Understanding and dealing with disinformation: Towards a systemic approach

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ABSTRACT

Disinformation is untrue information that is intentionally spread to mislead. Today, off- and on-line disinformation is a growing, multi-faceted societal problem that cannot be addressed with simple solutions. Decision makers face the challenge of managing or solving disinformation problems without creating more, potentially bigger problems. An appropriate and reliable understanding of the situation and the problem is essential to its resolution.

In this paper, we discuss our framework for understanding complex systems, which combines the Iceberg model, Endsley's Situational Awareness and OODA Loop (SA-OODA). Under our framework, disinformation can be perceived at different level of events, trends, or system structure. Depending on what is perceived and integrated into a model, decision makers can understand the extent and impact of disinformation, as well as the underlying causes (purposes) and conditions; based on this understanding, decision makers can develop or evaluate potential solutions. To this end, we show how Visual Analytics helps to explore the context of disinformation in the information environment.

The effectiveness and sustainability of potential solutions therefore relies on the level of consideration, and on the appropriateness and reliability of the model. The appropriateness of the perceived and integrated information depends on whether it helps decision makers answer their questions and whether it corresponds to reality. Reliability is determined by the degree of completeness and certainty of the information. This, in turn, depends on the transparency of the system, which is governed by the system's structural features. To address the growing phenomenon of disinformation, we propose an approach based on a systemic view that supports the assessment of the information presented. It focusses on the understanding of the context of disinformation, on the purpose of its dissemination, and its impact on society.

1.0 INTRODUCTION

Disinformation is untrue information that is intentionally spread to deliberately mislead or deceive people and can also create confusion and / or fear. This differs from misinformation which disseminates false information unknowingly, unintentionally, and unplanned [8,21]. Today, off- and on-line disinformation is a growing, multi-faceted societal problem that cannot be addressed with simple solutions. Our decisions are highly influenced by (dis)information that is widely and easily accessible on digital and non-digital platforms which spans across all aspects of our life, such as medical, political, financial etc. Time and again, disinformation is well organized often with ample resources. The Internet and social media have enabled a revolution for disinformation. Furthermore, disinformation can be spread at astonishing speed, scale, with significant impact, and without borders. It is also extremely damaging and dangerous to our well-being and our society. Moreover, the consequence of disinformation can be growing distrust in information and unwillingness to share information [9,10]. While disinformation is in no way new its significance and spread has grown hugely in recent years. There is, therefore, an ever-increasing need to address the problems of disinformation, to understand its nature, characteristics, scale and its root causes.

In order to address the threat of disinformation, we need to understand what disinformation is so as to detect and deter its spread. In the Oxford English Dictionary, it is defined as *"the dissemination of deliberately false information"*. Fallis defined disinformation as *"misleading information that is intended to be (or at least foreseen to be) misleading"*. He proposed a conceptual analysis approach to clarify the concept of disinformation [7]. He identified a concise set of required and sufficient conditions that correctly determines if something in question falls under the concept. In the case of disinformation, he identified three necessary features of disinformation, namely:

1. it is a type of information;
2. it is a type of misleading information (likely to produce false belief), and;
3. it is no accident that is misleading.

All instances of disinformation must satisfy these three criteria.

In short, disinformation is misleading information that has the function to mislead.

2.0 UNDERSTANDING COMPLEX PROBLEMS

Military, legal, financial, healthcare systems, for example, are complex systems within our society which, in turn, a higher order system. Decision makers within such systems face the challenge of solving multi-faceted problems. The interactions within these systems and between these systems could result in situations that might be problematic within and between these systems and our society. Therefore, decision makers must be aware that a solution to address undesirable situations in one system or more (sub)systems should not result in further and more (or even bigger / wider) problems.

Real world problems are complex problems in complex situations. They are typically poorly defined and do not have a clearly defined set of means to reach "ill defined" goal states [14]. Indeed, problem solving in complex problems / situations such as disinformation required an in depth, appropriate and reliable understanding of the problem; Einstein said, "*If I had only one hour to save the world, I would spend fifty-five minutes defining the problem and only five minutes finding the solution.*".

In this paper, we discuss our framework for understanding complex systems, which combines the SA-OODA model (Endsley's Situational Awareness (SA) model [3] and OODA loop [16]) and the Iceberg model [18]. The SA-OODA model shows how we perceive and comprehend situations, project the future and decide and act on the resulting projection. The iceberg model provides a means to understand a system / situation from different layers. We also show how Visual Analytics helps to explore the context of disinformation in the information environment.

Under our framework, disinformation can be perceived at different system layers such as at the event, behaviour, or system structure layer. Depending on what has been perceived, decision makers need to be able to understand the causes of the problems, their underlying conditions, and the impact of the problems. In doing so, different understandings from different perspectives through different layers can be gained; and thence, hypotheses of future situations and appropriate solutions can be made. Furthermore, we also considered the appropriateness and reliability of the information perceived and its integration into the model.

2.1 Situational Awareness Model

What is situation awareness? In simple terms, it means being aware of ones surrounding. Endsley's work on situation awareness (SA) is an established model of SA, in particular for dynamic decision making in complex dynamic situations and systems [3].

"Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." [3].

Endsley considered there are three Levels of situation awareness, namely: (1) perception, (2) comprehension and (3) projection [3], see Figure 1. This links cognitive psychology with human factors in complex systems / situations to support informed decisions and act upon the decisions [4,5,6]. Endsley also considered SA as state of knowledge. In SA, decision makers must therefore understand that the integrated meaning of what they are seeing as their decision is governed by their understanding of the "whole" situation. Indeed, SA is the operator's internal model of the state of the environment, *i.e.* their mental model. This awareness must be accurate and complete [11]. Elements are "things" that the decision makers need to perceive and understand, which are specific to different systems, situations, and contexts. However, the decision-making process is not included in the SA model as Endsley considers them as two separate processes.

The first stage of achieving SA is to perceive the dynamics and the status of the attributes of all the relevant elements in the environment, such as observing disinformation events, their trends over a period of monitoring, the evidence that a change has occurred based on various measures. In the second stage, the disjointed elements perceived from Level 1 are synthesised / integrated to form a holistic picture of the environment, thus enabling comprehension of the significance of what has been perceived from, in our application, the disinformation events / trends. Therefore, in the second stage, the decision makers integrate the perceived disjoint events / trends into a whole picture, a mental model or external model to understand the relationships between the events and trends, the significance of the events and trends, and how they influence the desired state of the system, *i.e.*, in our application, the stability of our society. In the third stage, projecting future actions (Level 3), which is the highest level of SA, the decision makers through their knowledge of the status as well as the dynamics of the perceived elements (Level 1) and the resulting comprehension of the situation (Level 2), forecast future events, *i.e.* project the evolving situation into the future. The three Levels represent ascending levels of SA, *c.f.* linear stages. Level 3 forecasts are based on the assumptions that the perceived events, trends / patterns will remain unchanged, thus the forecast will only hold true if there is no change - otherwise it will be different.

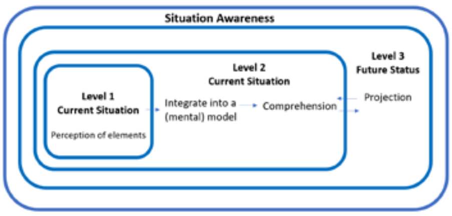


Figure 1: Concept of Situation Awareness according to Endsley [3]

2.2 Observe-Orient-Decide-Act (ODDA) Loop

US Air Force Colonel John Boyd proposed the Observe-Orient-Decide-Act (OODA) loop that represents the decision cycle of pilots in the Air Force environments [16], see Figure 2. It captures the continuous nature of C^2 (Command & Control). Furthermore, it provides a framework to support the identification and comparison of the four critical phases of both the enemy's and own decision cycle. Advantage over the enemy could be achieved if it results in a faster and better decision-making cycle. It is a simple control system that commences from observing the environment through orientation and decision and completes by acting upon the decision. The OODA loop is composed of four phases:-

1. **O**bserve: observe the surrounding and gathering information upon which decision and action are based.
2. **O**rient: understand and analyse the causal relationships and significance of the observed data in relation to one's situation and environment, *i.e.* connecting the dots.
3. **D**ecide: Decide on a course of action.
4. **A**ct: Act swiftly and decisively.

All four phases are interrelated and can overlap. From the observation phase, data / information is collected and then analysed and understood in the orientation phase. The decision makers then make their decision (upon which they act) based on what they know, their experience, training, prior knowledge, and intuition. Thus, if the OO phases are correct and accurate then the success of the DA phases follow.

Figure 2: OODA Loop

In the real-world situations and environments are constantly changing. OODA loop is a bottom-up sequential process. It does not take into consideration decision-making in complex and dynamic situations, *i.e.* feedback and feed-forward loops are not included in the loop to support dynamic decision making. The phases are not clearly defined. Work has been conducted to address the limitations and to suggest alternatives, extensions and modifications, but the original version is still widely used for its simplicity [2, 17]. It is applicable to the decision-making process in a wide range of other applications and domains.

2.3 SA-OODA Loop

Endsley's SA model is concerned with understanding the situation rather decision making. It is considered to be the operator's internal model of the state of the environment. While there are many factors that contribute to the decision-making process, SA is an important state preceding the decision-making process. Endsley pointed out that it is possible to make a wrong decision even with the perfect SA and equally it is also possible to make the correct decision with bad SA. In general, however, decision-making process benefits from good SA. Endsley stressed the importance of SA in the decision-making process, in particular taking into account SA in the process. Although there is a strong connection between SA and decision making, Endsley states that the two processes should be treated independently of each other. The OODA loop, by contrast, is a bottom-up sequential approach, it does not represent the dynamic and complex situations.

The two model complement each other and there are shared elements between them [2,16]. The Observe phase in OODA corresponds with Endsley's Level 1 Perception. While the Orient phase can be characterized by Level 2 Comprehension and Level 3 Projection. Incorporating SA Levels into the OODA loop enhances the OODA model with the temporal elements for decision-making in complex dynamic situations / problems providing for example a clearly defined process for the Orient phase. This allows the SA model to be integrated into the decision-making process, *c.f.* separate and independent processes.

Figure 3 shows the combine Endsley's SA model with the OODA loop to integrate SA into the decision-making process, thus providing a dynamic temporal decision making process that includes SA in its process – the SA-ODDA loop.

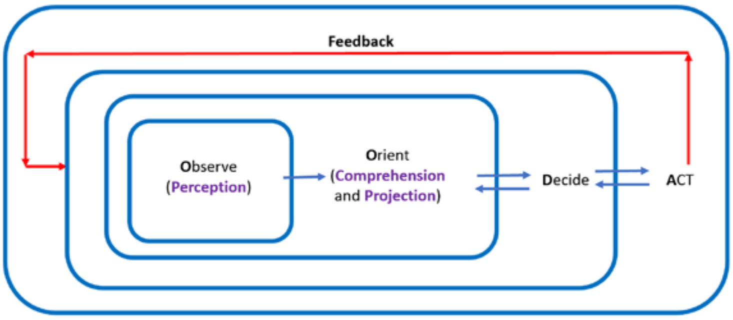


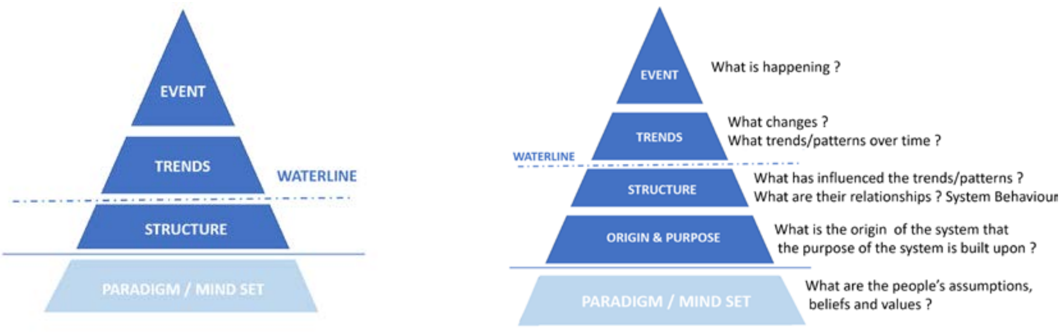
Figure 3: SA-OODA

3 ENHANCED ICEBERG MODEL

System thinking is concerned with how the various elements in a system interact and influence each other, *i.e.* system as a whole and not isolated individual elements [1, 12, 13]. In system thinking the whole is greater than the sum of its parts; the property of the whole, not the property of the parts. The product of interactions, not the sum of actions of the parts. Senge defines system thinking as " …discipline for *seeing wholes, it is a framework for seeing inter-relationships rather than things, for seeing patterns of change rather than statics snapshots*" [18]. The Iceberg model is a system thinking model that provides an effective means of understanding the origin of a problem, *i.e.* root cause through different layers in a system [18].

Figure 4 (a) shows a tradition Iceberg model with four layers. The top layer, the event layer is sometimes referred to as the tip of the Iceberg. In this layer, events (disinformation) which are the outcomes of the system can be observed at any specific time, *i.e.* what is happening. The next layer down is the trends layer, this layer refers to the changes we can observe over a period to detect patterns or trends that characterise the disinformation events. This in turn shows the behaviour of the system, how it functions and is organised, and the underlying structure of the system, *i.e.* the structure layer which the next layer down and is referred to as below the waterline. Thus, the events and trends are governed by the system structure, and they are interrelated. In a previous paper [21] we introduced an additional layer, namely Origin and Purpose. From knowledge of the origin, certain assumption can be made about the purpose and certain structural characteristics. According to Meadows: *"The least obvious part of the system, its function or purpose, is often the most crucial determinant of system's behavior."* [12]. The purpose of the system is achieved through the structure and organisation of the system and its resulting behaviour. The assumptions about the purpose of the system and its structural characteristics can be made based on its origin, Figure 4(b). Some Iceberg models also include a paradigm / mind set or a mental model which represents the underlying assumptions of the people based on their attitudes, beliefs (paradigm), expectations, experience, training, and values that influence (mostly subconscious) both the creation and their perception of a system [22, 23]. It is therefore important for the observers to be mindful of the view through which they see a problem, and if it is indeed appropriate for the system.

In summary, the Iceberg model provides an effective means not simply to react to a problem (based on observing visible events), but for going into further / deeper layers to unravel the reasons (purpose) that caused the problem to exist in the first place, through understanding the trends, behaviour and structure of the systems.



(a) (b)

Figure 4: (a) Iceberg model and (b) Enhanced Iceberg Model [22]

4. PROBLEM SOLVING FRAMEWORK AND SYSTEM TAXONOMY

"*Problems cannot be solved with the same mindset that created them*" Albert Einstein

In order to develop a solution to a problem we first need to understand the problem. In the SA-OODA loop the perception and integration of elements into a model (mental / external) leads to the comprehension of the situation / problem then decision and action. While in the Iceberg model different aspects of the situation or system can be perceived and understood through different layers of the system. In this section we introduce our Framework that combine the two models to provide an improved understanding of problems / situations.

4.1 Understanding Events and Trends

In this section we discuss events and trends and their roles in the SA-OODA and Iceberg models. In level one of the SA-OODA model, decision makers see what is happening by perceiving disinformation events and identifying changes by trends or patterns of events, *i.e.* the events and trends layer in the Iceberg model. At the second comprehension level (Orient Phase), the decision makers integrate the perceived information into a holistic representation, a mental model or external model to understand the relationships between the events and trends, how they affect the originally desired states of the system. While in level 3 (Orient Phase) decision makers make forecasts about future, *i.e.* projection. The projections are based on the assumptions that perceived events and trends which are incorporated into the understanding of the situation / problem will remain unchanged. The resulting decisions (solutions) and actions (implementation of the solutions) are based on the SA.

4.2 Why Events and Trends - Structural, Origin & Purpose

In this section we explore the reasons why events and trends happen. The decision makers at the first level of SA-OODA identify what (sub)systems are involved in the perceived events, such as their origin, purpose, structure and organization. The perceived information is then integrated into a model to understand:-

(1) What do the systems do?
(2) How do they work?
(3) What are the structure and organization that give rise to the behaviour?
(4) What purpose do they serve?
(5) What is the explanation of the events and trends?

In answering these questions, the decision makers can predict the future system behaviour, thus the expected events, *i.e.* projection in the orient phase. The appropriateness and reliability of the prediction is dependent on the appropriateness and reliability of the model.

4.3 Appropriateness and Reliability of Understanding

The appropriateness and reliability of the perceived and integrated information in a model are dependent on whether it supports the decision makers in answering their questions and whether it corresponds to reality. The reality of the perceived and integrated information is dependent on its completeness and certainty. In short to understand the effects of a problem such as disinformation, an appropriate model should correspond to the disinformation events and trends and their relationship. The reliability of the information collected depends on how complete the collection of information is and whether it is reliable, objective and can be validated, *i.e.* certainty and value. To this end, we propose the collection of background data or information, its evaluation in terms of its appropriateness, credibility and reliability. In NATO, under the Admiralty Code, information is assessed on two dimensions, namely, the source reliability, and information credibility. It assesses the information based on whether the information comes from a reliable source and whether the information is credible [15]. The reliability of the source is based on a technical assessment of its capability, or in the case of Human Intelligence sources, their history, track records *etc*. It is assessed on a scale of five categories: completely reliable, usually reliable, fairly reliable, usually reliable to unreliable. The credibility of the information is based on the likelihood and degree of corroboration by other sources: this ranges from completely credible, probably true, possibly true, through doubtful to improbable. This helps the decision makers understand the degree of reliability of the information source and the credibility of the information. These two factors will support decision-making based on the appropriateness and reliability of the information. It is recommended that reliability and credibility should be considered independently, *i.e.* reliability should not impact credibility and vice versa (C2, for example, is usually a reliable source and probably true). We propose the extension of this by adding the assessment of relevance to the problem, see Table 1.

Table 1: Reliability, Credibility and Relevance, adapted from [14]

	Reliability of the collection capability		Credibility of the Information		Relevance
A	Completely reliable	1	Completely credible	I	Completely relevant
B	Usually reliable	2	Probably true	II	Probably relevant
C	Fairly reliable	3	Possibly true	III	Possibly relevant
D	Not usually reliable	4	Doubtful	IV	Slightly relevant
E	Unreliable	5	Improbable	V	Irrelevant
F	Reliability can not be judged	6	Truth cannot be judged	VI	Undecided

To understand the underlying cause(s) of a problem, an appropriate model should represent the purpose(s), structure and organization of the real system(s) as observed. The perception is dependent on the (in)transparency of the system characteristics to the observer which is influenced by certain characteristics of the real system and on the fundamental paradigm and mind set of the observer, and, if it indeed depicts the real system. However, inappropriate underlying assumptions or beliefs about the systems may result in perception of characteristics that differ from reality.

4.4 System characteristics

In a previous paper we proposed a framework for problem understanding at different system layers including a system taxonomy to support decision makers in appropriately perceiving the structure of a real system [22]. In this paper we adapt our framework by combining the SA model and the OODA loop in our framework , see Figure 5. This shows systems can have different structural properties which lead to different system's behaviour and, also different analysability. In terms of the behaviour structure, systems can be open or closed, *i.e.* whether or not they interact with the environment outside the system respectively. If there is an interaction with the external environment or system(s), these must be included in the model to support the understanding of the system behaviour and resultant events. Subsystems are generally hierarchical, so when viewed at higher level, it is a subsystem perhaps with other subsystems within a higher-level system. When zooming into a sub-system it becomes a higher-level system perhaps with its own subsystem(s). There are also different relationships which range from simple trivial linear relationships (which are repeatable and independent of the past) to components in non-trivial systems which are inter-related/interdependent and / or with feedback loops. The latter are past dependent, *i.e.* the state or behaviour of one or more elements or (sub)systems affect the state or behaviour of one or more elements (sub)systems and vice versa. Systems can have static or dynamic structure. Structurally static systems can still have dynamic behaviour. Structurally dynamic systems on the other hand can adapt to changes both within and outside the system, *e.g.* selforganization [19]: sometimes referred to as the identity paradox, that is "if you want to stay the same, you have to change".

If the structure and organization of the systems are transparent then the observers can analyse the systems. If they are partial transparent then it is not completely analysable. The extent of transparency to an observer influences how completely a system can be captured and understood, this has bearing on the reliability of the model, which in turn impacts the resulting understanding and predictions. The knowledge of the origin and purpose supports the understanding of the structure, organization and the resultant behaviour of the system.

There are simple, complicated and complex systems [19]. Simple and complicated systems (shown in pink in Figure 5) have closed, trivial and static structure with a linear, repeatable, and past-independent behaviour. They differ in the number of system elements and relationships. Complex systems, on the other hand, have an open, non-trivial and dynamic structure, and this is likely to be the case for disinformation. They are also non-linear, past dependent, dynamic and some also have emergent behaviour. Their structural properties are partly (in)transparent for the observed (unknown unknowns) [19]. Thus, the model of the systems is incomplete and erroneous which leads to incomplete and incorrect understanding of the problems and with highly uncertain predictions.

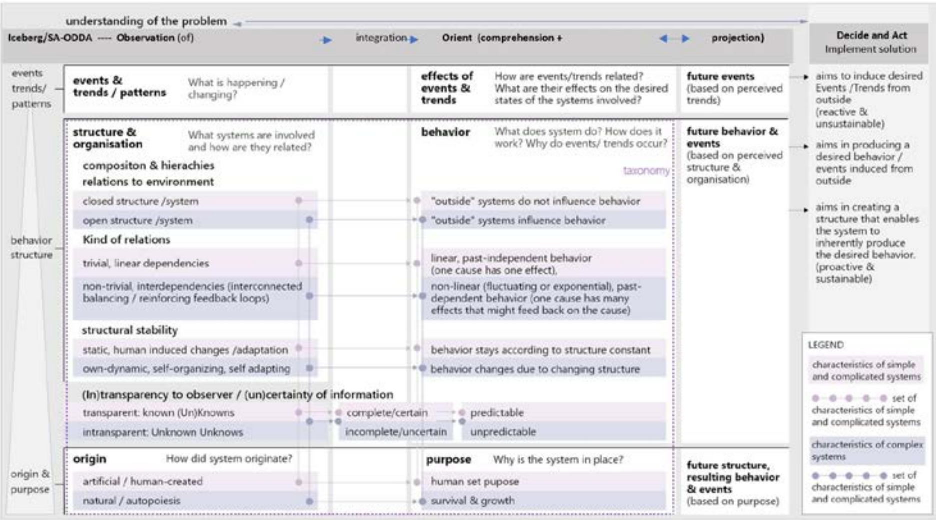


Figure 5: Framework for understanding problems on different system layers adapted from [19]

5.0 EXPLORING THE CONEXT OF (DIS)INFORMATION IN SOCIAL MEDIA

Mostly, disinformation in social media is not hidden and it is not the task of finding the needle in a haystack. Disinformation is aiming to have an impact and to influence the opinion of people and therefore profiteers of disinformation trigger mechanisms to facilitate and enhance its dissemination.

Often disinformation is not directly generated by its profiteers themselves, but is discovered by them, evaluated in terms of its value to their own narrative, and then further supported in its dissemination. One medium where disinformation is preferably disseminated are social media platforms, like *e.g.* twitter. Twitter sees itself as a short message service and classifies what is posted as public. The Twitter API allows content to be retrieved on a keyword basis and for individual users continuously in a stream. This makes Twitter very interesting for studies on dissemination mechanisms in social media.

From a systemic viewpoint there are three structural characteristics of twitter that shape dissemination of information:

1. Easy tagging of content with hashtags
2. Users are linked by simple follower relations
3. AI-generated Newsfeeds

Hashtags is a phenomenon that was popularised by twitter and actually developed into a kind of self-organizing mechanism, and users started deliberately using the #-character to make content searchable by tags. Hashtags are often used to communicate the context of a message [20]. Often new hashtags are created / invented to put a message in the context of current events and clearly indicating an opinion (*e.g.* #armukrainenow, #putinspuppet). In this way, clearly identifiable new trends emerge on Twitter alongside the background noise of content-related common hashtags. The newsfeed of a user is mainly determined by the activities of users he is linked to as a follower. Following a user on Twitter can have different motivations. It could be that you like the content or that you want to keep up to date with what the other side is saying about current topics. Designating the link as "follow" encourages both.

There are different activities, or different ways in which users can respond to the content of others. First users can write a short text with embedded media from scratch, but users can also use contributions from other users and comment, quote, retweet or simply like it. Normally, users follow many other users that an algorithm makes a selection of which activities from their own follower list are included in the newsfeed. Details of the algorithm is not publicly available, but in general content you interacted most in the past will be considered in calculating the ranking of new content for your newsfeed. Most common is to retweet content, and it will show up likely in the newsfeed of your followers. Since you are not adding any new content to it, it will be perceived that you agree with the content. It is different when commenting on or quoting a tweet, then it can mean both agreement and disagreement, which is made clear by your own additional contribution. For commenting and quoting, one has a different target group in one's sights. If you comment, you usually want to communicate something to the author and the users interested in the tweet, if you quote a tweet, the addressees are more likely to be your own followers.

The exploitation of these structural features helps to understand the context of trends in twitter. Figure 6 shows the interface of NewsHawk® [25] a tool specialized for monitoring and exploring Tweets based on ones specified list of keywords.

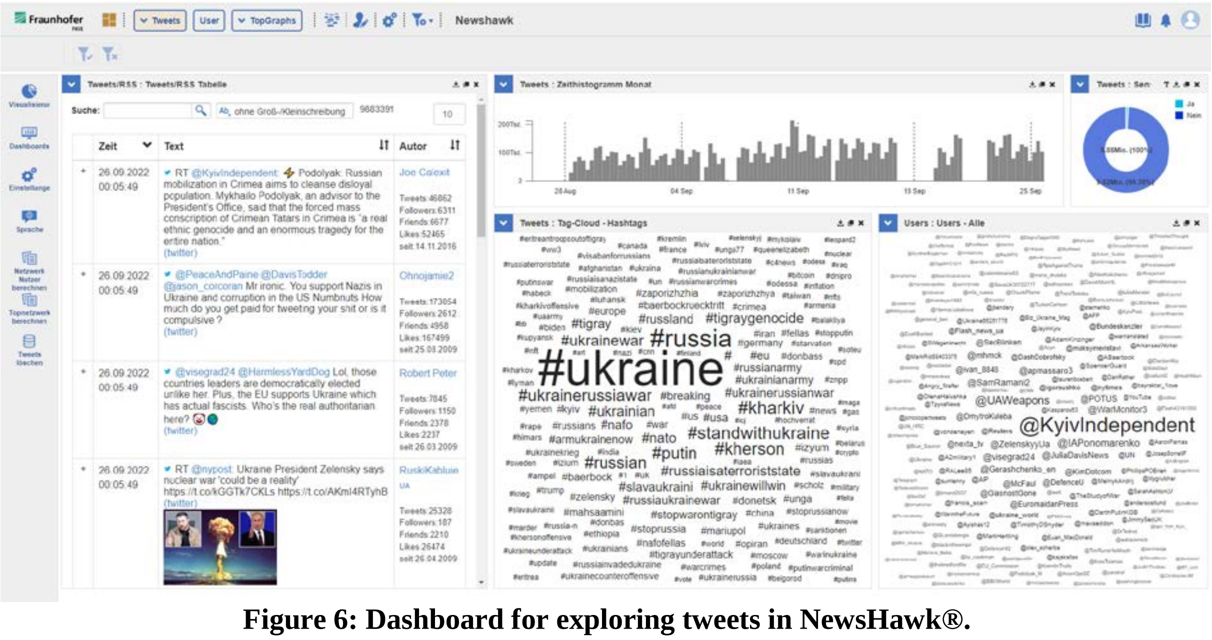


Figure 6: Dashboard for exploring tweets in NewsHawk®.

In the main dashboard site, there are different widgets that give an overview on statistics of the tweets in the database, that has been collected based on a list of keywords and a list of users to follow. By selecting items within the visualizations, all visualizations will be filtered based on the selected items, *e.g.* hashtags or users. The visualizations of the widgets can be switched by dropdown menus. In this way, users can easily create different combinations of visualizations within the dashboard to make drill down operations from different perspectives. The visualizations from which the users can choose in the dropdowns are:

- Wordclouds of Hashtags, searchkeys, general keywords
- Userclouds of authors, retweets, mentions, quotes
- Top-lists of: retweets, quotes, comments, media, shared urls
- Trends of hashtags
- Histograms on creation date of tweet, user account creations dates, number likes and followers of users.

To show a top quoted tweet, the most popular tweets that quoted the tweets by number of retweets, you can choose one visualization for the top retweets and one with the top quotes. By selecting one tweet from the table of the most quoted tweets, the table of top retweets shows the tweets most retweeted that quoted the selected tweet. To examine the accounts' creation date of users that contributed most to a specific topic, you choose a histogram on accounts' creation dates and select a hashtag for a topic from the hashtag-cloud. Many recently created accounts are suspicious.

For the context of specific topics, it might also be useful to see the activity patterns in a graph as it is shown in Figure 7. Each node represents a user. The number of interactions recorded for this user for this topic scales its size. The colors of the links indicate the activity type, if it is a retweet, a comment (responded_to), a quotation or a mention. In the graph, clear patterns can be identified, *e.g.* clusters of mentions. The graph can be filtered on users and link types.

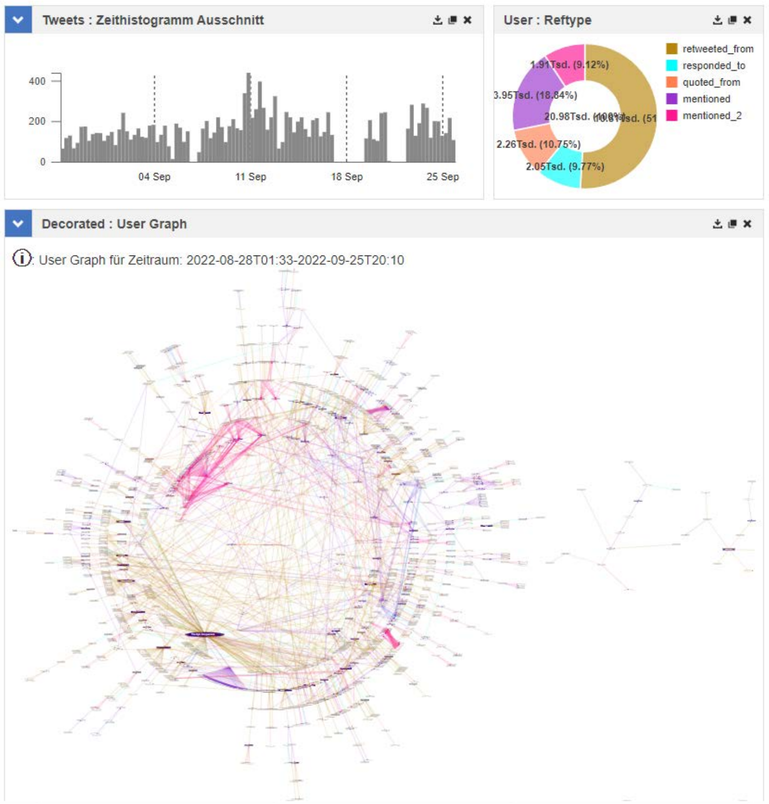


Figure 7: Dashboard for exploring tweets in NewsHawk®.

Filtered on the link type of retweets shows more clearly the top users who have retweeted, and which users retweeting them and what they have in common. In this way, you can see the different camps and what the most influential accounts are. This graph only contains the users, but not the content, also the graph will become too big if all users are shown, so it only contains the most influential ones. By selecting users in the graph, the associated activities can be displayed directly.

To show the correlations and the progression of content over time, graphs as shown in Figure 8 can be computed. It shows the top 100 retweets as nodes whose size scales with the number of retweets. The retweets are connected with edges if both retweets were retweeted by a certain percentage of common users. The layout is hierarchical with horizontal layers for the time slices. It has been shown that in this way, the different camps become even more apparent.

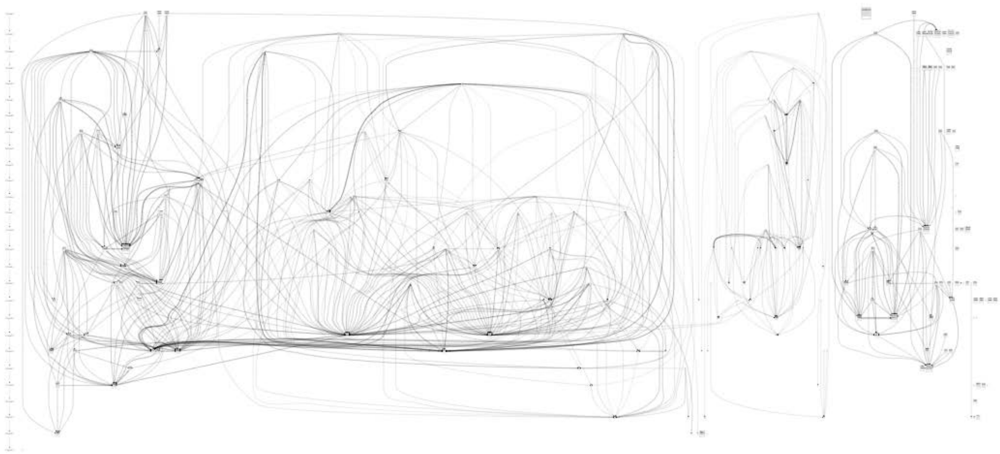


Figure 8: Top Retweets linked by common set of users.

In the same sense, user networks can also be calculated not based on activities but on shared content, as shown in Figure 9. Here, each node is again a user. Two users are then connected with an edge if they frequently retweet the same content. Again, this often reveals interesting patterns that can be analyzed further.

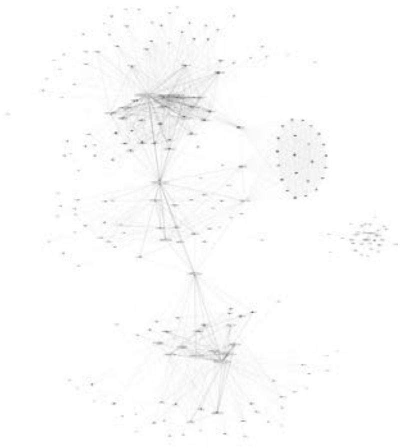


Figure 9: Pattern a graph of users linked by common retweets

6.0 CONCLUSIONS

Problem solving in complex situations, such as disinformation, depends on an appropriate and reliable understanding of the problem. A framework has been proposed to show problems can be perceived as events and trends or within system structures. Events and trends can provide an understanding of their inter-relationship and their impact on the desired state of an affected system. Solutions based merely on the events and / or trends are usually reactive and not sustainable, *i.e.* treating the symptoms not the cause. However, the use of system structure provides an effective means to understand what the system does, how it works, reveal the underlying causes and conditions that leads to the perceived behaviour and resulting events and trends. Solutions derived from this understanding tend to be more proactive and sustainable; they will also tend to produce structure(s) that have the desire behaviour and outcomes (events). The appropriateness of the perceived and integrated information is dependent on whether they assist the decision makers in answering their questions, and if they relate to reality. The reliability, credibility and relevance of the gathered information thus play a crucial role in understanding the problems and building the model. The perception of the system structure is governed by the mindset of the observer and the degree of transparency of the real systems. The system taxonomy within our framework summarizes the relevant structural behaviour of different types of systems, namely simple, complicated and complex systems and the characteristics of their resulting behaviour as well as their impact on the (in)transparency of the structural information and hence the (in)completeness in the models and the associated (un)certainty of the predicting behaviour.

In the case of visual analytics in the Iceberg model of systems thinking: If one wants to tackle the problem of disinformation on the lower levels of the Iceberg, *i.e.* structure and mental model, the following two options come into mind, respectively

- Structural level → redesign of dissemination mechanisms in social media, especially in the algorithms generating the personalized newsfeed of the user.
- Mental Model → Disinformation awareness/competencies of the users.

First steps have already been taken during the Covid-pandemic. On Facebook every post on Covid has been extended with links to official sites. This is clearly a measure at the structural level and therefore probably also falls short. It is often perceived by users as paternalism and therefore often achieves the opposite. Measures at the mental level of the users would be more far-reaching. They require the promotion of users' skills in dealing with social media, *e.g.*, understanding the distribution mechanisms and questioning the content presented in their newsfeed (*Why is this being displayed to me*?). In this sense, functionality of NewsHawk® could be made available to the public in a user-friendly form. “Health”-metrics for their follower network could be calculated and presented to the user, gamification design could motivate users to keep their information bubble healthy and to explore their follower network on its own.

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