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Coloring Les Mis

A Multilayer Network Approach for Modeling
Interpersonal Relationships

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Abstract

In network science, interpersonal relationships have traditionally been modeled with one type of edge. This is often an inadequate approximation of reality and does not capture the full nature of relationships. To address these shortcomings, researchers have identified ten social dimensions that can be used to describe the social character of relationships, and developed “Natural Language Processing”-tools. The purpose of this thesis was to explore how the ten social dimensions can be applied in network science to capture the social character of interpersonal relationships when modeling social systems. The goal was to create a network that captures the social character of interpersonal relationships. We constructed a proof-of-concept by modeling the relationships between characters in the movie *Les Misérables* (1998).

Firstly, we constructed a dataset that contained the subtitle, speaker, receivers, and time of every utterance in the movie *Les Misérables* (1998). We then used Natural Language Processing to classify each utterance according to the ten social dimensions, and modeled characters and their verbal interactions with a Multilayer Temporal Text Network. From which we derived a Directed Weighted Multilayer Network representing the characters and the strength of their connections in each of the ten social dimensions. Finally, we generated weighted distributions that represented the Directed Weighted Multilayer Network’s representation of relationships between pairs of characters. These distributions were compared with a human’s perception of the relationships. The results showed that the distributions and the human’s perception either partially or largely matched for multiple relationships, indicating that the network captured key social characteristics of multiple relationships.

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Populärvetenskaplig sammanfattning

Sociala relationer påverkar de flesta aspekter av våra liv. De påverkar vad vi blir i livet, de möjligheter vi ges, vilka beslut vi fattar och vilka handlingar vi begår. Olika typer av relationer har olika karaktär och påverkar våra liv på olika sätt. Till exempel har relationen mellan ett gift par i regel andra särdrag än relationen mellan två kollegor. Ett gift par ger, förhoppningsvis, varandra kärlek medan två kollegor, förhoppningsvis, utbyter arbetsrelaterad information.

Inom nätverksteori modelleras relationer med hjälp av noder—vilka representerar individer—och bågar—vilka representerar kopplingar mellan individer. Denna metod är effektiv eftersom den gör det möjligt att bättre förstå komplexa sociala system genom att tillämpa matematiska, beräkningsmässiga och statistiska verktyg. Ett vanligt tillvägagångssätt är att använda viktade bågar för att modellera och skilja på relationer enligt deras styrka, där vikten representerar hur stark en koppling är. Styrka är en viktig aspekt av sociala relationer och viktade bågar har varit ett framgångsrikt koncept som har bidragit till att öka kunskapen om sociala system. Dock är styrka bara ett av många särdrag och utgör inte hela karaktären av en relation. Exempelvis kan en person ha ett lika starkt relationsband till sin mamma som den har till sin partner, men relationerna är fundamentalt annorlunda, vilket inte fångas om relationerna enbart modelleras efter sin styrka. För att bemöta dessa tillkortakommanden har forskare identifierat tio sociala dimensioner som kan användas för att karaktärisera olika typer av relationer, samt utvecklat ”naturlig språkbehandlings”-verktyg som kan klassificera interaktioner mellan människor enligt dessa sociala dimensioner.

Syftet med denna uppsats var att utforska hur dessa sociala dimensioner kan appliceras inom nätverksteori för att fånga den sociala karaktären av relationer när man modellerar sociala system. Målet var att skapa ett nätverk som fångar den sociala karaktären av sociala relationer. Vi konstruerade ett Koncepttest genom att modellera relationerna mellan karaktärer i filmen *Les Misérables* (1998).

Till att börja med tog vi fram ett dataset som innehåller undertexten, talaren, mottagarna och tidpunkten för alla verbala yttranden i filmen *Les Misérables* (1998). Därefter använde vi naturlig språkbehandling för att klassificera alla yttranden enligt de tio sociala dimensionerna, och modellerade alla verbala interaktioner med en typ av nätverksmodell som vi kallar Multilayer Temporal Text Network. Från detta nätverk genererades en nätverksmodell som vi kallar Directed Multilayer Social Network. Denna modell innehöll flera nätverkslager där varje lager representerade relationsbanden i en av de tio sociala dimensionerna. Slutligen erhöll vi distributioner genom att extrahera bågvikten—*i.e.* styrkan av ett relationsband—mellan par av karaktärer från varje lager i nätverket. Vi tog även fram tidslinjer som illustrerar hur distributionerna utvecklades över tiden.

Vi utvärderade nätverket genom att jämföra distributionerna med en människas uppfattning om relationerna. Flertalet relationer stämde delvis eller huvudsakligen överens med deltagarens uppfattning om relationerna. Vilket indikerar att nätverket fångade viktiga sociala särdrag av flertalet relationer.

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Acronyms

DMSN Directed Multilayer Social Network.

DWMN Directed Weighted Multilayer Network.

DWP Directed-Weighted Projection.

MTTN Multilayer Temporal Text Network.

NLP Natural Language Processing.

TTN Temporal Text Network.

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1 Introduction

Interpersonal relationships shape most aspects of our lives. They affect who we become, the opportunities we are given or denied, the decisions we make and the actions we take [20]. Different relationships have different characteristics and affect our lives in different ways. For example, the character of a relationship between a father and son is different from that of a relationship between a husband and wife; a father might offer his son guidance and financial support, whereas a wife might offer her husband intimacy and companionship.

In network science, interpersonal relationships are modeled with nodes and edges, where nodes represent individuals, and edges represent connections between them [18]. This approach is effective because it allows us to better understand complex social systems by applying mathematical, computational, and statistical tools. It is common practice to model and differentiate between relationships according to their strength by using edge weight. Strength is an important aspect, but does not constitute the full character of a relationship. For example, a person might have an equally strong bond with its mother and spouse, but the relationships have fundamentally different characteristics, which is not captured when modeling the relationships according to their strength alone. To address these shortcomings, researchers [6] have identified ten social dimensions that can be used to describe the social character of interpersonal relationships, and developed “Natural Language Processing”-tools to “color” connections according to these dimensions [4].

The purpose of this thesis was to explore how the ten social dimensions can be applied in network science to capture the social character of interpersonal relationships when modeling social systems. The goal was to create a network that captures the social character of interpersonal relationships. We constructed a proof-of-concept by modeling the relationships between characters in the movie *Les Misérables* (1998). The relationships were modeled with a multilayer network, where each layer represented connections in one of the ten social dimensions. The strength of connections were determined by using Natural Language Processing to classify verbal interactions according to the ten social dimensions. We evaluated the accuracy of the network by comparing the network’s representations of the relationships with a human’s perception of the relationships. Figure 1 illustrates a network formed by some characters from the movie *Les Misérables* (1998).

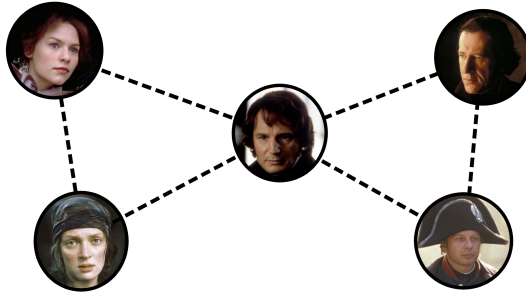


Figure 1: A social network formed by some characters from the movie *Les Misérables* (1998). The nodes represent characters and the edges represent the main relationships between them.

2 Background

The following chapter covers topics that are central to the thesis. The first section covers Natural Language Processing, the second section covers the ten social dimensions, the third section covers networks, the fourth section covers *Les Misérables*, and the fifth section covers the software that was used for this thesis.

2.1 Natural Language Processing

Natural Language Processing (NLP) is a subfield of artificial intelligence focused on making computers communicate through natural language [11]. NLP can be divided into two parts, Natural Language Understanding and Natural Language Generation. Natural Language Understanding is the process of making computers interpret and analyze natural language, whereas Natural Language Generation is the process of making computers produce natural language.

Making computers communicate through natural language is a challenging task because most natural languages contain an infinite number of sentences, and the same sentence or word can have different meanings depending on the context [5]. Various tools and methods have been developed to overcome these challenges. The use of neural networks has significantly advanced the field of NLP [11], and in 2025, a NLP-tool were able to pass the Turing test for the first time—a test in which a computer has to convince a human that the computer is human [10]. NLP is successfully applied in areas such as machine translation, text categorization, spam filtering, information extraction, summarization, and dialogue systems [11].

2.2 Ten Social Dimensions

Interpersonal relationships can take on many different forms and most people entertain various types of relationships. Deri *et al.* [6] derived ten social dimensions that can be used to describe the social character of relationships. The dimensions are [4]:

Knowledge: Exchange of ideas or information.

Power: Having power over the behavior and outcomes of another.

Status: Conferring status, appreciation, gratitude, or admiration upon another.

Trust: Will of relying on the actions or judgments of another.

Support: Giving emotional or practical aid and companionship.

Romance: Intimacy among people with a sentimental or sexual relationship.

Similarity: Shared interests, motivations or outlooks.

Identity: Shared sense of belonging to the same community or group community.

Fun: Experiencing leisure, laughter, and joy.

Conflict: Contrast or diverging views.

They demonstrated the usefulness of these dimensions by applying them to a link prediction problem—a problem in which they predicted if pairs of nodes with a common neighbor were connected to each other. By classifying edges according to the dimensions, they were able to predict more accurately whether nodes were connected to each other, compared to methods that did not consider these dimensions.

Choi *et al.* [4] trained a NLP-tool (see Section 2.5.1) that was able to classify text from conversations according to these dimensions and used it to classify relationships between pairs of users on twitter. To classify a relationship between two users, they classified the text of each mention, reply, and retweet between the two users. The relationship was then labeled with the most frequent dimension and compared to a label provided by one of the users. The results showed a significant correlation between the classifications and the users’ own perceptions of their relationships.

2.3 Networks

A network is a model of a real-world system that consists of nodes and edges, where nodes represent entities, and edges represent connections between them [18]. Modeling systems as networks makes it possible to study them with mathematical, computational, and statistical tools. There are numerous types of networks that are suited for different contexts. The following sections cover the types of networks that constitute the building blocks of our method.

2.3.1 Directed Networks

Many systems have “directed” connections [17]. Examples of which include the internet, where hyperlinks run in one direction from one web page to another, and citation networks, where citations point from one paper to another. The direction of connections can be captured with directed networks. A directed network is a network that has directed edges—edges that point from one node to another. We indicate the direction of an edge by the order of the nodes; edge (A, B) runs from node A to node B .

2.3.2 Weighted Networks

Many systems have connections of different “strength” [18]. For example, individuals in a social circle might interact more or less frequently, servers on the internet might have different amounts of data flowing between them. The strength of connections can be captured with weighted networks. A weighted network is a network that has weighted edges—edges with a number w indicating the strength of the connection.

2.3.3 Multilayer Networks

A multilayer network is a network with nodes and edges organized into different layers, where different layers represent different aspects of the modeled system [12]. For example, a person’s social circle may be split into one layer where edges represent friendships, one layer where edges represent professional interactions, and one layer where edges represent online communication. Numerous studies have demonstrated the benefits of applying a multilayer structure when modeling various types of systems [3]. For example, multilayer networks have been used to uncover patterns between users on platforms such as Netflix, Youtube, and Facebook.

A *multilayer network* consists of a set of items I , a set of layers L , and a graph $G(V, E)$, where $V \subseteq I \times L$ and $E \subseteq V \times V$ [9]. Interdonato *et al.* [9] uses the term “actors” instead of “items”. We replace “actors” with “items” because “actors” is used for temporal text networks (see Section 2.3.2). A node represents a specific item in a specific layer, and edges can go between any pair of nodes. Figure 2 illustrates an example of a multilayer network.

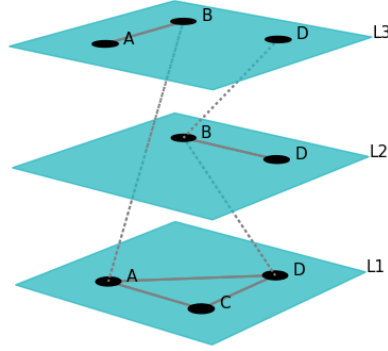


Figure 2: A multilayer network with items $I = \{A, B, C, D\}$, layers $L = \{L1, L2, L3\}$, nodes $V = \{(A, L1), (C, L1), (D, L1), (B, L2), (D, L2), (A, L3), (B, L3), (D, L3)\}$, and edges $E = \{((A, L1), (C, L1)), ((A, L1), (D, L1)), ((C, L1), (D, L1)), ((B, L2), (D, L2)), ((A, L3), (B, L3)), ((D, L1), (B, L2)), ((A, L1), (B, L3)), ((B, L2), (D, L3))\}$.

Directed Weighted Projection

In multilayer networks, projection is a group of simplification techniques that reduces the number of layers [9]. Here, we define a projection method that we call *directed-weighted projection (DWP)*.

When performing DWP of layer L_y onto layer L_x in a directed multilayer network, an edge $((I_a, L_x), (I_b, L_x))$ is added if edges $((I_a, L_x), (I_z, L_y))$ and $((I_z, L_y), (I_b, L_x))$ exist, where I_a and I_b are any pair of items in layer L_x and I_z is any item in L_y . The weight w of $((I_a, L_x), (I_b, L_x))$ is equal to the number of items I_z in layer L_y that meet the aforementioned criteria. Figure 3 illustrates an example of DWP.

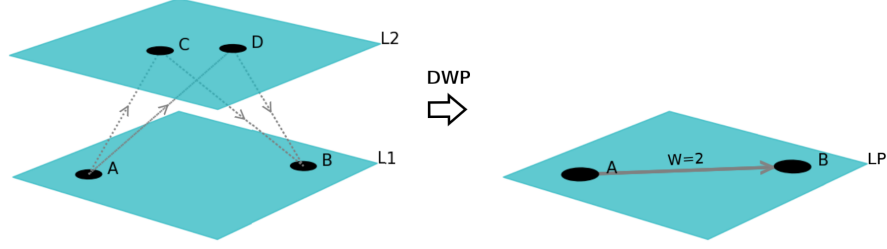


Figure 3: Two layers $L1$ and $L2$ are reduced to one layer LP by performing DWP of $L2$ onto $L1$.

2.3.4 Temporal Text Networks

Temporal text network (TTN) is a type of network model that captures time, text, and topology—making it effective for modeling systems where humans exchange information through text [21].

A TTN is a directed bipartite graph—*i.e.* a network that contains two types of nodes, where edges are directed and only go between nodes of different types— $G(A, M, E)$, where A is a set of actors, M is a set of messages and $E \subseteq (A \times M) \cup (M \times A)$ [21]. Actors are producers and consumers of messages. A message has one producer, but can have any number of consumers. Messages contain text produced by actors and may also contain additional complementary data. The direction of an edge indicates the message’s producer and consumers. The edge $e = (a_i, m_j)$ indicates that actor a_i produced message m_j , while the edge $e = (m_j, a_i)$ indicates that message m_j was consumed by actor a_i . Edges has a timestamp indicating any arbitrary aspect of time, e.g. time of message production or consumption. Figure 4 illustrates an example of a TTN.

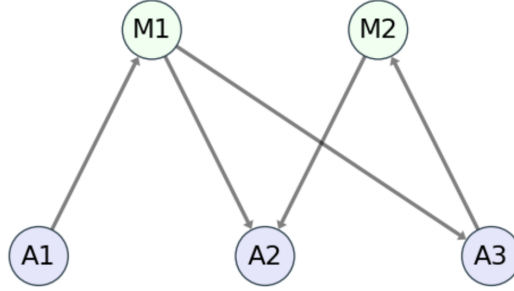


Figure 4: A TTN with actors $A = \{A1, A2, A3\}$, messages $M = \{M1, M2\}$, and edges $E = \{(A1, M1), (A3, M2), (M1, A2), (M1, A3), (M2, A2)\}$. $A1$ is the producer of $M1$ and $A2$ and $A3$ are the consumers of $M1$. $A3$ is the producer of $M2$ and $A2$ is the consumer of $M2$.

2.4 Les Misérables

2.4.1 Original Novel

Les Misérables is a French novel written by Victor Hugo [22]. It was first published in 1862 and is considered one of the greatest novels of the 19th century. The novel begins in 1815 and culminates in the 1832 June Rebellion in Paris. It follows the lives and interactions of several characters, but the main story is that of Jean Valjean, a reformed ex-convict who struggles to escape his past. The novel draws attention to social problems; Hugo motivates the novel in its preface as follows [8]:

“So long as there shall exist, by reason of law and custom, a social condemnation, which, in the face of civilization, artificially creates hells on earth, and complicates a destiny that is divine with human fatality; so long as the three problems of the age—the degradation of man by poverty, the ruin of women by starvation, and the dwarfing of childhood by physical and spiritual night—are not solved; so long as, in certain regions, social asphyxia shall be possible; in other words, and from a yet more extended point of view, so long as ignorance and misery remain on earth, books like this cannot be useless.”

Networks formed by the novel’s characters and their co-appearances in different chapters have been used to study various topics in network science. For example, such a network was used by Min and Park [15][16] to demonstrate a network-based framework for modeling narratives, by Grover and Leskovec [7] to demonstrate node2vec (an algorithm for generating vector representations of nodes), and by Newman and Girvan [19] to demonstrate a set of algorithms for discovering community structure (groups of densely connected nodes) in networks.

2.4.2 1998 Film

Les Misérables has been popularized through numerous adaptations for film, television, and theater [22]. Les Misérables (1998) is an English-speaking movie adaptation that was released in 1998.

Movie Plot

Jean Valjean is released from prison after serving 19 years for stealing food. He struggles to find shelter until Bishop Myriel lets him stay the night at his house. During the night, Valjean gets caught by Myriel when he is in the process of stealing silverware. Valjean strikes Myriel and flees into the night. Valjean is apprehended by the police, but Myriel saves him from prison by telling the police that the silverware was a gift. Valjean is made to promise Myriel that he will become a better person.

Valjean assumes a fake identity and becomes a successful factory owner and the mayor of Vigau. Inspector Javert, a former guard where Valjean was imprisoned, arrives at Vigau and is installed as the chief of police. Javert eventually realizes that the mayor is the former inmate Valjean and is determined to return him to prison.

Fantine, a single mother employed at Valjeans factory, is fired, unknowingly to Valjean, for having a baby out of wedlock. She becomes sick and turns to prostitution to afford paying her daughter Cosette's extortionate caretakers—the Thénardiens.

Fantine is assaulted by a group of men and strikes one of them to retaliate. This prompts Javert to assault and arrest her. Beauvais, a subordinate of Javert, informs Valjean about the situation. Valjean uses his power as mayor to prevent Fantine from being sent to prison and nurses her in his home.

Valjean is informed that a man who got caught for stealing apples is accused of being Valjean. Valjean attends the trial, which takes place in another town called Arras, and reveals that he is the real Valjean to save the man from life in prison.

Fantine's health deteriorates while Valjean is away to attend the trial. Valjean returns home and promises her that he will raise Cosette as his own child before she dies. Javert tries to arrest Valjean, but Valjean manages to overpower Javert and escapes from Vigau. Valjean travels to the Thénardiens to get Cosette. He discovers that Cosette is being abused and brings her with him to Paris. When they arrive in Paris, they are chased by Javert, but they manage to escape by hiding in a religious convent. They then live together as father and daughter within the convent for the next ten years.

They leave the convent because Cosette is unhappy living there and does not want to take her monastic vows. Cosette falls in love with a radical political activist named Marius. Marius and his associates are under surveillance by Javert, who is now working as a police inspector in Paris. Javert eventually catches on to Cosette and Valjean. Valjean tells Cosette about his past and decides that they must leave Paris for England in order to escape Javert.

Marius takes part in an uprising against the king. The revolutionaries establish barricades and take control of a part of the city. Cosette and Valjean are caught behind the barricades. Javert goes undercover as a revolutionary behind the barricades in an attempt to arrest Valjean before he leaves Paris. Javert is caught by Marius and kept as a prisoner while awaiting execution. Valjean takes it upon himself to execute Javert, but lets him free.

Soldiers break through the barricades and injure Marius. Valjean tries to carry Marius to safety but is apprehended by Javert. Valjean convinces Javert to spare Marius and is allowed to bring Marius home. Valjean says farewell to Cosette before being escorted back to Javert. Javert, perplexed by Valjeans good-heartedness, spares Valjean and commits suicide by shackling himself and jumping into a river. Valjean walks away as a free man.

2.5 Software

2.5.1 Tendimensions

Tendimensions is a NLP-tool for detecting the presence of the ten social dimensions in text [1]. It takes text and a social dimension as input and outputs a score between zero and one, indicating the probability that the text expresses the social dimension. The tool is built on a LSTM-model that is trained on 7,885 sentences from Reddit posts, 400 sentences from movie lines, and 436 sentences from Enron emails [4]. The model's performance varies depending on the social dimension. When classifying the Reddit sentences according to

the social dimensions, the model achieved its lowest average AUC score of 0.75 for dimension “Identity”, and its highest average AUC score of 0.98 for dimension “Romance”. We used Tendimensions to detect which dimensions that were expressed in utterances made by characters.

2.5.2 Multinet

Multinet is a Python package for analyzing multilayer networks [13]. The package contains data structures, measures, and algorithms for multilayer networks. Multinet was used to construct networks.

2.5.3 Gephi

Gephi is an open-source software for interactive network visualization and analysis [2]. It provides access to network data and allows for spatializing, filtering, navigation, manipulation, and clustering of networks. Gephi was used to visualize the networks that were created by Multinet.

3 Data

For this thesis, we used a subtitle file corresponding to the movie Les Misérables (1998). The following chapter explains how we obtained the file and its structure.

Les Miserables (1998) - subtitles

We downloaded an XML-file from Netflix containing English subtitles for Les Misérables (1998) and converted it to SRT-format. A SRT-file consists of subtitle segments ordered in chronological order [23]. Each segment contains a number indicating the sequential position of the segment, a subtitle block, a timestamp marking when the subtitle should appear, and a timestamp marking when the subtitle should disappear. The time format is hours:minutes:seconds,milliseconds. The structure of a SRT-file is illustrated in Figure 5. The SRT-file contained 1386 subtitle segments.

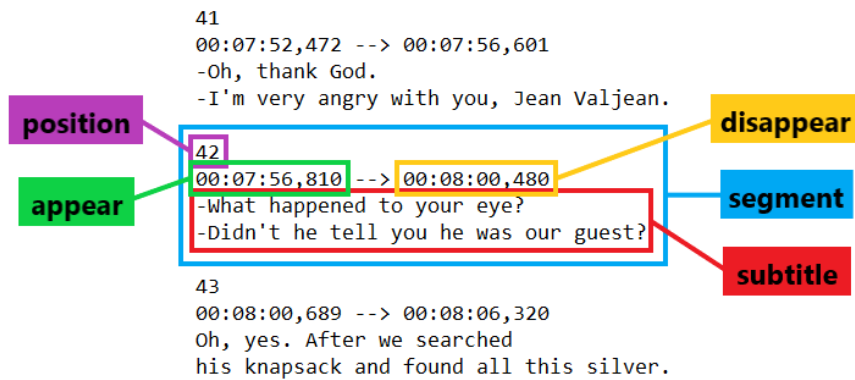


Figure 5: Three subtitle segments from the Les Misérables (1998) SRT-file. The blue box marks one subtitle segment, the purple box marks the segments sequential position, the red box marks the segments subtitle block, the green box marks the subtitles appear timestamp, and the yellow box marks the subtitles disappear timestamp.

The subtitles followed the Swedish standard for subtitling dialogues [14]. Each subtitle block consisted of one or two lines of text and each line corresponded to an utterance made by one character. If two characters made utterances that corresponded to the same subtitle block, dialogue dashes were present at the beginning of each line. This is illustrated in Figure 6.

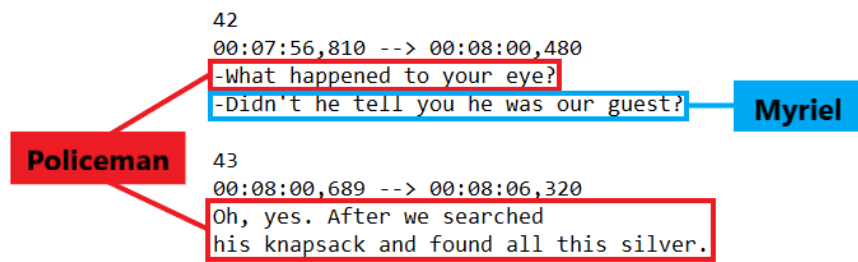


Figure 6: Two subtitle segments from the Les Misérables (1998) SRT-file. The first line of text in the upper subtitle block corresponds to an utterance made by Policeman and the second line corresponds to an utterance made by Myriel. Both lines of text in the bottom subtitle block corresponds to an utterance made by Policeman.

4 Method

We decided to model a network from a movie. This decision was made because we believe that many movies portray relationships that are realistic enough to be mapped to real-world counterparts—mapped in the sense that we are able to associate and draw parallels between relationships in movies and relationships in our own personal lives—and that this would allow us to evaluate the networks representations of relationships by comparing them with the movie. *Les Misérables* (1998) was deemed an appropriate movie because 1) the novel’s familiarity within network science and 2) the movie portrays several relationships that have a fundamentally different character compared to each other. We decided to model the movie with a *Directed Weighted Multilayer Network (DWMN)*. This model was deemed appropriate because 1) a multilayer structure would enable us to model relationships across the ten social dimensions, 2) weight would enable us to capture the tie strength in each dimension, and 3) direction would allow us to capture the bidirectional nature of relationships.

The DWMN was created through a series of steps. Firstly, we constructed a dataset that contained the subtitle, speaker, recipients, and time of every utterance in the movie *Les Misérables* (1998). We then classified each utterance according to the ten social dimensions and modeled characters and their verbal interactions with a *Multilayer Temporal Text Network (MTTN)*. We then derived the DWMN from the MTTN to model the characters and the strength of their relationship ties in each of the ten social dimensions. In order to evaluate the DWMN, we generated weight distributions—indicating the edge weight of each dimension—and compared them visually with distribution labels provided by a human. We also generated timelines indicating how the distributions evolved over time. Figure 7 illustrates the complete process. The following sections cover the construction of the dataset, the MTTN, the DWMN, the distributions and timelines, and the labels.

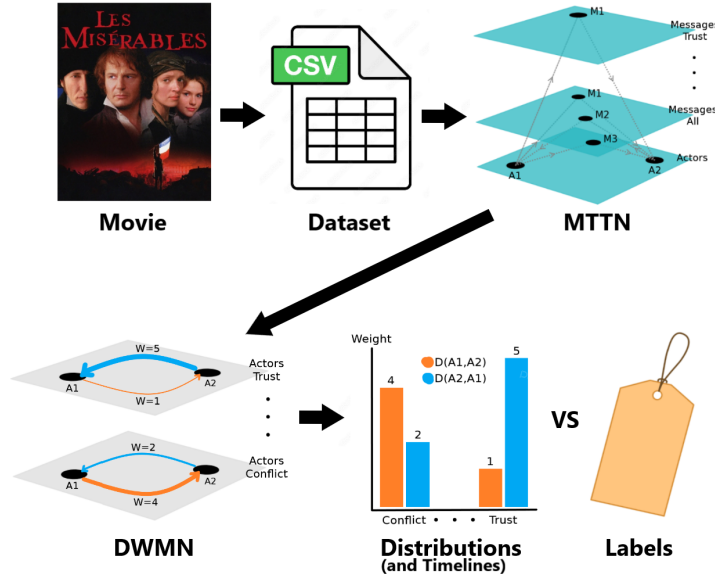


Figure 7: Flowchart for constructing and evaluating the DWMN.

4.1 Dataset

To construct the MTTN, we needed data for message producers, message consumers, textual content of messages, and time of messages. Thus, we decided to construct a dataset with the following columns:

speaker: contains the name of the character(s) that made the utterance.

addressed: contains the name of the characters that was addressed by the speaker.

all_recipients: contains the names of every character that heard the speaker’s utterance.

text: contains the subtitle corresponding to the speaker’s utterance.

start: contains the second at which the subtitle appeared.

end: contains the second at which the subtitle disappeared.

Data for columns “start”, “end” and “text” were obtained by extracting the “appear” timestamp, “disappear” timestamp, and “subtitle block” from each subtitle segment in the Les Misérables SRT-file. This is illustrated in Figure 8. Each segment corresponded to one row in the dataset. However, if a segment contained a subtitle block with two lines of text starting with a dialogue dash, the segment was split between two rows in the dataset—one row for each line of text. This was done so that all subtitle in a single row would correspond to an utterance by the same speaker. The “appear” timestamp was allocated to the “start” column in the first row, and the “disappear” timestamp was assigned to the “end” column in the second row. The “end” column of the first row and the “start” column of the second row were assigned the same time t which was calculated with the following formula:

$$t = t_{\text{appear}} + (n\text{letters}_{\text{line}1} / n\text{letters}_{\text{line}1\&2})(t_{\text{disappear}} - t_{\text{appear}})$$

Where t_{appear} is the “appear” timestamp, $t_{\text{disappear}}$ is the “disappear” timestamp, and $n\text{letters}_{\text{line}x}$ is the number of letters in line x .

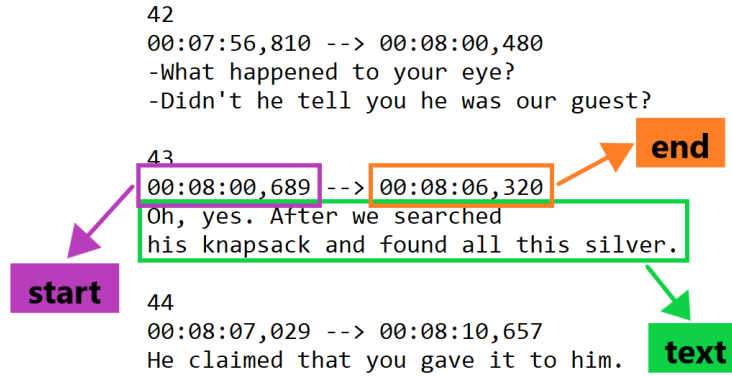


Figure 8: Three subtitle segments from the Les Misérables (1998) SRT-file. The “disappear” timestamp in the purple box was allocated to the “start” column, the “disappear” timestamp in the orange box was allocated to the “end” column, and the “subtitle block” in the green box was allocated to the “text” column.

Data for columns “speaker”, “addressed”, and “all_recipients” was gathered by watching the movie and manually annotating each row. The speaker(s) was determined by observing who made the utterance corresponding to the subtitle in the “text” column. Language, tone, body language, gaze, and spatial positions were considered to determine who was addressed by the speaker and the recipients of the utterance. For a character to be considered a recipient, it had to hear the utterance and either be addressed or speak at some point during the movie or be mentioned in the closing credits. Every character who was deemed a recipient, including the addressed character, was allocated to the “all_recipients” column. The annotation process is illustrated in Figure 9.

During the annotation process, we also split rows to form new rows if different parts of the subtitle in a row were addressed to different characters. This was done so that all subtitle in a single row would be addressed to the same characters. Start and end timestamps for the newly formed rows were set in the same way as during the splitting process when gathering data for columns “start”, “end” and “text”.

Characters were named according to the following hierarchy:

1. name used in the movie.
2. name in the closing credits.
3. name used in the original novel.
4. attributes or profession.

Groups of undefined characters were given a collective name that reflected the characteristics of the group. Members of the group were given a name that reflected the collective name plus a unique id-number.



Figure 9: Screenshot from Les Misérables (1998). For the utterance corresponding to the screenshot, the first character from the left was allocated to the columns “addressed” and “all_recipients”, the second character was allocated to the “speaker” column, and the third, fourth, and fifth characters were allocated to the “all_recipients” column.

Finally, we merged rows that corresponded to the same continuous utterance. The assumption was made that consecutive rows with the same characters in the columns “speaker”, “addressed” and “all_recipients” corresponded to the

same continuous utterance and were consequently merged into one row. The resulting row was assigned the start time of the first row, the end time of the last row, and the combined subtitles of all rows.

4.2 Multilayer Temporal Text Network

We constructed a MTTN to model all verbal interactions. A MTTN was deemed an appropriate model because it could capture the speaker, recipients, time and textual representation of each utterance, as well as the social dimensions expressed by each utterance. We decided that it was important to store the textual representation of utterances because it would enable the use of NLP for determining the social dimensions expressed by utterances. We decided that it was important to store the time of utterances because relationships evolve over time.

Actors represented movie characters and messages represented utterances. One message was created for each speaker in each row of the dataset. The speaker was assigned as the producer of the message and the addressed characters were assigned as consumers of the message. The subtitle in the “text” column was added as textual content of the message. The timestamp in the “start” column was added as a message attribute instead of edge attribute since Multinet did not support attributes for inter-layer edges. Actors, messages, and their functions are illustrated in Figure 10.

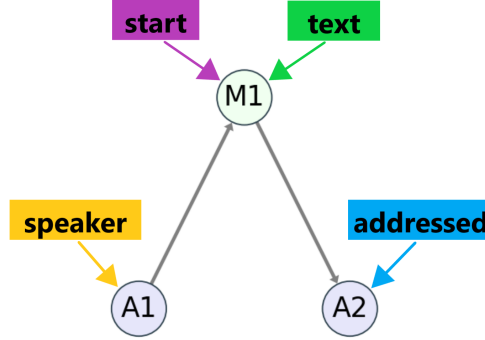


Figure 10: A message $M1$ produced by actor $A1$ and consumed by actor $A2$. $A1$ represents the speaker, $M1$ represents the utterance made by the speaker, and $A2$ represents the character that was addressed by the speaker.

Actors and messages were split between layers $L_{MTTN} = \{A, M_{all}, M_{conflict}, M_{fun}, M_{identity}, M_{knowledge}, M_{power}, M_{romance}, M_{similarity}, M_{status}, M_{support}, M_{trust}\}$, where A is an abbreviation for *Actors* and M is an abbreviation for *Messages*. A contained all actors, M_{all} contained all messages, and M_{sd} , where sd is an abbreviation for social dimension, contained messages whose textual content expressed the corresponding social dimension. The textual content of each message was fed to the NLP-tool *Tendimensions* and received a score between zero and one for each social dimension. If a dimension scored higher than two thirds, the message was assigned to the corresponding layer. The MTTN is illustrated in Figure 11.

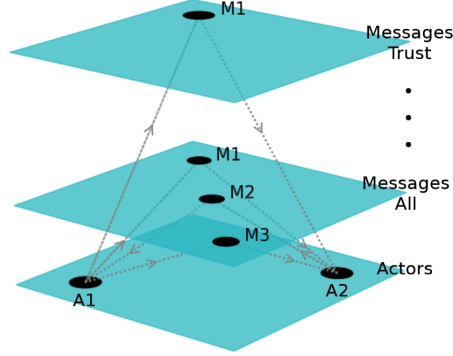


Figure 11: Two actors $A1$ and $A2$ in MTTN. $A1$ is the producer of messages $M1$ and $M2$, and $A2$ is the producer of message $M2$. The textual content of $M1$ expresses trust.

4.3 Directed Weighted Multilayer Network

We modeled the characters and the strength of their relationship ties in each of the ten social dimensions with a DWMN. The DWMN had layers $L_{DMSN} = \{A_{all}, A_{conflict}, A_{fun}, A_{identity}, A_{knowledge}, A_{power}, A_{romance}, A_{similarity}, A_{status}, A_{support}, A_{trust}\}$, where A is an abbreviation for *Actors*. A_x in DWMN was the directed weighted projection in MTTN of M_x onto A . Consequently, the weight w of edge $((A1, A_x), (A2, A_x))$ in DWMN represented the number utterances corresponding to layer x that were made by character $A1$ and addressed to character $A2$. We also added a timeline t to each edge in DWMN. The timeline consisted of the timestamp of each message that contributed to the edge weight w . The process for constructing the DWMN is illustrated in Figure 12.

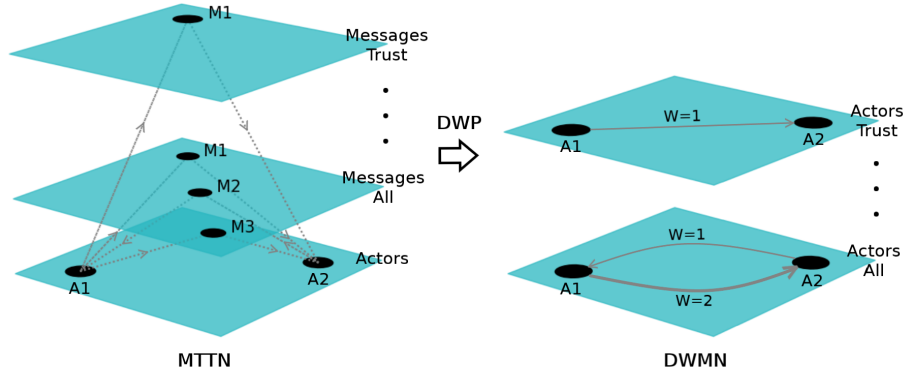


Figure 12: Two actors $A1$ and $A2$ in MTTN and DWMN. $Actors_{All}$ in DWMN is the weighted directed projection in MTTN of $Messages_{All}$ onto $Actors$. $Actors_{Trust}$ in DWMN is the weighted directed projection in MTTN of $Messages_{Trust}$ onto $Actors$.

4.4 Distributions & Timelines

We created two distributions of weights, $D(A1, A2)$ and $D(A2, A1)$, over the ten social dimensions for a relationship between characters $A1$ and $A2$. $D(A1, A2)$ consisted of weight w of edges $((A1, A_{sd}), (A2, A_{sd}))$ in DWMN, and $D(A2, A1)$ consisted of weight w of edges $((A2, A_{sd}), (A1, A_{sd}))$ in DWMN, where A is an abbreviation for *Actors* and sd is an abbreviation for social dimension. Both distributions were visualized in a histogram. The process for generating distributions is illustrated in Figure 13.

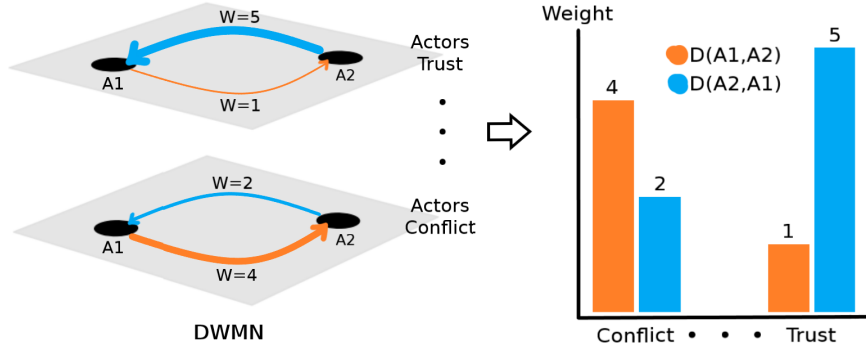


Figure 13: Two actors $A1$ and $A2$ in DWMN and their relationship distributions $D(A1, A2)$ and $D(A2, A1)$. $A1$ addressed $A2$ with four utterances expressing conflict and one utterance expressing trust. $A2$ addressed $A1$ with two utterances expressing conflict and five utterances expressing trust.

We created two timelines, $T(D(A1, A2))$ and $T(D(A2, A1))$, to indicate how the weights of $D(A1, A2)$ and $D(A2, A1)$ developed over time. To construct timeline $T(D(A1, A2))$, we extracted timeline t from edges $((A1, A_{sd}), (A2, A_{sd}))$ in DMSN. We then derived the accumulated weight of each dimension for each minute of *Les Misérables* (1998). The same process was repeated for timeline $T(D(A2, A1))$. Each timeline was visualized with a heat map.

4.5 Labels

To obtain distribution labels, we had a person watch *Les Misérables* and individually assign and rank social dimensions for four relationships:

1. Valjean-Javert.
2. Valjean-Cosette.
3. Valjean-Fantine.
4. Javert-Beauvais.

These relationships were chosen because 1) each of these relationships had a different character compared to the other three and 2) these relationships were the relationships with the largest number of corresponding utterances. The participant was told which relationships that it was going to rank before

watching the movie. This was done to ensure that the participant would pay attention to these relationships when watching the movie.

The participant had to provide a ranking for each perspective of each relationship. For each perspective, the participant had to assign the social dimensions that it believed best described the perspective, and rank the assigned dimensions in descending order. The participant were allowed to give the same rank to several dimensions if it perceived the dimensions to be equally prominent. The participant had to assign at least one dimension to each perspective.

5 Results

The following chapter presents our results. The first section covers the Les Misérables (1998) dataset, the second section covers the MTTN, the third section covers the DWMN (with directed edges merged to undirected edges), the fourth section covers the labels, and the fifth section covers the weight distributions and their timelines.

5.1 Dataset

Table 1: Les Misérables (1998) dataset

	speaker	addressed	all_recipients	text	start	end
0	Old lady	Valjean	Valjean	You can't sleep here.	181.348000	182.821103
1	Valjean	Old lady	Old lady	Get away from me.	182.821103	184.018000
2	Old lady	Valjean	Valjean	Why don't you go to an inn?	184.226000	185.812000
3	Valjean	Old lady	Old lady	Why do you think?	186.020000	187.063575
4	Old lady	Valjean	Valjean	Did you knock on doors? Ask people?	187.063575	189.231000
...	...	...	...	...	...	...
1045	Javert	Valjean	Valjean	You're my prisoner. Do what I tell you! You do...	7565.472820	7586.246000
1046	Valjean	Javert	Javert	I don't have the right to kill you.	7587.247000	7589.791000
1047	Javert	Valjean	Valjean	But you hate me.	7589.999000	7592.544000
1048	Valjean	Javert	Javert	I don't hate you. I don't feel anything.	7592.752000	7599.050000
1049	Javert	Valjean	Valjean	You don't want to go back to the quarries, do ...	7599.259000	7648.808000

Table 1 shows the Les Misérables (1998) dataset. The dataset contains 1049 rows.

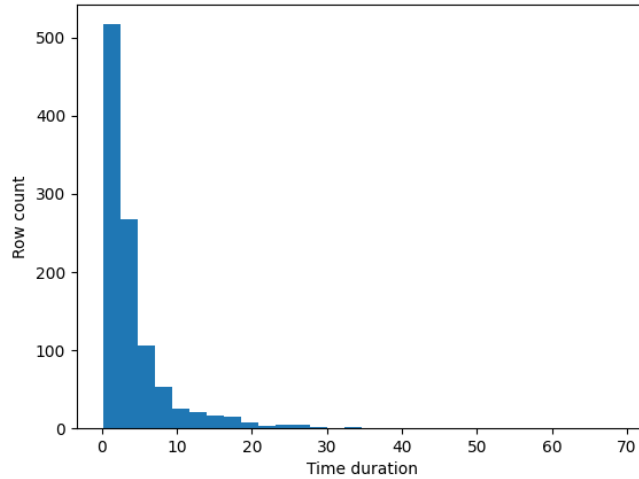


Figure 14: Time span of rows. The X-axis indicates the number of seconds, and the Y-axis indicates the number of rows.

Figure 14 shows how the time span of rows are distributed. The time span of a row is the content of column “end” minus the content of column “start”. The distribution is heavily shifted towards shorter time spans. A majority of rows have a time span between one and four seconds, and only a few rows have a time span longer than 20 seconds.

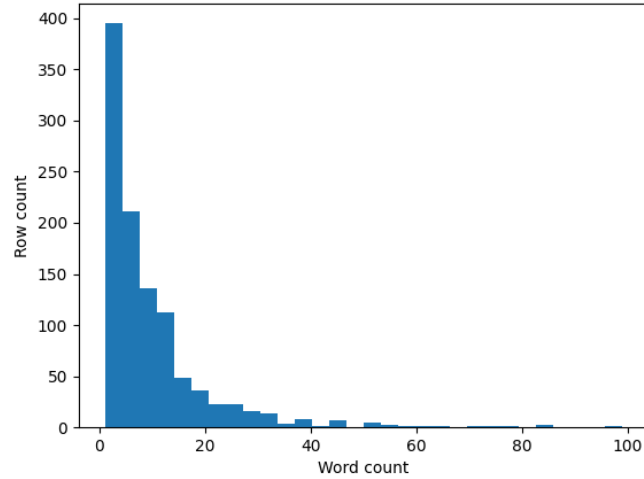


Figure 15: Word count of rows. The X-axis indicates the word count, and the Y-axis indicates the number of rows.

Figure 15 shows how the word count of rows are distributed. The word count of a row is the number of words in the “text” column. The distribution is heavily shifted towards low word counts. A majority of rows contain between one and eight words, and only a small portion of rows contain more than 20 words.

5.2 Multilayer Temporal Text Network

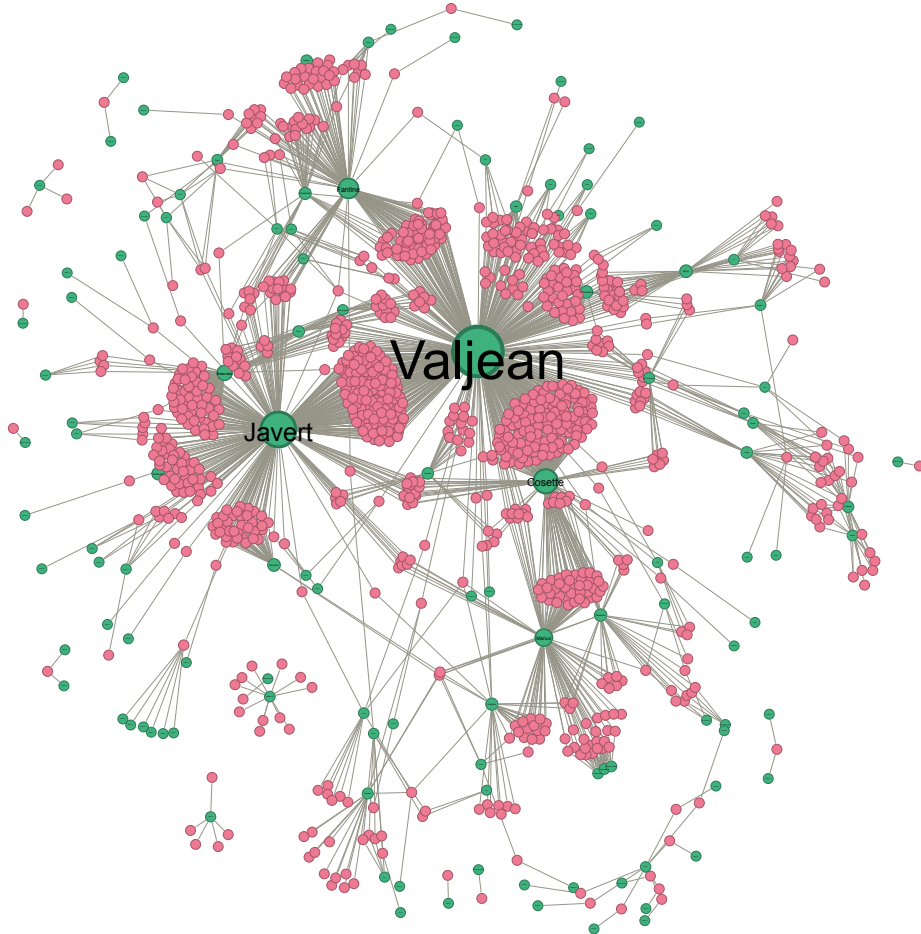


Figure 16: Actors and messages in the MTTN. Actors are represented with green nodes and messages with red nodes.

Figure 16 illustrates all messages and actors in the MTTN. The network contains 119 actors and 1064 messages. The figure indicates that there are a few key actors—Valjean, Fantine, Javert, Cosette, and Marius—that produced and/or consumed a large portion of the messages.

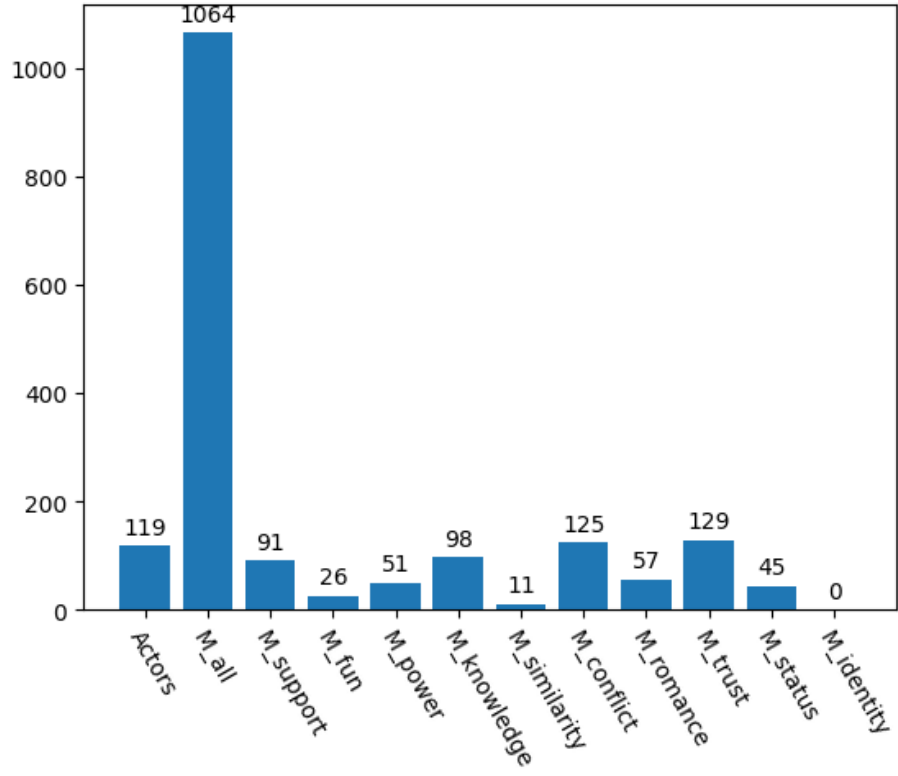


Figure 17: Number of nodes in each layer of the MTTN. “M” is an abbreviation for Messages.

Figure 17 shows the number of nodes in each layer of the MTTN. *Messages_{all}* contains the largest number of nodes, followed by layers *Messages_{trust}*, *Messages_{conflict}*, and *Actors*.

5.3 Directed Weighted Multilayer Network

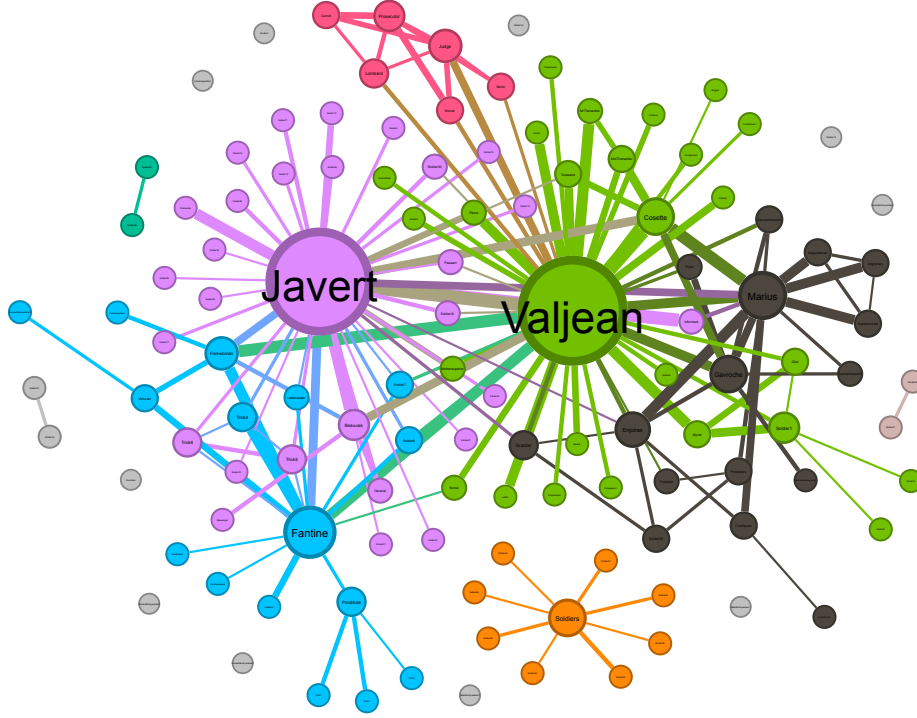


Figure 18: Layer $Actors_{all}$ in the DWMN (undirected edges). Node color indicates cluster membership.

Figure 18 illustrates layer $Actors_{all}$ in DWMN (undirected edges). $Actors_{all}$ contains 119 nodes and 165 edges. Node color indicates cluster membership (clusters were generated by Gephi). There are four main clusters, each of which is centered around one of the characters Javert, Valjean, Marius, or Fantine. There is also a notable cluster formed around “soldiers”, and a notable cluster formed by participants at the trial in Arras.

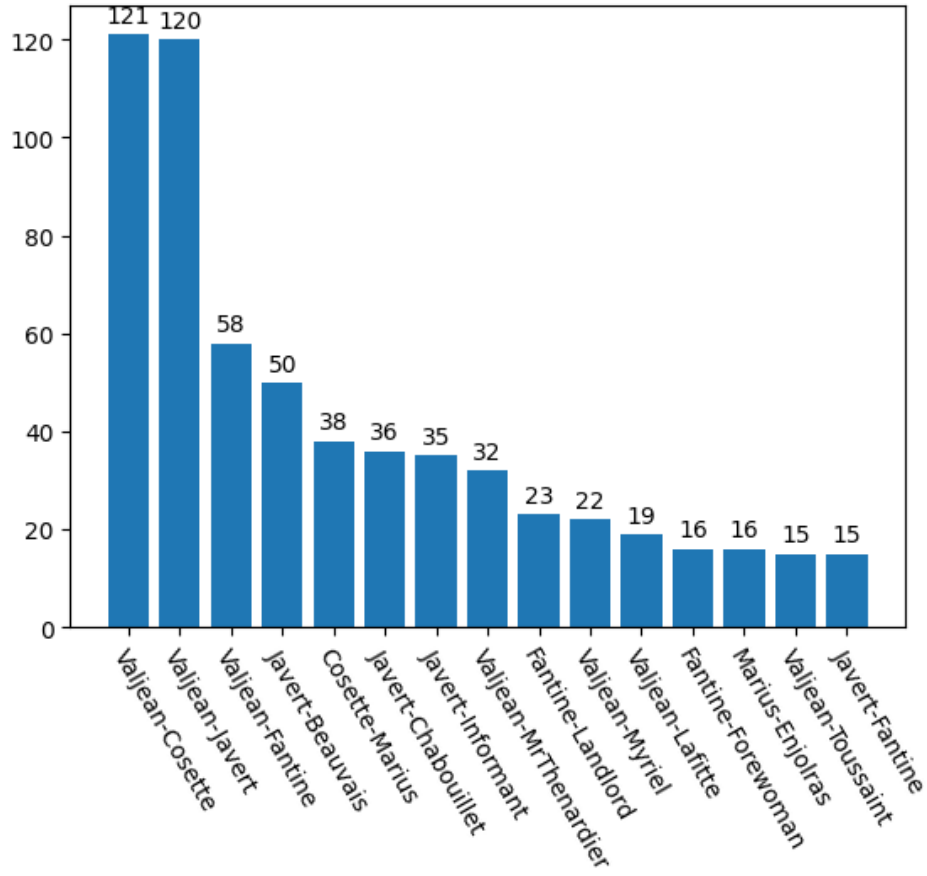


Figure 19: Edge weights w in layer $Actors_{all}$ in the DWMN (undirected edges).

Figure 19 shows the 15 largest edge weights w in layer $Actors_{all}$ (undirected edges). The two edges with the largest weight are Valjean-Cosette and Valjean-Javert, which have roughly twice as much weight as the third and fourth heaviest edges, Valjean-Fantine and Javert-Beauvais.

5.4 Labels

Table 2: Relationship's and corresponding labels. $A \rightarrow B$ indicates that it is the perspective of A in relationship A-B.

Relationship	Label
<i>Valjean – Javert</i>	
Valjean $\rightarrow$ Javert	1. Conflict 2. Power
Javert $\rightarrow$ Valjean	1. Conflict 2. Power 3. Status
<i>Valjean – Cosette</i>	
Valjean $\rightarrow$ Cosette	1. Trust 2. Power 3. Support
Cosette $\rightarrow$ Valjean	1. Trust
<i>Valjean – Fantine</i>	
Valjean $\rightarrow$ Fantine	1. Support 2. Identity
Fantine $\rightarrow$ Valjean	1. Trust
<i>Javert – Beauvais</i>	
Javert $\rightarrow$ Beauvais	1. Power 2. Identity 3. Conflict
Beauvais $\rightarrow$ Javert	1. Conflict

Table 2 shows labels for relationships Valjean-Javert, Valjean-Cosette, Valjean-Fantine, and Javert-Beauvais. Arrow direction indicates the perspective. Character A $\rightarrow$ Character B indicates that it is the perspective of A in relationship A-B.

5.5 Distributions & Timelines

5.5.1 Valjean-Javert

Figure 20 shows the weight of edges that run between Valjean and Javert in DWMN. The X-axis indicates the layer and the color indicate the edge direction—blue indicating edges pointing from Valjean to Javert, orange indicating edges pointing from Javert to Valjean, and green indicating the sum of the edges. Distribution “Valjean→Javert” is dominated by “conflict”, which is followed by “knowledge”. Distribution “Javert→Valjean” is dominated by “conflict”, which is followed by “knowledge” and then “power”. Figure 21 indicates how the distributions evolved over time.

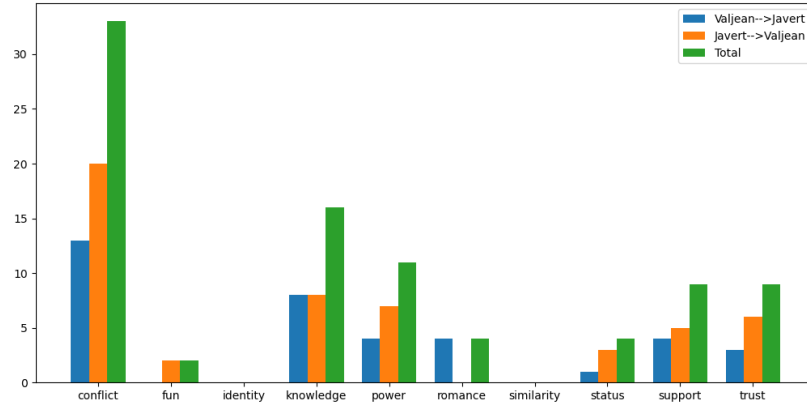


Figure 20: Weight distributions and the sum of the distributions. The X-axis indicates the layer in the DWMN, and the Y-axis indicates the edge weight in the DWMN.

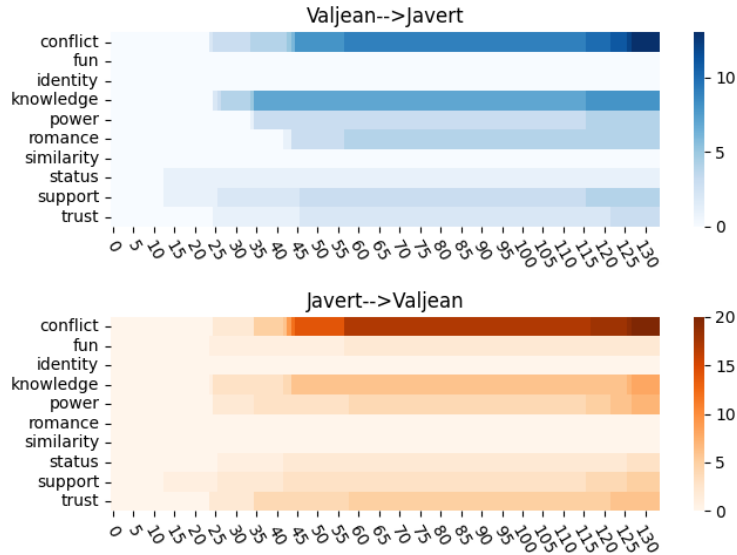


Figure 21: Timelines indicating how the weights of each distribution developed over time. The X-axis indicates the dimension, the Y-axis the timestamp, and the color intensity the message-count.

5.5.2 Valjean-Cosette

Figure 22 shows the weight of edges that run between Valjean and Cosette in DWMN. The X-axis indicates the layer and the color indicate the edge direction—blue indicating edges pointing from Valjean to Cosette, orange indicating edges pointing from Cosette to Valjean, and green indicating the sum of the edges. The most prominent dimensions in distribution “Valjean→Cosette” are “support” and “trust”, which are closely followed by “knowledge”. Distribution “Cosette→Valjean” is dominated by “conflict”, which is followed by “trust”. Figure 23 indicates how the distributions evolved over time.

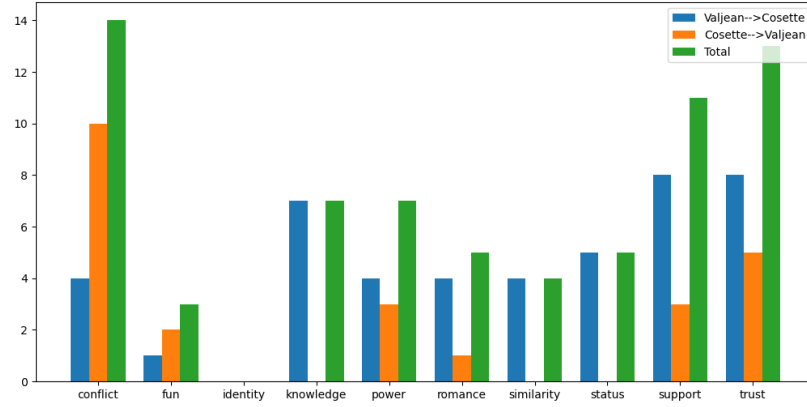


Figure 22: Weight distributions and the sum of the distributions. The X-axis indicates the layer in the DWMN, and the Y-axis indicates the edge weight in the DWMN.

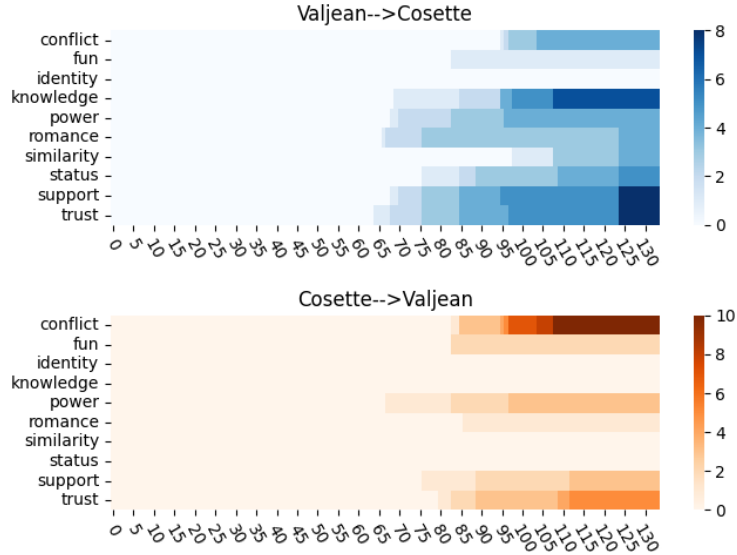


Figure 23: Timelines indicating how the weights of each distribution developed over time. The X-axis indicates the dimension, the Y-axis the timestamp, and the color intensity the message-count.

5.5.3 Valjean-Fantine

Figure 24 shows the weight of edges that run between Valjean and Fantine in DWMN. The X-axis indicates the layer and the color indicate the edge direction—blue indicating edges pointing from Valjean to Fantine, orange indicating edges pointing from Fantine to Valjean, and green indicating the sum of the edges. The most prominent dimension in distribution “Valjean→Fantine” is “trust” which is followed by “knowledge” and “support”. Distribution “Fantine→Valjean” is dominated by “trust”, which is followed by “conflict”. Figure 25 indicates how the distributions evolved over time.

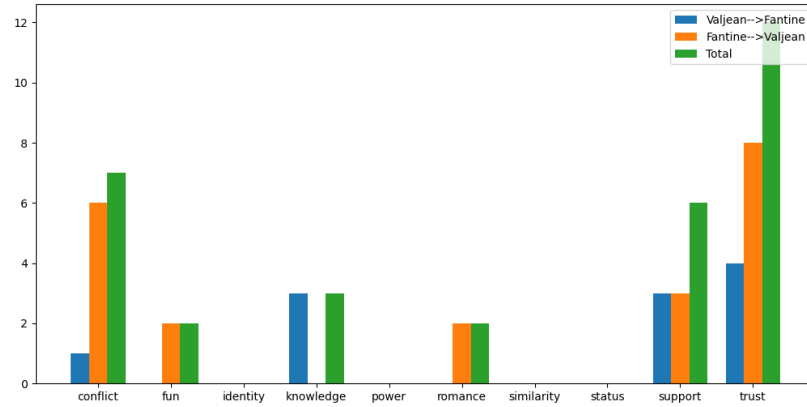


Figure 24: Weight distributions and the sum of the distributions. The X-axis indicates the layer in the DWMN, and the Y-axis indicates the edge weight in the DWMN.

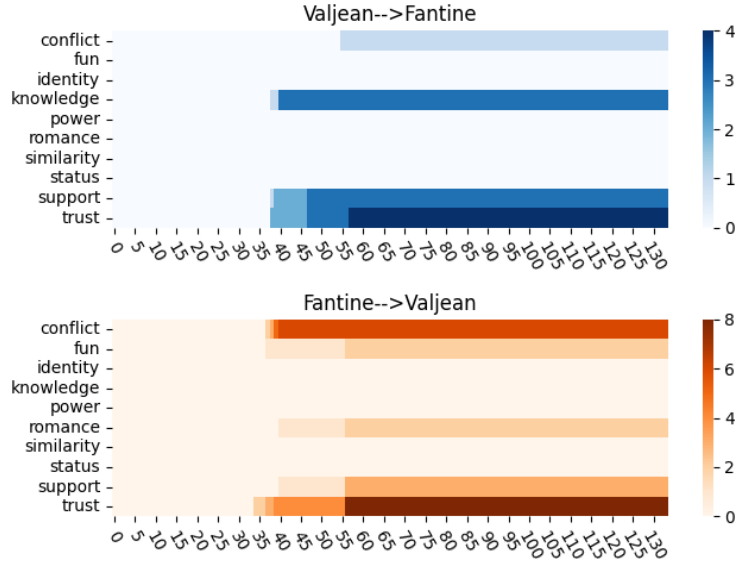


Figure 25: Timelines indicating how the weights of each distribution developed over time. The X-axis indicates the dimension, the Y-axis the timestamp, and the color intensity the message-count.

5.5.4 Javert-Beauvais

Figure 26 shows the weight of edges that run between Javert and Beauvais in DWMN. The X-axis indicates the layer and the color indicate the edge direction—blue indicating edges pointing from Javert to Beauvais, orange indicating edges pointing from Beauvais to Javert, and green indicating the sum of the edges. Distribution “Javert→Beauvais” is dominated by “knowledge”, which is followed by “support” and “fun”. Distribution “Beauvais→Javert” is dominated “trust”, which is followed by “knowledge”. Figure 27 indicates how the distributions evolved over time.

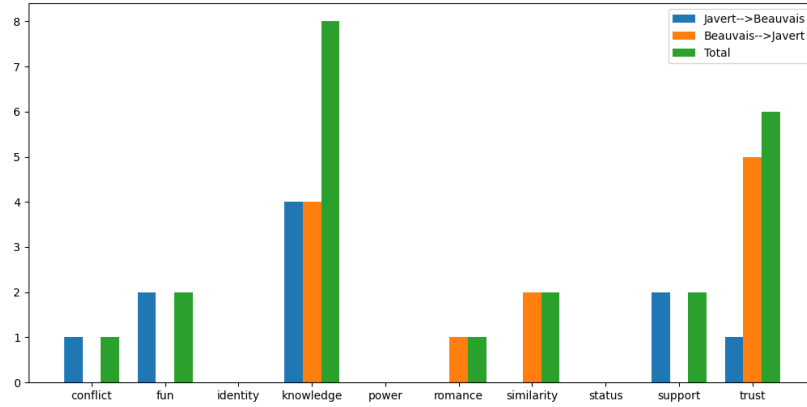


Figure 26: Weight distributions and the sum of the distributions. The X-axis indicates the layer in the DWMN, and the Y-axis indicates the edge weight in the DWMN.

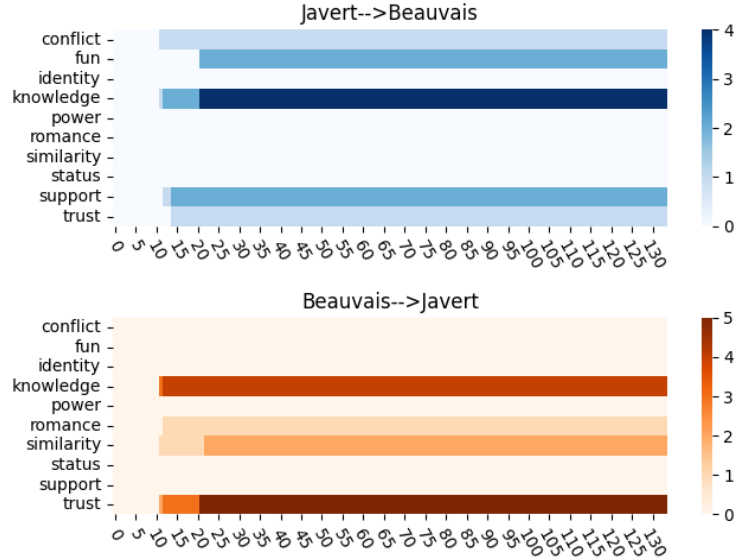


Figure 27: Timelines indicating how the weights of each distribution developed over time. The X-axis indicates the dimension, the Y-axis the timestamp, and the color intensity the message-count.

6 Analysis

The following chapter contains a comparison between the distributions, *i.e.* the DWMN's representation of relationships, and the distribution labels, *i.e.* the participant's perception of the relationships.

Valjean-Javert

Valjean's perspective: According to the label, the most prominent social dimensions are 1. Conflict and 2. Power. This is partially matched by the distribution, in which the most salient social dimensions are 1. Conflict and 2. Knowledge. This indicates that the network partially captures the character of Valjean's perspective.

Javert's perspective: According to the label, the most prominent social dimensions are 1. Conflict, 2. Power, and 3. Status. This is largely matched by the distribution, in which the most salient social dimensions are 1. Conflict, 2. Knowledge, and 3. Power. This indicates that the network largely captures the character of Javert's perspective.

Valjean-Cosette

Valjean's perspective: According to the label, the most prominent social dimensions are 1. Trust, 2. Power and 3. Support. This is largely matched by the distribution, in which the most salient social dimensions are 1. Trust & Support and 2. Knowledge. This indicates that the network largely captures the character of Valjean's perspective.

Cosette's perspective: According to the label, the most prominent social dimension is Trust. This is partially matched by the distribution, in which the most salient social dimensions are 1. Conflict and 2. Trust. This indicates that the network partially captures the character of Cosette's perspective.

Valjean-Fantine

Valjean's perspective: According to the label, the most prominent social dimensions are 1. Support and 2. Identity. This is partially matched by the distribution, in which the most salient social dimensions are 1. Trust, 2. Support, and 3. Knowledge. This indicates that the network partially captures the character of Valjean's perspective.

Fantine's perspective: According to the label, the most prominent social dimension is Trust. This is largely matched by the distribution, in which the most salient social dimensions are 1. Trust and 2. Conflict. This indicates that the network largely captures the character of Fantine's perspective.

Javert-Beauvais

Javert's perspective: According to the label, the most prominent social dimensions are 1. Power, 2. Identity, and 3. Conflict. This is not matched by the

distribution, in which the most salient social dimensions are 1. Knowledge, 2. Support, and 3. Fun. This indicates that the network does not capture the character of Javert’s perspective.

Beauvais’ perspective: According to the label, the most prominent social dimension is Conflict. This is not matched by the distribution, in which the most salient social dimensions are 1. Trust, 2. Knowledge, and 3. Similarity. This indicates that the network does not capture the character of Beauvais’ perspective.

7 Discussion

7.1 Limitations

There are two main factors which should be considered before drawing any conclusion from the analysis: 1) the labels were based on the perception of one person. It is possible that a different set of participants would have generated other labels. For example, Cosette and Valjean argues at several points during the movie. Valjean even slaps Cosette on the cheek after finding out that she has a romance with Marius. However, the participant did not consider “conflict” to be an important characteristic of either perspective, which is likely that a different person would. 2) the distributions were evaluated by visually comparing them with the labels. This opens up the possibility of interpretation bias, and it is possible that a different author could have discovered different patterns and drawn different conclusions from the same set of labels and distributions. A strict mathematical evaluation would be appropriate for a more robust evaluation.

It is important to note that the DWMN’s accuracy or usefulness is not necessarily determined by how well it matches human perception. The network might be an accurate and useful model of interactions even if it does not represent a relationship in the same way that a human perceives it. For example, Beauvais shares a considerable amount of information with Javert. He guides Javert through Vigua and informs him about the town right after they first meet; he also provides information about crime and the mayor at a later point in the movie. This is reflected by the distribution “Beauvais→Javert” which is dominated by “knowledge”, but not by its label which only contain “conflict”.

7.2 Weaknesses

There are several factors related to the construction of the DWMN that might have had a negative impact on the network’s accuracy. We do not know how much each factor affected the overall structure of the network, but we discovered instances for each factor where it had a negative impact on it.

1. *We only used the textual representation of utterances to determine the strength of connections in different dimensions.* Text carries a lot of information, but factors such as tone, facial expressions, body language, or body contact can change the meaning of an utterance or convey a message on its own. Omitting such factors resulted in the wrong dimensions being identified and the right dimensions not being identified. For example, there is a lot of tension between Javert and Beauvais; Bauavis even laments the fact that Valjean did not kill Javert. However, the tension is mainly conveyed through tone, body language, and facial expressions, which explains why its not captured by the network.

2. *We did not consider the referent of an utterance.* Not considering the referent resulted in utterances contributing to the wrong dimensions and/or the wrong relationships. For example, Enjolras tells Valjean “You kill him [Javert] in the alley. We don’t want his blood in here with ours.” The utterance clearly convey “conflict” between Enjolras and Javert, and perhaps “trust” or “power” between Enjolras and Valjean. However, the utterance was addressed to Valjean and thus contributed to “conflict” between Enjolras and Valjean.

3. *We did not consider the context of an utterance.* Not considering the context resulted in utterances contributing to the wrong dimensions. For example, Gavroche tells Cosette "Thank you. No one is as kind and as beautiful as you.", to which she replies "You're such a convincing liar. I fear for your mortal soul." Tendimensions classified Cosette's response as "conflict", which is reasonable if the utterance is analyzed in a vacuum. However, given the context, it is clear that the utterance should be viewed as a joke and contribute to "fun" and not "conflict".

4. *We did not consider the importance of an utterance.* An utterance that was crucial for the plot or defining for a relationship carried the same weight as an utterance that could have been omitted without affecting the movie. This might have had a negative effect on the proportions of the dimensions. For example, the utterance "Javert." carried the same weight as "You[Valjean] don't want to go back to the quarries, do you? Then for once, we agree. I'm[Javert] going to spare you from a life in prison, Jean Valjean. It's a pity the rules don't allow me to be merciful. I've tried to live my life without breaking a single rule. You're free."

5. *The accuracy of Tendimensions was limited.* This resulted in utterances contributing to the wrong dimensions. For example, the utterance "You can't sleep here." was classified as "fun" and "romance", and "You deliberately left your child with strangers to conceal her?" was classified as "conflict", which is reasonable, and "romance", which is incorrect.

8 Closing Remarks

8.1 Conclusion

The goal was to create a network that captures the social character of interpersonal relationships. We created a network that models the relationships between characters in the movie *Les Misérables* (1998) since this would allow us to evaluate our approach by comparing the network with the movie. For multiple relationships, the network’s representation either partially or largely matches the participant’s perception. This indicates that the network captures key social characteristics of multiple relationships in *Les Misérables* (1998). However, there are several areas that could be improved to create a more accurate network, and we do not know to what extent the results apply to the real world. This thesis should be viewed as an experiment in how to model interpersonal relationships and serve as an inspiration for future work.

8.2 Future Work

This thesis has contributed to the understanding of how the ten social dimensions can be used to model social systems. While we were able to capture key social characteristics of multiple relationships in *Les Misérables* (1998), there are several avenues that should be explored to better capture the social character of interpersonal relationships: 1) the classification of utterances could be improved by incorporating additional factors such as context, tone, body language, and facial expression, 2) the weight contribution of utterances could be improved by exploring different methods for weighting utterances according to their importance, and 3) the allocation of utterances could be improved by exploring different methods for determining which relationship an utterance should be allocated to. Finally, our approach should be applied and tested in domains other than film to determine its usefulness for modeling social systems in the real world.

8.3 Lessons Learned

Writing this Master’s thesis took a lot more time than expected. We worked hard but did not achieve the results we wanted. Although the results are not what we aimed for, writing this thesis was an educational experience. This thesis reminded us of the importance of identifying a clear problem and purpose before starting a project. In addition, we learned how important it is with good communication to avoid unnecessary work.

8.4 Ethical Considerations

The author ensures that the work is free of plagiarism or research misconduct, and that the results are accurately represented. The author also ensures that the participant was informed about the purpose of the research, participated voluntarily, and is kept anonymous.

8.5 AI Statement

The author declares that generative artificial intelligence has not been used in relation to this thesis; not for research, not for writing code, and not for writing the report.

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