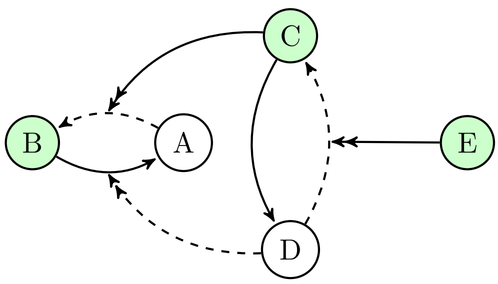



Figure 4: EAF about the weather forcasts with preferences over arguments. Dashed attacks are canceled out. Double-arrow-headed edges represent attacks on attacks. Green nodes represent accepted arguments in the unique preferred extension.

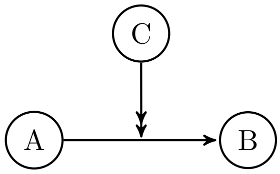



Figure 5: EAF with $\langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle = \langle \{A, B, C\}, \{(A, B)\}, \{(C, (A, B))\} \rangle$.

**Lemma 2.24.** Let $S'$ be a conflict-free subset of $\mathcal{S}$ in $\langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle$. Then for any $A, B \in S'$ $A$ does not defeat$_{S'}$ $B$.

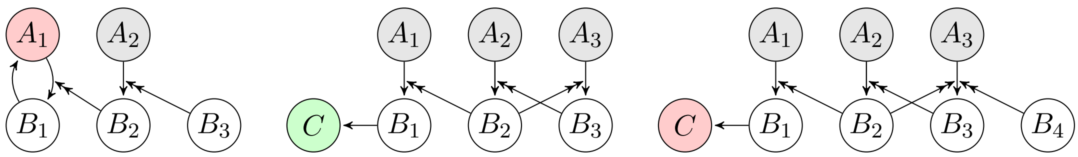
**Definition 2.25.** $R_{S'} = \{X_1 \rightarrow^{S'} Y_1, ..., X_n \rightarrow^{S'} Y_n\}$ is called a **reinstatement set** for $C \rightarrow^{S'} B$ ($C$ defeats$_{S'}$ $B$), iff:

- $C \rightarrow^{S'} B \in R_{S'}$,
- $\forall_{i=1}^{n} X_i \in S'$,
- $\forall X \rightarrow^{S'} Y \in R_{S'}, \forall Y' : (Y', (X, Y)) \in \mathcal{D}$, there is a $X' \rightarrow^{S'} Y' \in R_{S'}$.

*(A set of attacks is called a reinstatement set (for a particular attack $C \rightarrow^{S'} B$), if for every attack relation in $R_{S'}$, which is attacked from another argument $Y'$, there is a attack relation in $R_{S'}$ that attacks this argument $Y'$ again and ensures the attack on the argument to hold. So a reinforcement sets guaranties that an attack on an argument is successfully performed, nevertheless what other attacks in the system exist. Hence these reinforcement sets can be used to define acceptability of arguments as seen in Theorem 2.26.)*

The acceptability of an argument can now be formally defined based on the reinstatement set.

**Definition 2.26.** $A \in \mathcal{S}$ is **acceptable** w.r.t. $S'$, iff: $\forall B : B \rightarrow^{S'} A$, there is a $C \in S' : C \rightarrow^{S'} B$ and there is a reinstatement set for $C \rightarrow^{S'} B$.




(a) $A_1$ is not acceptable w.r.t $S' = \{A_1, A_2\}$ (b) $C$ is acceptable w.r.t $S' = \{A_1, A_2, A_3\}$ (c) $C$ is not acceptable w.r.t $S' = \{A_1, A_2, A_3\}$

Figure 6: EAFs with acceptable and not acceptable sets $S'$. $A_x$ are elements of $S'$.

**Example 2.11.** In Figure 6(a) $S' = \{A_1, A_2\}$ is not admissible since $A_1$ is not acceptable w.r.t. $S'$. In Figure 6(b) $C$ is acceptable w.r.t $S' = \{A_1, A_2, A_3\}$ as there is a reinstatement set $\{A_1 \rightarrow^{S'} B_1, A_2 \rightarrow^{S'} B_2, A_3 \rightarrow^{S'} B_3\}$ for $A_1 \rightarrow^{S'} B_1$. In Figure 6(c) there is an additional argument $B_4$ such that $B_4 \rightarrow (C_3 \rightarrow B_3)$ and no argument in $S'$ that defeats$_{S'}$ $B_4$, then no reinstatement set for $A_1 \rightarrow^{S'} B_1$ would exist, hence $C$ is not acceptable w.r.t. $S'$.

Similar to Dung's theory, admissible, preferred, complete and stable extensions of an EAF can now be defined.

**Definition 2.27.** Let $S'$ be a **conflict free** subset of $\mathcal{S}$ in $\langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle$. Then:

- $S'$ is an **admissible** extension iff every argument in $S'$ is acceptable w.r.t $S'$.
- $S'$ is a **preferred** extension iff $S'$ is (w.r.t. set inclusion) a maximal admissible extension.
- $S'$ is a **complete** extension iff each argument which is acceptable w.r.t. $S'$ is in $S'$.
- $S'$ is a **stable** extension iff $\forall B \notin S', \exists A \in S'$ such that $A$ defeats$_{S'}$ $B$.

By using this definition, we can define again **sceptically**, respectively **credulously**, accepted arguments under the semantic $s \in$\{preferred, complete, stable\} iff $A$ is in every (at least one) $s$ extension.

**Example 2.12.** The example given in Figure 4 has only the single preferred, complete and stable extension $\{B, C, E\}$. Figure 5 has the admissible sets $\{A\}, \{A, C\}, \{A, B, C\}$. $\{A, B, C\}$ is the only preferred extension which is as well stable.

**Lemma 2.28.** Let $\Delta = \langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle$ be an EAF, $S'$ an admissible extension of $\Delta$ and let $A, A'$ be arguments which are acceptable w.r.t. $S'$. Then:

- $S'' = S' \cup \{A\}$ is admissible.
- $A'$ is acceptable w.r.t. $S''$.

**Lemma 2.29.** Let $\Delta = \langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle$ be an EAF.

- The set of all admissible extensions of $\Delta$ form a complete partial order w.r.t. set inclusion.
- For each admissible extension $E$ of $\Delta$ there exists a preferred extension $E'$ such that $E \subseteq E'$.

The definition of the characteristic function for an EAF is similar but not equal to Dung's definition.

**Definition 2.30.** Let $\Delta = \langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle$ be an EAF, $S' \subseteq \mathcal{S}$, and $2^{\mathcal{S}_C}$ denote the set of all conflict free subsets of $\mathcal{S}$. The **characteristic function** $F_\Delta$ of $\Delta$ is defined as follows:

- $F_\Delta : 2^{\mathcal{S}_C} \to 2^{\mathcal{S}}$
- $F_\Delta(S') = \{A | A$ is acceptable w.r.t. $S'\}$.

From here on we will always refer to a fixed EAF, hence we can simply write $F$ rather than $F_\Delta$. Equally to Dung's Framework, any conflict-free set $S' \subseteq \mathcal{S}$ in $\Delta$ is admissible iff $S' \subseteq F(S')$, and complete iff $S'$ is a fixed point of $F$. We can apply $F$ iteratively on an EAF: $F^0 = \emptyset, F^{i+1} = F(F^i))$. Note, that for EAFs the characteristic function $F$ is in general **not** monotonic (e.g. $C$ is acceptable w.r.t $S' = \{A_1, A_2, A_3\}$ in 6(b), but is not acceptable w.r.t. the conflict-free $S'' = S' \cup \{B_2, B_3\}$).

**Lemma 2.31.** Let $F$ be the characteristic function of an EAF, and $F^0 = \emptyset, F^{i+1} = F(F^i)$. Then $\forall i, F^i \subseteq F^{i+1}$ and $F^i$ is conflict free.

**Definition 2.32.** $\Delta = \langle \mathcal{S}, \mathcal{R}, \mathcal{D} \rangle$ is a **finitary** EAF iff $\forall A \in \mathcal{S}$, the set $\{B | (B, A) \in \mathcal{R}\}$ is finite and $\forall (A, B) \in \mathcal{R}$, the set $\{C | (C, (A, B)) \in \mathcal{D}\}$ is finite.

**Definition 2.33.** Let $\Delta$ be a finitary EAF and $F^0 = \emptyset, F^{i+1} = F(F^i)$. Then $\cup_{i=0}^{\infty}(F^i)$ is the **grounded extension** $GE(\Delta)$ of $\Delta$.

**Remark 2.34.** Similar to Dung's framework we can state the following relations between different extensions:

- Every EAF has at least one preferred extension (implied by Theorem 2.29 as $\emptyset$ is an admissible extension for every EAF).
- Every stable extension of an EAF is a preferred extension.
- The grounded extension for EAF is not defined over the least fix point of the characteristic function $F$, but can be defined for finitary EAFs over the union of all characteristic functions $F^i$.

In addition Modgil *et al.* introduce in [8] the concept of a special class of EAFs, *hiearchical EAFs*, which are defined by the existence of a partition of $\Delta$ into multiple regular Dung argumentation frameworks. Due to this restriction it is possible to define a least fix point of the characteristic function $F$, hence defining the grounded extension $GE(\Delta)$ in the same way as it has been defined in Dung's framework.

Furthermore [8] presents as well the concept of **Preference symmetric extended argumentation frameworks**. This extension limits the attacks on attacks (so the set $\mathcal{D}$) only on attacks between symmetrically attacking arguments. However, this is a to narrow restriction for our purposes, therefore this will not be described here.

## 2.3 Other Approaches to work with Preferences in $AF$

Other approaches to deal with preferences in argumentation frameworks have been proposed by [9, 10, 11, 12, 13]. A preference-based argumentation framework (PAF) defined in [10] is a triple $\langle \mathcal{S}, \mathcal{R}, Pref \rangle$ where $Pref$ is a (partial of complete) order preordering on $\mathcal{S} \times \mathcal{S}$. The difference between this approach and the one we use is mostly the requirement of a strict ordering that has to be associated with $Pref$ and must be explicitly defined.

value-based argumentation frameworks (VAFs) as proposed in [11] define an argumentation framework as a 5-tuple: $\langle \mathcal{S}, \mathcal{R}, V, val, P \rangle$ ($\mathcal{S}$: Arguments, $\mathcal{R}$: Attack relation, $V$: nonempty set of values, $val(\cdot) : \mathcal{S} \rightarrow V$: value mapping function, $P$: set of audiences $\{a_1, ..., a_n\}$ where each audience names a total ordering $>_{a_i}$ on $V \times V$). By referring to one specific audience we retrieve a audience specific value-based argumentation framework (aVAF). The set of audiences $P$ is introduced to be able to make use of preferences between values in $V$, so we might have as many audiences as there are orderings on $V$. The new definition of an argument that defeats another argument takes into account the audience $a$ and the $val(\cdot)$ of both arguments to define successful attacks. This approach requires an – in our case unknown – value mapping function $val(\cdot)$ and doesn't argue with preferences in a natural way.

However [8] proves, that an aVAF can be transferred to an *equivalent* EAF by representing the aVAF with three layers, the outer layer expressing the audience, the second layer expressing the pairwise orderings on values in $V$. The inner layer is based the actual arguments and attacks in the aVAF.

Defeasible reasoning and preferences and their impact on argumentation frameworks are formalised as logical formalism by [12, 13] in the underlying logical formalism which will be used to instantiate a regular Dung framework.

## 2.4 Statistical Model Selection via Argumentation

The foundation of this MSc Project is the paper [1]. The goal of this project is to use Argumentation Theory for Statistical Model Selection in mostly clinical environments. The demand into systems that support clinicians in the analysis of this data in their day-to-day practice is extending (because of increasing availability, growing size of datasets available for clinicians, and raising awareness on evidence based decision making extend). In the following section a short summary on the paper will be given.

To overcome the issue of clinicians analysing data and models on their compatibility [1] proposes an approach of an intelligent model selection system which is capable of suggesting appropriate model(s) to a clinician during the design stage of a study, taking in account the research question, the clinical data and any external relevant input and preferences. In addition this system should be able to support its decision by providing the argumentation for and against a model to the user. As clinicians might not always be qualified to perform the statistical analysis required for their research question, the process of designing models, specifying its requirements and providing the arguments for or agains these models should be separated from the actual design process and be done by a statistician. The statistician is thereby charge of understanding the data in the context of the research question and provide arguments that are able to recommend the best suited statistical analysis for a particular research question.

Furthermore Sassoon *et al.* [1] addresses the problem of defeasible knowledge, as the (counter)arguments for a model are often contradicting and the system, the clinician and the statistician might have some preferences for one or the other model. Therefore Sassoon *et al.* propose to split the problem into two parts (i) a (defeasible) *knowledge base* that contains the statistical model definitions, the objectives and assumptions of a model; (ii) *argumentation schemes* to guide the model selection process and to represent expressed preferences.

The *knowledge base* is used to instantiate the *argumentation schemes.* The knowledge base itself defines how research objectives can be achieved through different statistical models considering their given assumptions. *Research objectives* are defined as different 'families' of analysis (e.g. survival analysis or categorical outcome variable analysis).

**Statistical Knowledge Base**

The statistical knowledge base (SKB) consists of objectives $O = \{o_1, ..., o_u\}$ (different types of research questions), models $M = \{m_1, ..., m_v\}$ and assumptions $A = \{a_1, ..., a_w\}$. Models represent statistical analysis techniques employable to answer a research question. Assumptions are conditions that ought to be met to employ a model.

**Definition 2.35.** Let $R_{OM} : O \times M$ be a m:n[6]-relationship such that $(o_i, m_j) \in R_{OM}$ implies objective $o_i$ can be achieved by means of model $m_j$.

**Definition 2.36.** Let $R_{MA} : M \times A$ be relation between models and their assumptions. $(m_i, a_j) \in R_{MA}$ implies the model $m_i$ requires the assumption $a_j$ to be true to be applicable. Let $A(m_i) = \{a_j | (m_i, a_j) \in R_{MA}\}$ be the set of assumptions of $m_i$.

[6] Each objective can be achieved by one or more models, each model can answer one or more objectives.

As it will not always be possible to find a model where all assumptions are met, it will be necessary to apply a model even when there are some violations regarding the assumptions. Hence we need to specify whether an assumption $a_j$ is *critical* to a model. If a critical assumption doesn't hold its model must not be applied under any circumstances.

**Definition 2.37.** Let $C \subset R_{MA}$ be the set of critical assumptions. To apply a model $m_i$ all critical assumptions $A_c(m_i) = \{a_j | (m_i, a_j) \in C\}$ must be met.

Each *assumption* will be either specified as a specific property of the data set (assessed by applying tests on the data set) or as a characteristic of the population of interest or the way in which the data set was collected from that population (relying on the expertise of a domain expert). Sassoon proposes a partitioning of all assumptions: $A_t$ denotes the set of tests (and apply a test on the available data set). $A_q$ denotes the set of queries (and will be assessed by asking the clinician for an opinion). Lets define $A_t(m_i) = \{a_j | (m_i, a_j) \in A_t\}$ and $A_q(m_i) = \{a_j | (m_i, a_j) \in A_q\}$. Note that critical assumptions can be in either $A_t$ or $A_q$: $C \subset R_{MA} = A_q \cup A_t,\ A_q \cup A_t = \emptyset$.

The Figure 7 shows the structure between *objectives*, *models* and *assumptions* in a small example. The assumptions $\{a_1, a_2, a_3\} \in A_t$ are based on the provided data set, $\{a_3, a_5\} \in A_q$ are based on the domain expertise. Objectives $\{o_1, o_2\}$ can be achieved by the possible model $m_1$, $o_3$ can only be achieved by $m_3$. Note that $m_3$ is still a possible model although the non critical assumption $a_4$ doesn't hold.

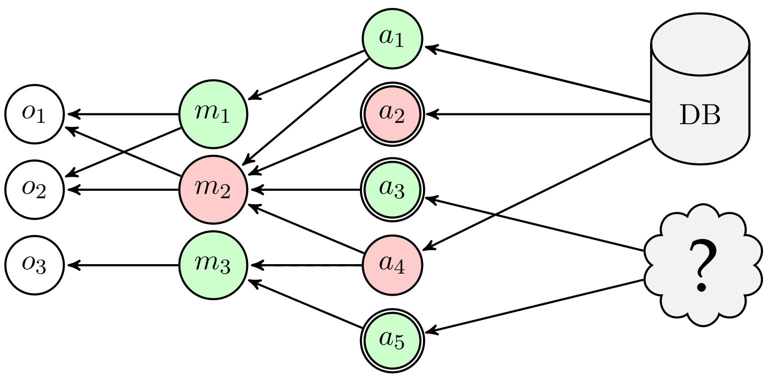



Figure 7: Example of a SKB. Double circled assumptions represent critical assumptions. Green coloured assumptions hold while red coloured assumptions do not hold. Green coloured models are the possible models.

**Different Processes to instantiate Arguments from the Knowledge Base**

To achieve an objective $o_c$ (which has been selected by the clinician) a number of models $m_i$ might be possible providing their critical assumptions $A_c(m_i)$ are met. The process of instantiating the arguments can be seen in AS1. To elaborate one model $m_i$ which is preferred over the other possible models we define a Model Preference as depicted in AS2.

- Model $m_i$ achieves objective $o_c$.
- The data set meets the set of assumptions $A'_t = A_t(m_i)$.
- The research project meets the set of assumptions $A'_q = A_q(m_i)$.
- $A_c(m_i) \subseteq A'_t \cup A'_q$.

---

$\Rightarrow$ $m_i$ is a possible model for the research question $o_c$.

AS 1: Constructed argument for a Possible Model.

Depending on the purposes of models and on the reasons for preferring one model over another there are different ways of implementing $(*)$ in the generic definition provided in AS2. These different reasons to prefer one model over another depend on the context and on the application, however [1] proposes different approaches to express the preference of one model over another.

- $m_i$ is a possible model.
- $m_j$ is a possible model.
- there is some reason to prefer $m_i$ over $m_j$ $(*)$

---

$\Rightarrow$ $m_i$ is preferred over $m_j$.

AS 2: Argument for a Model Preference between two possible models.

To express the preferences for one model over another, Sassoon *et al.* [14] propose to use EAF [8] in combination with PAF [9, 15] approaches, both been presented earlier in this paper. These modifications enable argumentation on preferences which are encapsulated as arguments, therefore we will be able to consider conflicting preferences in our system and ensure scalability and express orders of importance between statistical reasons to prefer one model over another and clinician's preferences in specific contexts.

# 3 Project Plan

To provide a schedule and to check whether the project is still proceeding on a good pace, a project plan has been developed after performing the requirements analysis and discussing various aspects of the project with the client (the main author of the paper summarised in subsection 2.4). This project plan can be found as a Gantt-Chart in Figure 8. Further details of it can be seen in Figure 9 and Figure 10. In general, light blue colour is used for tasks related to the actual thesis (writing, reports, research). Blue coloured tasks represent requirement, analysis and development tasks. Light green tasks are related to project reports whereas dark-green tasks stand for feedback cycles. Green milestones (diamonds) represent internal release candidates of the development iterations. Red milestones represent external milestones and due dates.

This schedule will be updated over time according to the actual progress of the project.

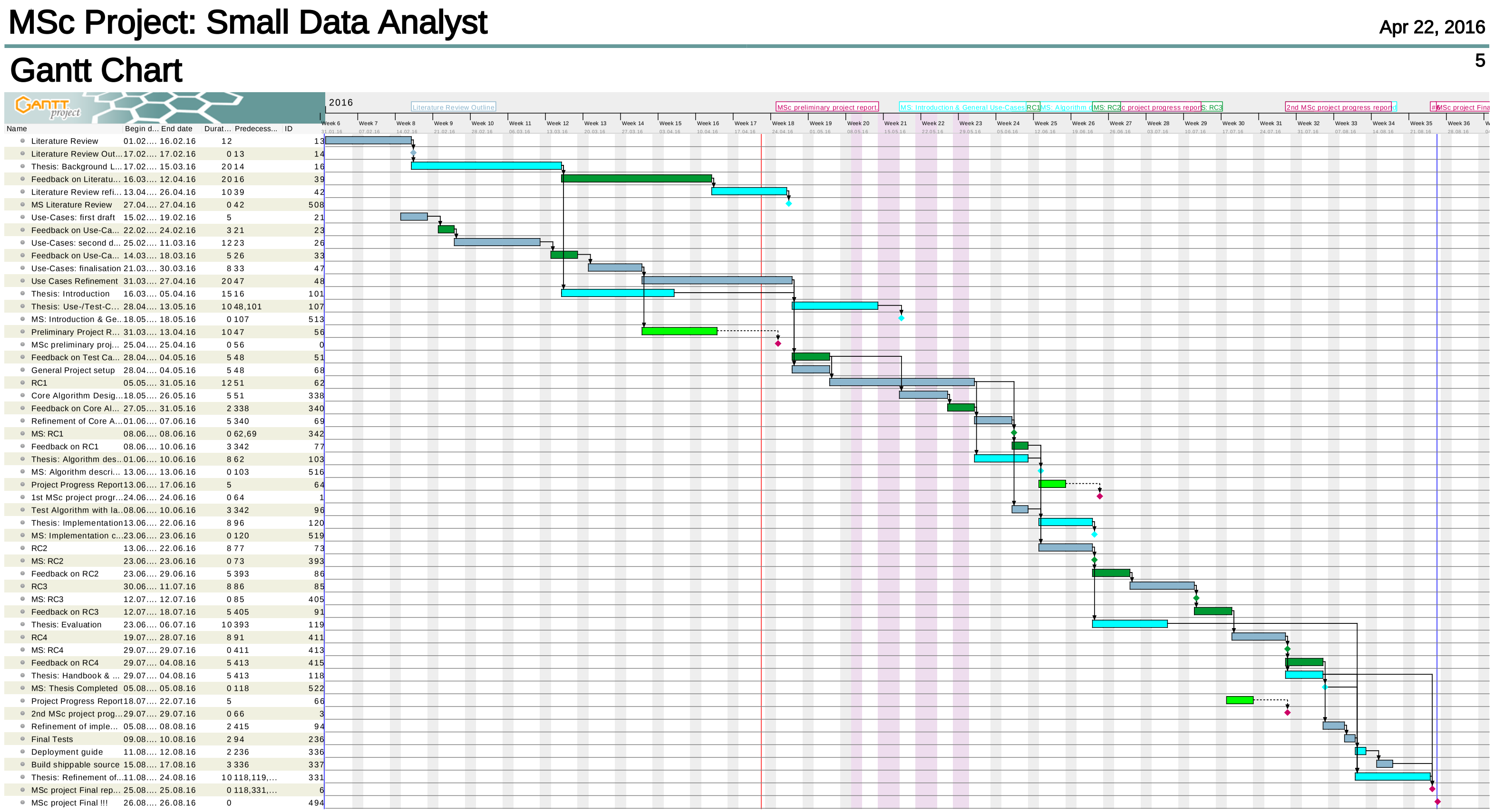



Figure 8: Project plan for the whole development and research

## MSc Project: Small Data Analyst

Apr 22, 2016

2

### Tasks

| Name | Begin date | End date | Duration | Predecessors | ID |
|---|---|---|---|---|---|
| Literature Review | 01.02.16 | 16.02.16 | 12 | | 13 |
| Literature Review Outline | 17.02.16 | 17.02.16 | 0 | 13 | 14 |
| Thesis: Background Literature Review | 17.02.16 | 15.03.16 | 20 | 14 | 16 |
| Feedback on Literature Review | 16.03.16 | 12.04.16 | 20 | 16 | 39 |
| Literature Review refinement | 13.04.16 | 26.04.16 | 10 | 39 | 42 |
| MS Literature Review | 27.04.16 | 27.04.16 | 0 | 42 | 508 |
| Use-Cases: first draft | 15.02.16 | 19.02.16 | 5 | | 21 |
| Feedback on Use-Case Draft | 22.02.16 | 24.02.16 | 3 | 21 | 23 |
| Use-Cases: second draft | 25.02.16 | 11.03.16 | 12 | 23 | 26 |
| Feedback on Use-Case Draft | 14.03.16 | 18.03.16 | 5 | 26 | 33 |
| Use-Cases: finalisation | 21.03.16 | 30.03.16 | 8 | 33 | 47 |
| Use Cases Refinement | 31.03.16 | 27.04.16 | 20 | 47 | 48 |
| Thesis: Introduction | 16.03.16 | 05.04.16 | 15 | 16 | 101 |
| Thesis: Use-/Test-Case and Design | 28.04.16 | 13.05.16 | 10 | 48, 101 | 107 |
| MS: Introduction & General Use-Cases | 18.05.16 | 18.05.16 | 0 | 107 | 513 |
| Preliminary Project Report | 31.03.16 | 13.04.16 | 10 | 47 | 56 |
| MSc preliminary project report. | 25.04.16 | 25.04.16 | 0 | 56 | 0 |
| Feedback on Test Cases & Use Case Refinement | 28.04.16 | 04.05.16 | 5 | 48 | 51 |
| General Project setup | 28.04.16 | 04.05.16 | 5 | 48 | 68 |
| RC1 | 05.05.16 | 31.05.16 | 12 | 51 | 62 |
| Core Algorithm Design & Implementation | 18.05.16 | 26.05.16 | 5 | 51 | 338 |
| Feedback on Core Algorithm | 27.05.16 | 31.05.16 | 2 | 338 | 340 |
| Refinement of Core Algorithm | 01.06.16 | 07.06.16 | 5 | 340 | 69 |
| MS: RC1 | 08.06.16 | 08.06.16 | 0 | 62, 69 | 342 |
| Feedback on RC1 | 08.06.16 | 10.06.16 | 3 | 342 | 77 |
| Thesis: Algorithm description | 01.06.16 | 10.06.16 | 8 | 62 | 103 |
| MS: Algorithm description | 13.06.16 | 13.06.16 | 0 | 103 | 516 |
| Project Progress Report | 13.06.16 | 17.06.16 | 5 | | 64 |
| 1st MSc project progress report | 24.06.16 | 24.06.16 | 0 | 64 | 1 |

Figure 9: Detailed description and properties of single task listed in the project plan (Page 1/2)

MSc Project: Small Data Analyst Apr 22, 2016

## Tasks

3

| Name | Begin date | End date | Duration | Predecessors | ID |
|---|---|---|---|---|---|
| Test Algorithm with large datasets & refinement | 08.06.16 | 10.06.16 | 3 | 342 | 96 |
| Thesis: Implementation | 13.06.16 | 22.06.16 | 8 | 96 | 120 |
| MS: Implementation chapter | 23.06.16 | 23.06.16 | 0 | 120 | 519 |
| RC2 | 13.06.16 | 22.06.16 | 8 | 77 | 73 |
| MS: RC2 | 23.06.16 | 23.06.16 | 0 | 73 | 393 |
| Feedback on RC2 | 23.06.16 | 29.06.16 | 5 | 393 | 86 |
| RC3 | 30.06.16 | 11.07.16 | 8 | 86 | 85 |
| MS: RC3 | 12.07.16 | 12.07.16 | 0 | 85 | 405 |
| Feedback on RC3 | 12.07.16 | 18.07.16 | 5 | 405 | 91 |
| Thesis: Evaluation | 23.06.16 | 06.07.16 | 10 | 393 | 119 |
| RC4 | 19.07.16 | 28.07.16 | 8 | 91 | 411 |
| MS: RC4 | 29.07.16 | 29.07.16 | 0 | 411 | 413 |
| Feedback on RC4 | 29.07.16 | 04.08.16 | 5 | 413 | 415 |
| Thesis: Handbook & User Manual | 29.07.16 | 04.08.16 | 5 | 413 | 118 |
| MS: Thesis Completed | 05.08.16 | 05.08.16 | 0 | 118 | 522 |
| Project Progress Report | 18.07.16 | 22.07.16 | 5 | | 66 |
| 2nd MSc project progress report | 29.07.16 | 29.07.16 | 0 | 66 | 3 |
| Refinement of implementatio | 05.08.16 | 08.08.16 | 2 | 415 | 94 |
| Final Tests | 09.08.16 | 10.08.16 | 2 | 94 | 236 |
| Deployment guide | 11.08.16 | 12.08.16 | 2 | 236 | 336 |
| Build shippable source | 15.08.16 | 17.08.16 | 3 | 336 | 337 |
| Thesis: Refinement of all | 11.08.16 | 24.08.16 | 10 | 118, 119, 236, 522 | 331 |
| MSc project Final report + source code + supplemental files | 25.08.16 | 25.08.16 | 0 | 118, 331, 337 | 6 |
| MSc project Final !!! | 26.08.16 | 26.08.16 | 0 | | 494 |

Figure 10: Detailed description and properties of single task listed in the project plan (Page 2/2)

# Acronyms

# References


[1] I. Sassoon, J. Keppens, and P. McBurney, "Towards argumentation for statistical model selection.," in *COMMA*, pp. 67–74, 2014.

[2] I. Jacobson, I. Spence, and K. Bittner, *USE-CASE 2.0 The Guide to Succeeding with Use Cases.* Ivar Jacobson International SA., Dezember 2011.

[3] B. Liao, *Efficient Computation of Argumentation Semantics.* Academic Press, 1st ed., 2014.

[4] P. M. Dung, "On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games," *Artificial Intelligence*, vol. 77, no. 2, pp. 321 – 357, 1995.

[5] R. Reiter, "A logic for default reasoning," *Artificial Intelligence*, vol. 13, no. 12, pp. 81 – 132, 1980. Special Issue on Non-Monotonic Logic.

[6] L. Amgoud, N. Maudet, and S. Parsons, "Modelling dialogues using argumentation," in *MultiAgent Systems, 2000. Proceedings. Fourth International Conference on*, pp. 31–38, 2000.

[7] D. W. a. E. C. W. Krabbe, *Commitment in Dialogue: Basic Concepts of Interpersonal Reasoning.* State University of New York Press, 1995.

[8] S. Modgil, "Reasoning about preferences in argumentation frameworks," *Artificial Intelligence*, vol. 173, no. 910, pp. 901 – 934, 2009.

[9] L. Amgoud and C. Cayrol, "A reasoning model based on the production of acceptable arguments," *Annals of Mathematics and Artificial Intelligence*, vol. 34, no. 1, pp. 197–215, 2002.

[10] L. Amgoud and C. Cayrol, "On the acceptability of arguments in preference-based argumentation," in *Proceedings of the Fourteenth conference on Uncertainty in artificial intelligence*, pp. 1–7, Morgan Kaufmann Publishers Inc., 1998.

[11] T. J. M. Bench-Capon, "Persuasion in practical argument using value-based argumentation frameworks," *Journal of Logic and Computation*, vol. 13, no. 3, pp. 429–448, 2003.

[12] J. L. Pollock, "Defeasible reasoning," *Cognitive science*, vol. 11, no. 4, pp. 481–518, 1987.

[13] H. Prakken and G. Sartor, "Argument-based extended logic programming with defeasible priorities," *Journal of Applied Non-Classical Logics*, vol. 7, no. 1-2, pp. 25–75, 1997.

[14] I. Sassoon, J. Keppens, and P. McBurney, "Incorporating preferences and argumentation schemes for statistical model selection," 2014.

[15] L. Amgoud, S. Parsons, and L. Perrussel, "An argumentation framework based on contextual preferences," *Proceedings of the 3rd International Conference on Formal and Applied Practical Reasoning (FAPR'00)*, pp. 59–67, 2000.