Social Media Influence Analyzer

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In a time where online social media has a significant influence on both individuals and groups of people in our modern societies, there is a need to have a digital tool that helps gather and construct data from online social media, then use this data to detect influence between individual users by detecting, measuring, and classifying the strength and topic field of influence in the process. This project proposes a method for influence detection, then build a technical solution on top of it to enable analyzers of online social media to have a visual and scientific understanding of the influence flow in social media network.

Keywords: Social-media, influence-detection, influence-topic-classification, text-classification, graph-centrality, graph-node-ranking, IT-system-architecture, logging, caching, HTTPS-Basic-Authentication.

Motivation

Upon the rise of the digital revolution through the last two decades, people around the world are no longer limited to the constraints of place and time to socialize with each other. The newly introduced concept of digital media has transformed the way our society function and socializing no longer requires the physical presence of society members. As a result of the introduction of multiple social media platforms, people from all over the world can now engage in local, national, and global events, participating in society and expressing themself in an open arena where physical boundaries do not stand in the way.

Today and after a very short time of experiencing the advantages of social media platforms, our society has become almost totally dependent on such platforms, and most social events and happenings does not pass away from being recorded and discussed in the wide arena of social media. This effect generates a huge amount of valuable data that has a big potential of revealing the type and strength of social influence between society members and opens for many useful applications in multiple fields.

The most obvious application from social data is understanding how social media is used as a tool to mobilize groups of people in controversial social events such as political elections. The serious allegation of Russian interference in the US presidential election in 2016 is one application of analyzing social influence on social media.

Furthermore, by mapping and visualizing social influence between users on social media, we can speed up and improve the detection of fake news and other illegal activities on social media, and by removing their damaging effects on multiple social environments, we can create a healthier society that benefits all its members.

Social influence is also highly valuable for commercial use, as many companies are interested in detecting different types of social influence to reveal new marketing trends and allow businesses to develop more specialized marketing strategies and customized products which often increase the competition in economy and generate more values for companies and their surrounding societies.

These were some applications that can benefit from analyzing influence between users on social media, and there is still both uncovered and undiscovered areas where understanding social influence is highly crucial for the purpose of the application.

# **Introduction**

Data from social media has a great potential in revealing how strong the influence is between different users, just like in real life every action a user commit and how society members react to this action can serve as an object for analysis which helps in drawing a big but rather detailed picture of how users influence each other across many societies and fields.

The aim of this research is to establish a ground foundation for extracting information about user activities on social media and use such information to detect social influence between network users. Such foundation is desired to make up the core of a future technical solution that enables social media analyzers with little or no technical experience in data processing and visualization to perform social media analysis on regular periods with a continuous timeline.

To serve this purpose, we start by determining the common characteristics in available user functionalities on the most popular social media platforms, then produce a model for data structure based on these similarities in user functionality, and by taking a starting point of common user functionalities, we increase the flexibility of this research to be applied to as many social media platforms as possible, and perhaps combine results from several platforms in one single analysis if needed.

After establishing an agreement on the data model to be used for collecting and storing crawled data from social media, we dive into the main core functionality of detecting social influence between network users. Multiple techniques of detecting and scoring social influence will be implemented to fit the different needs of a final analysis. The desired result is a user-oriented influence graph where each node represents a participating user, while each edge between two given users represents the influence between them with respect to direction of influence, and holding the score of influence strength along with its classified field of influence whether it is in sports, politics, or economy etc.

Following the previous effort, we evaluate the performance of the influence graph model and go through test results from both dummy and real-life data using crawled data from a rising social media platform called “Reddit”. We will then try to highlight the most interesting and useful features of the produced influence graph and push its power of detecting influencers and their area of influence to the limit. The final two processes of test and evaluation are together a vital step to confidently rely on the quality of the produced model of the influence graph by ensuring its informative capabilities in social analysis.

Furthermore, a technical solution is to be designed and implemented to work hand in hand with the theoretical approach and function as a possible practical implementation used as a proof of concept and as a helping tool in testing and evaluation. During the process of designing and building this technical solution, many important aspects of data protection, reliability and availability are discussed and dealt with to improve the ecosystem of this application.

This was a brief introduction of the upcoming research in a nutshell, but first let’s take notes and learn from some interesting pre-attempts in studying influence between users of online social media.

# **Related Works**

Among the community of data science, a wide variety of studies has focused on extracting information from online social media, and a great amount of effort has been dedicated to studying social influence between users to better understand the behaviour of individuals for many purposes. Research of social influence takes different forms and vary in size and scope, while some researchers take on the very fundamentals of detecting social influence, others dive through it to reveal details such as a specific influence or hidden behaviour patterns on different levels. In this section, we explore some related work in the field of social activity on online social media and try to get an inspiration that helps direct the effort of this research in the right path.

## **Measuring Influence Between Users of Online Social Media.**

A good fundamental approach is described by a social network analysis carried out by Y. Guo, J. Cao & W. Lin. The fellow researchers divide the influence evaluation models into 2 main categories; the first category is based on network topology which measures social influence between different users by considering the user degree, shortest path, and some random walk characteristics, while the second category bases the influence between users on their interactions through different activities organized in a tree-like structures containing submissions and multilevel comments. However, and despite the reasonably good classification and overview, the published paper of this research lacks some proven results of an experimental approach [1].

## **Data-driven Influence Learning.**

A short but rather interesting experimental and mathematical approach is introduced by a paper on Data-driven Influence Learning in Social Networks published by F. Wang, W. Jiang, G. Wang & D. Xie. In this paper, the process of influence diffusion is divided into two parts: the launcher (influence strength) and the receiver (influence threshold) which can generate an accurate and finer grained influence diffusion model according to this research. [2]

Furthermore, the researchers highlight the importance of having a solid criterium when scoring the strength and threshold properties of social influences. Another important acknowledgment is the difficulty and complexity associated with detecting influence relationships between users as a by-product of big datasets that usually include a considerable amount of noisy or less important datapoints, making it essential for any algorithm used in learning and testing the influence models to perform a minimal scan over the data in the most efficient way possible.

## **Alternatives of Information Gathering.**

Most well-known providers of social media platforms assist developers and data scientists with instructions on how to crawl their platforms by offering multiple endpoints and methods that can be used for gathering data for analysis.

Multiple researchers spot the light on this initial aspect of gathering data from social media platforms. A significant research is one that mainly describes the alternative of Pushshift Reddit Dataset by J. Baumgartner, S. Zannettou, B. Keegan, M. Squire and J. Blackburn. [3] This research paper offers an undirected but also claimed to be a more efficient and flexible way to gather data from the “Reddit” social media platform, in comparison to using the official Reddit API endpoint.

It also gives an excellent brief description of the FAIR data[[1]](#footnote-1) principles which is highly relevant when choosing the source of data especially when it comes to accessibility and findability.

Another advantage of this research is its extension in discussing a series of the other major alternatives for gathering data from “Reddit”, highlighting their strengths and weaknesses in a constructive manner.

## **Topic Detection in Socical media platforms.**

As mentioned in the introduction, we are set to determine the category of a detected influence between users, this opens for the use of artificial intelligence for the purpose of classification between different topics where a certain user activity might fit in. Inspiration on possible solutions for this task can be obtained from a research about annotating and detecting topics in social media forum and modelling the annotation to derive directions carried out by B. Athira, J. Jones, S. M. Idicula, A. Kulanthaivel and E. Zhang. [4]

A practical case study from an online health community was represented to give a good introduction of data pre-processing and cleaning, then preceding to construct a reasonable mathematical approach in the training and testing of a machine learning model to be used for the purpose of topic classification.

Another contribution of this research is the use of various deep learning algorithms to classify posted content such as CNN[[2]](#footnote-2), LSTM[[3]](#footnote-3) and BiLSTM[[4]](#footnote-4), all in which enable the researchers to achieve a promising F1-score[[5]](#footnote-5) of about 0.75 to 0.80 in topic classification accuracy.

Furthermore, the above research offers a solution for a much-needed ability to minimize the amount of training data and dealing with the negative effects of label imbalance in a training dataset, then constructing a convincing conclusion after carrying out a process of well-performed testing and evaluation, where metrics of evaluation are carefully examined and explained in a good scientific approach [4].

## **Study Case Alternatives of Online Social Media.**

Determining which social media platform to crawl under testing and evaluation of a new modelling approach is important to produce a flexible influence model that can be used for analysis of as many social media platforms as possible, this is why it is desirable to work with real-life datasets gathered from a digital media platform that shares common user functionalities with as many popular social media platforms as possible, examples of such functionalities are posts or submissions, comments, and upvotes or commonly known as likes.

A social media platform that satisfies all these user functionalities is “Reddit” which is examined by the research with the title “Information and Social Analysis” carried out by T. Steinbauer at the University of California, Santa Barbara. [5]

Steinbauer starts off with a brief but very constructive comparison between the most popular sites for social news with Reddit included. The core of Steinbauer’s research lays in his analysis of subreddits, submissions and comments on the virtual platform of Reddit, this analysis helps explaining why Reddit should be used in evaluating the performance of an influence model and its ability to view the most influencing users in a social media platform. The reason for this is Steinbauer’s detailed analysis on which subreddits seems to have the most of user’s activity, and in addition his further construction of an example user-oritened influence graph that helps showing which user has the highest influence based on the user’s interactions through comments.

However, submission authors are not included in the dataset of the constructed influence graph, making this influence model less reliable if ignoring the often-significant role of posters in generating discussions on social media. Another downside of Steinbauer’s modelling of an influence graph is the limitation of not using any other criteria than user interaction through comments, such as the upvote score or number of thread or descendant comments posted on other comments or submissions.

Although Steinbauer has introduced a detailed result overview of his evaluations and analysis, there is still a question mark on the technical details because algorithms that has been used for producing the model of the influence graph are not provided to the reader in satisfying details.

# **Reddit as a case study social media**

There exist a wide variety of popular social media platforms and most of them are constantly gaining popularity among users from all over the world.

The following figure shows the market share of the top 7 most popular social media platforms during the last decade from 2010 to 2019, where market share data is obtained from statcounter.com which claims to base its statistics about digital market shares on a sample exceeding 10 billion pageviews per month. [6]



Figure 1, Worldwide market share of top popular social media platforms from the beginning of 2010 to the end of 2019 [7]

Although Facebook is the definite leading social media platform, it is still possible to observe a competition in popularity when looking at the next 6 platforms below Facebook, with Reddit having a popularity corresponding to all other social media platforms that are less popular than Reddit.

A normal side effect of a more popular social media is the large amount of data users generate on such platforms, which slows the process of extracting data from such platforms, and although data from a more popular media often has a higher integrity, it is important to keep a balance between data integrity and easiness in findability and accessibility. In this research, we try to compensate between these two factors by choosing a medium-sized social media platform for use during testing and evaluation of the influence graph model.

The market share of Reddit does nearly equal as the sum of at least 14 other social media platforms and all of these are reported to be below reddit in popularity including well established platforms such as LinkedIn and Instagram. This makes Reddit a suitable candidate to be used as a case study social media in this research, as Reddit offers our desired moderate balance between network size and easiness to crawl.

In addition, many of the most popular social media platforms tends to specialize in a certain area or field of social activities such as LinkedIn for professional life, and Facebook on the other hand mostly used for private and personal socializing, some digital platforms combine aspects from both areas such as the so-called digital news platforms that offers its users an opportunity to interact with each other in many aspects of socializing like professional and personal life combined. Reddit is considered as one those digital news platforms which is still gaining popularity and increasing in content since its launch in 2005.[[6]](#footnote-6)

A user on Reddit can create or join a group, make a submission on any group and comment on any submission or comment made by other users. A user can join a group, but it is not obligatory to join a group to be active in them or read their content. These groups are called subreddits and tend to specialize in a certain topic of interest in society, and for many users it is seen in a way that is somehow like reading the newspapers which is often divided into pages for multiple areas of concern such as politics, economy, or sports. The high separation between topics of interest in Reddit makes this platform ideal for testing how well an influence detecting algorithm can discover and classify different types of influence between users.

Reddit differs from other social media platforms in the sense that Reddit attracts users by their interest in topics and events in their social surroundings, while other social media often relays on the social affiliation of a future user. However, and on the other hand, many other social media platforms share a lot of common user functionalities with Reddit, such as groups, submissions, and comments.

This high similarity between Reddit and most popular social media platforms, along with Reddit’s ability to separate users into multiple different social groups, makes Reddit very suitable as an evaluation study case for this research as common functionality increases the modelling flexibility to be used on other social media platforms in future analysis, and its separation of social environments in groups serves the purpose of comparing the predicted type of social influence between users to the actual definition of the group where the interaction between users has occurred to give us an idea of how well our influence model is classifying topics of social influence.

Although Reddit is a user-oriented platform, its users often prefer to be anonymous, which is useful when presenting results without having to worry about neutrality issues, but Reddit’s users can also choose a username that can be used to identify them personally if they desire.

Another good reason for choosing Reddit as a study case is the highly developed endpoint crawling API which is very object-oriented and offers a wrapper library for the Python language. This eliminates the bother of dealing with HTTP requests and latency issues, as all of this is taken care off in the background of the Python Reddit API Wrapper. The Wrapper is free to use but it requires a registration which once done offers no restrictions on how often Reddit is crawled, unlike crawling by adding “.json” to the URL which have its downsides such as limitation for under 100 submissions at a time, and the blockage of multiple requests from the same IP address as a prevention measure from Reddit to stop denial of service attacks. All these downsides are escaped by using the Python Reddit API Wrapper which increases the reliability and stability of data streams from reddit. In other word the PRAW[[7]](#footnote-7) python module satisfies the following FAIR data principles:

* Findability:

Once using PRAW, it is easy to find and retrieve data from Reddit no matter how detailed the data is.

* Accessibility:

As mentioned earlier a programmer does not have to deal with HTTP requests and latency issues as when using a traditional API endpoint, this makes the programming experience much easier allowing programmers to focus on the objective of their work.

* Interoperability:

A good documentation and maintaining history of the PRAW module [8], along with its popularity between programmers which gives it an excellent record of ability to integrate with different products and systems that uses it.

* Reusability:

PRAW is highly object-oriented in both query language and retrieval results. This is helpful for the usability for integration in different projects and technical solutions both in present and future technologies.

Based on the above four FAIR data principles and the previous analysis of user habits and possibilities on Reddit and other social media platforms, Reddit makes a good case study in the testing and evaluation process when we are seeking to detect user influence and their area of influence. We shall than design our ground data structure to adapt for the common functionality between Reddit and the most popular social media platforms as we will go through in the upcoming section on the ground data structure.

# **Definiing a ground data structure**

Flexibility of design is an important requirement of this research, as we aim for a future application of the influence modelling developed in this research on as many other social media platforms as possible, and although this might be difficult to achieve as a result of the wide variety of available social media and the different user-functionalities in them, we can still notice some common user functionalities between the most popular social media platforms such as LinkedIn, Facebook and Reddit, this common functionality is no accident, as these social media platforms most likely inspired from real life social interactions to begin with, which in turn is a natural advantage for our application.

After studying the available user functionalities in Reddit compared with these same functionalities on the most popular social media platforms, it is easy to see a big potential for developing a generalized data model that can be used to structure data crawled from any of the applying social media platforms. It is therefore important to consider the desired results of this research before establishing a ground model for data structure.

Social influence can be defined to be the ability of one society member to change the thoughts or behavior of another society member, and although this definition is simple, the complexity is hidden in the way social influence plays out in real life society. Some people get influenced without any big significant reaction that can be recorded and studied, such influence is said to be of a passive type of influence, an example of passive influence is reading a newspaper where the reader gets influenced without adding any additional comments to the content.

The main goal of this research is to use recorded data from social media to visualize the influence flow between a group of people in a social interaction. For this reason, we are going to look at active social influence where we would expect the person who get influenced to react by submitting an activity on the content of influence. This requires an activity-based model, where activities such as submissions and comments are considered as indicators for social influence.

The second requirement of this research is the importance of visualizing the flow and direction of influence between members in a social media interaction. For this purpose, we will be building an interaction-based model that is able to retain the origin and target of each detected and measured influence, which benefits the storage of influence direction and in the big picture can be used to visualize the entire flow of social influence between society members.

The model can initially be based on four different entities a user can create and interact to; these entities are:

1. Network

Which holds information about the crawled social media platform or a smaller segment of it, having this entity, makes it possible to study multiple social media platforms at the same time which increases the flexibility of design.

1. Group

A group contains a bundle of submissions posted by users of the group. It also contains information about a certain group in form of identification and other attributes such as the group ID and name.

1. Submission

A submission is posted by one user and is assumed to be in text format with the possibility of further extension to multiple other formats like images and links in future improvements. The submission entity has multiple useful information stored in its attributes such as the current number of- comments, and -upvotes on this submission, along with information about the author of this submission and other identity attributes.

1. Comment

The comment entity is very similar to the submission entity containing a body text, identification of author and information about the location of a comment in the comment thread. And therefore, it has an additional feature which its ability to be a parent and/or a child of other comments. This means that comments can be modelled as a tree data structure that can grow unlimited.

The figure below shows a diagram of an entity-relationship model that will make the base of our data structure further on in this research. In addition to the four entities explained earlier in this section, four relationships bind these entities together defining their relations to each other. A network can contain multiple groups, and a group can contain multiple submissions or posts, where users can either comment on those submissions or on other comments that is a child descendant of the comment tree of a certain submission.



Figure 2, The Entity-Relationship model which represents the ground datastructure of this research.

Most of the popular social media platforms contains the four identified entities in this ER-model[[8]](#footnote-8), although they might have a different name, form, or purpose such as a company page on LinkedIn or a user profile on Facebook, but both can be treated as groups just like Reddit groups as well.

The attributes of entities open for more flexibility as we might have the need to extend or shrink our ER-model in the future i.e., by not including an upvote attribute or by adding a reaction attribute to submissions and comments. But also, attributes are generalized to match the very common details about of these entities in between the most popular social media platforms.

Now that we have a ground Entity-Relationship model to base our data structure on, we can proceed into discovering influences between users based of the interactions between them using these entities and relationship roles established in this section. In the next steps, we will elaborate the different stages of our influence modelling process for detecting and extracting social influence from online social media, the algorithms of the upcoming influence modelling are expected to have multiple dimensions for revealing the strength and types of social influence between different users online.

# **Influence Graph Modelling**

## **The Activity Thread.**

The previously established model of the ground data structure in figure 2 provides the required entities of detecting activity- and interaction-based social influence, we can observe a clear hierarchy between the following four entities: network, group, submission, and comment. This hierarchy enables us to model the data from a social network as a tree structure where network contains multiple groups that in turn contain a series of submissions which can contain multiple branches of comments, comments can have their own comments resulting in a tree that can grow endlessly as users add more comments on previous comments.

The figure below shows a small example of an activity thread tree of just one submission, which contains the activity of the submission in the root position and its several branches of comments each in its respective hierarchy level, we can call this thread the activity thread as each single node in this thread represents an activity object that a certain user had performed.



Figure 3, A set of submissions and comments is modelled as an activity tree by taking advantage of its natural thread hierarchy.

In the activity thread drawn in figure 3 above, we have 2 participating authors, the arrows indicate that the target activity was an interaction on the source activity, where a red arrow indicates an interaction from “User D” to the activity of “User A”, and a blue arrow indicates an interaction from “User A” to the activity of “User D”. In the next steps of influence modelling, we will investigate how we can use this activity thread to give birth to a weighted and directed activity-oritened graph that shows the interaction flow between users performing these activities, along with other details such as influence type and score magnitude.

Before we head further into more details, we should control the endless grow of the activity thread by defining comments based on their level in the activity tree to avoid any confusion when referring to different types of comments. As comments can have their own thread comments, we can establish a categorization of comments based on their level position in the thread hierarchy tree, where we can use two types of comments:

* Top Level Comments

Which are comments made directly on a submission.

* Sub Level Comments

Which are comments made on top comments or other sub comments.

The distribution of comments between top comments and sub comment can give us a picture of how involved members are in each submission, because observing more sub comments than top comments can indicate that authors are taking their time to read and react to top comments in addition to the submission which is an indication of a greater engagement from authors than if they just keep themselves to writing top level comments.

## **Scoring Influence.**

Since every tree is naturally a graph, we can take benefit from our hierarchical activity thread to construct a directed graph where each edge in this graph is directed from a parent activity to one of its child activities. And each edge represents one interaction between 2 submitters where target and source nodes are represented by their authors, showing that the author of the target activity has reacted to an activity submitted by the source author, which in turn can be considered as an influence indication directed from the source author towards the author of the child or target activity.

Knowing the direction of influence helps us detect influence between users, but it is not satisfying enough to give an idea of how strong a certain influence is, therefore we aim to grade all detected influence between users, so we can determine how strong a certain influence is in comparison to other influences in the influence graph topology. For this reason, we will give each influence edge a score that shows its strength.

Many techniques can be used to perform the scoring of influence; however, each technique have its strengths and weaknesses, and one way to reinforce the analysis system is by offering multiple scoring techniques to be used in analysis, to accomplish this, three different scoring techniques are used, each having some strengths and weaknesses depending on the use case of final influence analysis.

1. Interaction

This scoring technique measures how many times a studied user has reacted to activities performed on another user. The strength of this measure is in its ability to detect each interaction between users and differentiate them using the number of interactions as a score. But depending on the network, many users tend to interact one or two times in most cases, this is despite that the topic might be very interesting users who does interact that much. To accommodate such cases of low interaction influence, the following two scoring techniques can be applied in analysis.

1. Upvotes

By using the difference between upvotes or likes and downvotes or dislikes on a parent activity, we rely on the audience opinion on the parent activity given by other users. The submitting author of this activity is the influencer, and its influence takes the score calculated as the difference between upvotes and downvotes, this influence is then directed towards those users who comment on this parent activity, and thus they get influenced from the author of this activity having this influence score.

This scoring method gives a democratic approach that enables us to know whether an influence activity is supported or downvoted by a group of interested audience. At the same time, it is important to notice that in some networks such as Facebook, it is not possible for users to downvote an activity, which leave us without knowing for sure whether the influence is most likely to support an activity or not. However, it is still possible to accommodate this by counting the number of upvotes as a measure where 0 is the lowest score of an influence.

A downside of this upvotes-based scoring technique is that all child activities will get the same score, which can result in low differentiating effect between influence edges in the influence graph model.

1. Activity

The activity scoring technique scores influences based on how many edges of influence are found in the full branch of influence started from a parent activity.

Central people in society like politicians tends to influence the most people by triggering a great number of response activities. This scoring measure is based on the general extended impact of an influencer and can therefore help identify the central influencers and which users do they have an influence on.

The upside of this activity-based scoring technique is its ability to include the impact of all activities in an influence branch and still be able to differentiate between influence edges on child activities because of its branch oritened calculation, and it does not take in account all descendant activities of the parent activity.

The figure below contains a graph built on the skeleton of the previous activity thread in figure 3. It converts nodes from representing an activity object to represent the author of that activity, while preserving the hierarchical structure as it is in edges and their directions, it also introduces the three scores of interaction, upvotes and activity as separate weights calculated for each influence edge.



Figure 4, The activity graph is constructed by representing the nodes of activities using their authors, and applying the scoring techniques of interaction, upvotes and activity to score the individual influence edges.

When examining the activity graph example in figure 4, we can count 4 influence edges, half of these are directed from “User A” to “User D” and the others two are oritened in the opposite direction. We can digest the structure of this directed and weighted activity-oritened graph by merging all nodes and influence edges having the same unique pair of source and target authors of activities, while performing a simple addition of the respective scores for each of the three scoring measures. The final produced graph is to be called the influence graph with more details and examples on how to construct this graph model presented in the next section.

## **The Influence Graph.**

After going through the activity thread tree and its transformation to a directed and weighted activity graph, it is now easier to digest such a graph to produce the desired output of a person-oriented influence graph, where each node represents a unique author in this graph, and where edges are used to indicate a particular scored influence between two persons with respect to the direction of influence.

Looking at the previous activity thread in figure 3 and the activity graph in figure 4, we can count 2 submitters who are “User A” and “User D”, and together they submit 5 nodes of activity objects. To find out how much influence does “User A” have on “User D” and vice versa, we go through the following steps:

1. Creating a person node for each unique author in the activity graph.
2. Listing all influence edges stretched from “User A” to “User D” in the activity graph.
3. Merging all influence edges in step 2 by summing the values in each scoring measure to produce the respective score of each measure for this influence edge.
4. Step 2 and 3 above is to be repeated to find the influence in the direction from “User D” to “User A”, and the same goes for finding influence between any possible pair of two persons in the graph.

To further clarify the merging calculations of influence scores, we notice that an interaction score from “User A” to “User D” would be the number of edges going from activities submitted by “User A” and interacted to in activities submitted by “User D”, while the upvotes score is the sum of upvotes values recorded on these unmerged edges in the activity-oritened graph and the same goes for the activity score.

Following the four steps above, a new person-oritened graph is born with a unique node for each person, and with its influence edges having three scoring attributes that measure the strength of each represented influence. This resulted new influence graph visualizes the flow of influence between persons, how strong each influence is, and in which direction between them it is observed. An example of the previous four steps transformation from the activity graph in figure 4 to a person-oritened influence graph is presented in figure 5 below.

The example user-oritened influence graph below does have two users with two influence edges between them; according to the interaction score, both users does have equal influence in each other, while using the upvotes scoring technique, tells us that “User D” has a little more influence on “User A”, and the opposite is observed when using the activity scoring technique.

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Figure 5, The user-oriented influence graph contains a unique node for each person, and the edges of this graph indicate the weights and directions of influence between the persons in this influence graph.

## **Testing & Evaluation of The Influence Scoring Techniques.**

So far, we have proposed a staged method that is meant to detect influence between users who submits various activities such as submissions and comments on social media platforms. The output of this method is an influence graph where each node represents a person, and each edge indicates an influence from its source person into its target influenced person.

We are primally interested in the overall capability of the influence graph to visualize the flow of influence between activity authors in a dataset. For this reason, we are going to focus on the edges of influence between users as they hold score values obtained by using different influence scoring techniques that were detailed previously in this research.

We hereby plan to test the score distribution in the user influence graph after observing the effects of applying each scoring measure (i.e., Interaction, Activity, and Upvotes) to the same dataset, which is crawled from Reddit, and contains the top 3 newest submissions taken from each of the top 3 most popular subreddits according to internal Reddit.com statistics by using the python Reddit API wrapper on the 12th of July 2021 between 12 to 12:30 O’clock.

The following figure shows 3 box plots and 3 histograms that shows the score value distribution of each scoring measure recorded in edges of the person-oritened influence graph.

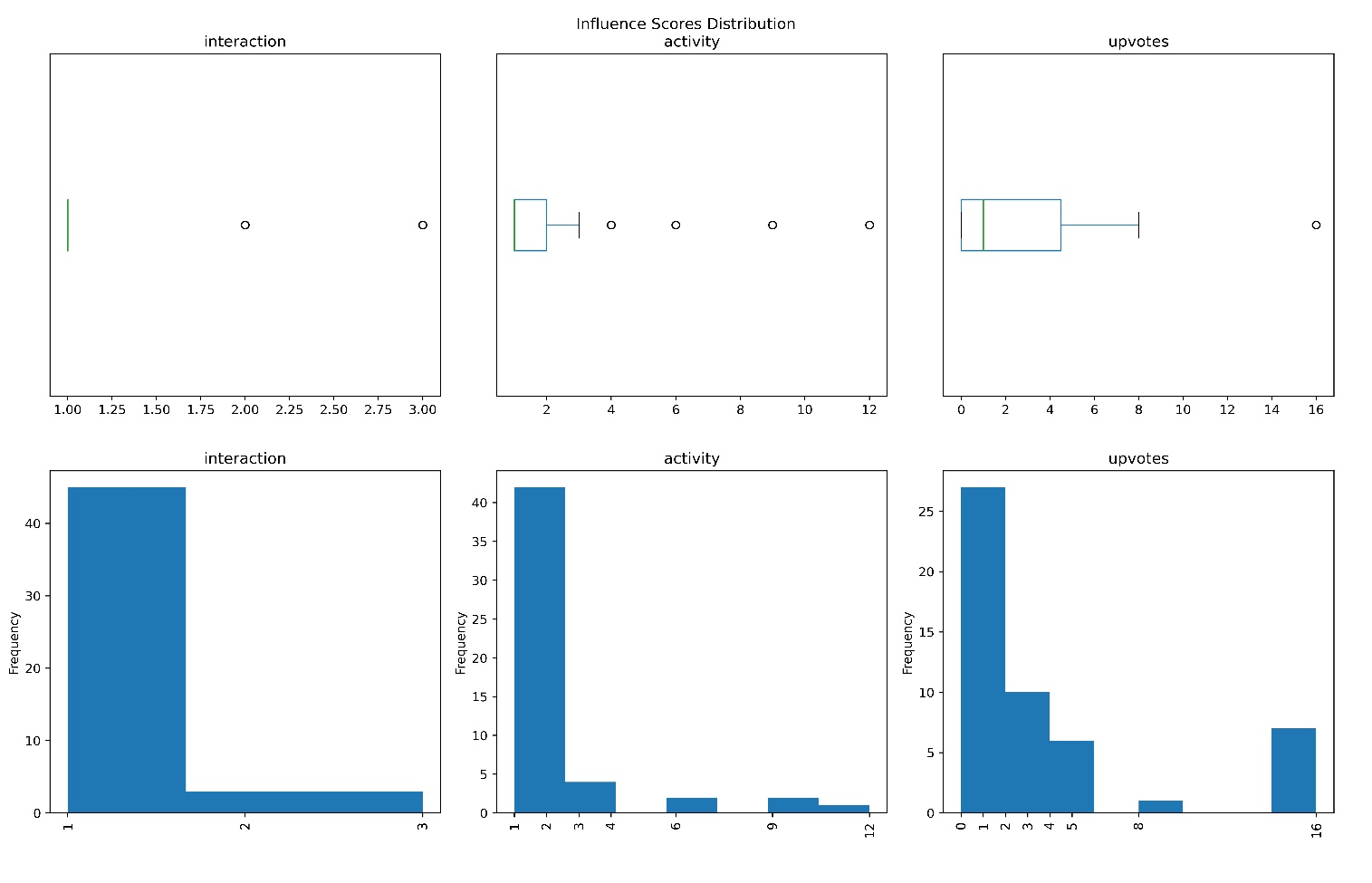


Figure 6, The single score distributions recorded in the edges of the influence graph, constructed on a dataset containing the top 3 newest submissions posted inside the top 3 most popular subreddits on the 12th of July 2021 between 12 to 12:30 O’clock.

Examining the distribution of interaction-based score values in the left box- and histogram plots in figure 6 above, gives a clear observation of low variance between score values which reduce the differentiating capability of the interaction scoring technique. However, a relatively good number of influences were successfully detected from the crawled dataset.

Moving on to the examination of activity-based score values in the middle of figure 6 above, we notice a slight decrease in the number of influences having the lowest score in comparison with the interaction-based score values on the left side. In addition, there is a noticeable extend in variance as the range of recorded values has increased from 1 to 3 in the interaction-based score values to a range between 1 to 12 using the activity score values. Four outliers on the right side of the box plot of activity scores also tells us that this scoring measure has more potential to differentiate between influences and present the detected influences that are having more significance than others.

Finally, we examine the upvotes-based score values to discover a higher achieved variance and a smaller number of outliers in the distribution of obtained score values. This result shows us the effectiveness of using the upvotes-based scoring technique for differentiating between detected influences.

Because each scoring technique might have its strengths and weaknesses in accordance with the purpose and motivation of the performed analysis, an analyzer might also wish to combine multiple scoring techniques and look on the distribution outcome of score values. In this research, the single scoring techniques are combined by performing an addition operation on all possible combination of the 3 scoring techniques in each edge in the influence graph. This results in the following four new scoring techniques:

* Interaction + Activity
* Activity + Upvotes
* Interaction + Upvotes
* Total = Interaction + Activity + Upvotes

Figure 7 below does plot the distribution of score values obtained from the double combined scoring techniques. An increase of variance is observed on all double combinations of scoring measures, especially when combining the activity and upvotes scoring techniques, which gives the highest achieved variance and therefore the best capability of differentiating between detected influences based on their scores, and independent of the purpose and motivation of analysis.



Figure 7, The double score distributions recorded in the edges of the influence graph, constructed on a dataset containing the top 3 newest submissions posted inside the top 3 most popular subreddits on the 12th of July 2021 between 12 to 12:30 O’clock.

Furthermore, it is also possible to examine the results of combining all scoring techniques to produce a single total score where the distribution of its scoring values is plotted in figure 8 below. This total score measure gives us an even wider range of possible score values, but with a nearly as equal variance as the combination of activity and upvotes scores, reasonably because of the low differentiating capability and low variance of the interaction score values.



Figure 8, The total score distribution recorded in the edges of the influence graph, constructed on a dataset containing the top 3 newest submissions posted inside the top 3 most popular subreddits on the 12th of July 2021 between 12 to 12:30 O’clock.

Based on the previous testing results, we can conclude that each scoring technique is mostly dependent on the nature of raw data generated by users on a social media platform who may have different ways of using the social media platform and therefore different ways of influencing each other. However, it is possible to mitigate the effect of how users use the network to influence each other by using a combined scoring technique which can have either an advanced formula or be as simple as an addition of the single scores in each influence edge of the user influence graph.

## **Testing & Evaluation of The Activity & Influence Graph Models.**

An important desire in any graph is to be informative, easy to read, and easy to visualize, we hereby wish to test how informative the activity and influence graphs in visualizing the picture of influence flow in the studied dataset.

We start by drawing the activity graph on a dataset crawled from Reddit and contains the top 3 newest submissions taken from each of the top 3 most popular subreddits according to internal Reddit.com statistics by using the python Reddit API wrapper on the 12th of July 2021 between 12 to 12:30 O’clock.

The activity graph has 3 types of nodes: the submissions, top level comments and sub level comments. In figure 8 below, we view the activity graph of this Reddit dataset and notice a little higher concentration of top-level comments having the red color in comparison to sub level comments with the blue color, which tells us that people in this dataset have a medium engagement in the threads of submissions, this engagement benefits the process of detecting social influence in the dataset when constructing the final person-oritened influence graph.



Figure 9, The activity graph, having the colors; yellow for submissions, red for top level comments, and blue for sub level comments. The graph is constructed on a dataset containing the top 3 newest submissions posted inside the top 3 most popular subreddits on the 12th of July 2021 between 12 to 12:30 O’clock.

The nodes of the activity graph in Figure 9 represents 69 activities in the crawled dataset from Reddit, having the count of 9 submissions, 38 top level comments and 22 sub comments. Since the percentage of sub comments is around 32%, it can be used as an indication of good social engagement from the participating persons in the dataset. This result is also highly visible by taking a quick look at the colored activity graph in figure 9 without having to calculate the exact number of each activity type. This highlights the importance of defining the types of activities to be used under the visualization of the activity graph.

By digesting this previous activity graph and merging its influence edges to transform it to a person-oriented graph, we obtain the influence graph shown in figure 10 below. The visualization of this graph takes advantage of the total combined score values to adjust the thickness of each influence edge, indicating its high or low score value in an intuitive display that allows analyzers to identify and focus on the high score influence.



Figure 10, The influence graph. The graph is constructed on a dataset containing the top 3 newest submissions posted inside the top 3 most popular subreddits on the 12th of July 2021 between 12 to 12:30 O’clock

In addition to visualizing the strength of each influence, the type on influence is also used as a label on each influence, where only one influence type is possible for each influence edge in the activity graph, but due to the merging into the influence graph some edges will accumulate multiple influence types as viewed in the right bottom of the influence graph in figure 10, this tells us that this influence is most likely to be in politics and technology.

Another important feature of the influence graph is the use of unweighted outdegree centrality to identify central influencers and distinguish them from other less influencing persons in the graph, which can be visualized using their calculated centrality value to be reflected on the size and opacity of the person node as in figure 10.

The use of unweighted centrality measures allows the analyzer to have a view that is dependent from the score of influence edges, as we observe in the influence graph in figure 10, where 3 significantly bigger person nodes are shown in the middle of the graph where no thick edges is to be found. But in the case of having the combination of a series of thick edges connected by a big sized person node in the graph, then it is a good indication of the high influence this person has on other connected persons. An example of this case is to be observed at the left bottom area of the graph on figure 10 above.

Looking at the overall collection of different features and tools provided by the final influence graph, it is clear to observe its beneficial capabilities under the process of social influence detection and analysis. Many applications can then benefit from easiness of interpreting the influence graph to determine the strength of influence, its predicted field of influence along with the centrality ranking of persons in the dataset.

## **Influence Field Classification.**

Being able to identify influencers on a social media platform is one objective of this research, another objective is to classify detected influence in multiple distinct topics such as politics, sports or economy. Knowing the type of influence between people enriches the process of analysis and gives it a topic-specific dimension that helps the analyzers to focus on the topics of interest during influence analysis. In this section, a classification method is proposed by integrating a text classification machine learning model into the process of building the activity and influence graphs.

Due to the normally large number of influences detected between people on online social media, a manual classification between different fields of influence is hard to perform and proof its reliability as topics can be perceived differently from one person to another. This is where artificial intelligence can come in handy by building a machine learning model with the task of classifying influences into multiple topics learned from a training dataset.

This training dataset can be static over time or continuously changing, the advantage that can be gained be having a dynamic training dataset is its ability to stay updated with the newest details that differs different fields of influence, while a static dataset will be frozen in time and might give false classification results in future use. For this reason, a dynamic process of updating the training dataset before being fed into a text classification model is implemented in this research. More details are included in some of the upcoming sections about the process of crawling dynamic training datasets and building the text classifier used to determine the field of influence based on texts from submissions and comments.

We hereby assume that we have a trained text classifier ready to be used to classify influence edges in the activity graph in between different fields of influence. Then when transforming the activity thread tree into an activity graph, we classify the influence type of each edge in the activity graph by constructing a combined text from the submission activity at the root of the activity thread tree, along with the texts from the source parent and target child activities of an edge, then input this constructed text into the text classifier to have an estimate about which influence field a particular influence edge is most likely to belong in.

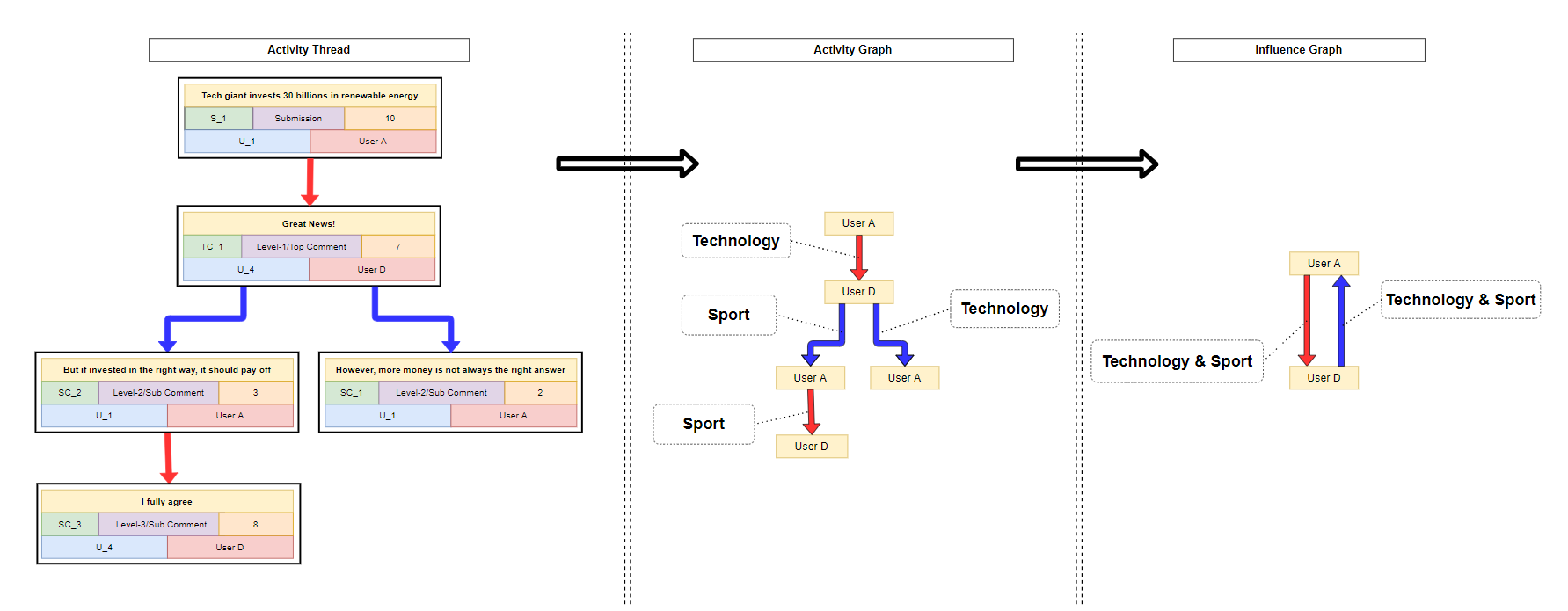
Adding the text of the submission activity to each classification trial increases the chances of having a more correct classification as the submission text tends to have a clear indication to the topic of discussion in its activity thread. However, using only the submission text as an input for classification of each activity edge leads to a sterile and little informative classification as all edges between activities in the activity thread will have the same classification, therefore the source parent and target child activities are also added to the input of the classification trial, which also helps detect any derailment between topics under the user discussion in the activity thread.

An overview of this process is drawn in figure 10 below, where 4 classifications had been performed on the 4 edges in the activity thread tree shown on the right of this figure, then labeling the corresponding 4 edges with the respective classification output results in the activity graph at the middle of this figure.

An example of such classification process is the edge between the comment “SC\_2” and “SC\_3” in the activity thread, here we construct an input text from the following activities:

* Submission activity: “Tech giant invests 30 billions in renewable energy”
* Parent activity: “But if invested in the right way, it should pay off”
* Child activity: “I fully agree”.

After adding spaces between these 3 texts, the classification method of our trained text classifier is used, which classify the influence edge into the sport category, and then store this output value in its respective edge between users in the activity graph at the middle of figure 10.



Finally, we gather the distinct classified fields of influence in each respective edge in the influence graph during the merging process from an activity graph to an influence graph. Noticing that an edge in the activity graph can only have one classified field of influence, but when constructing the influence graph, multiple edges having the same combination of source and target persons would be merged, and in result all distinct classified fields of influence will accumulate in the respective merged edge in the final influence graph.

When examining the texts submitted by authors in the activity thread, we might want to manually conclude that the influence constructed from this thread is to be reasonably related to technology, and although the used text classifier has classified some influences in the sport category, a final look at the influence graph confirms that the technology category is also included in the respective edges in the influence graph. This tells us that our implementation of influence field detection have the ability to investigate and capture any derailments of discussion under the activity thread, which represents a strength that enable this method to look beyond what the human eye can assume about a certain written discussion.

This classification process is very similar to the process of influence detection, as it has the same three staged skeleton which plays out by transforming the activity thread tree into an activity graph, then into a final influence graph. This similarity makes it easier to merge the three processes of influence detection, influence scoring and influence field detection, which can have the effect of reducing the runtime of a practical algorithm that implements these three processes all at once, so the need for multiple iterations over records in the dataset is eliminated. However, this can have a moderate increase on the complexity of such implementation, but this complexity can be dealt using best practices under programming.

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