Abstract — Modern society offers us many ways to socially interact with friends, colleagues, co-workers, etc. In this scenario, our social networks are in constantly changing and interests, objectives, and other things involved in each social interaction can be affected or even remain out of reach. For each change, the social network has to be re-analyzed to show us if the interests and objectives can still be attained. Each analysis carries its own variables, relevant information, contexts and difficulties, and this new analysis can be expensive for a Human entity. We argue that autonomic computing could help with the analysis and in decision-making, transforming the network into an autonomic social network: intelligent networks capable of analyzing themselves and suggesting actions to individuals or computational systems towards attaining one or more set goals.

Autonomic Social Networks; Social Network Analysis; Social Network; Autonomic Computing

I. INTRODUCTION

People are social creatures. We live in a full-throttle society as regards the ease of social interactions between individuals: assorted communication technologies, shorter physical distances based on better transport systems and means of communication.

Amongst these many possibilities, the Web has had a very important role. Erétéo et al. [1] consider the Web as the major means of communication currently in society and, consequently, an element of socialization. With the emergence of several websites that use the concept (Orkut, MySpace, FaceBook, Flickr, etc.), social networks are becoming increasingly present in Human life. They provide ways to share, organize, and select common contents, contacts, interests, and so on, and leave us a very interesting medium that can be used to study the behaviour of these relationships: data. Due to their intense use, these tools form a rich source of materials that allows the study of the characteristics of social networks, their interaction patterns, and construction. The study of such networks is one of the greatest challenges in the Knowledge Sciences [1].

However, notwithstanding the existence or absence of the technology to support social networks, we can see many social networks in our daily routines: friendship, neighbours, courtship, co-workers, the Academy, language courses and so on. This variety shows how wide the amount of existing social networks is, of which we are part even without noticing it. This produces a sizeable problem: complexity.

In a general way, if we contextualize ourselves in our several social networks, we could act towards their improvement to avoid and to deal with countless problems or unpleasant situations that may happen. Besides dealing with unpleasant situations, we could work in favour of opportunities that might arise.

People become unemployed, retire, are promoted, companies merge, deaths happen, new friendships, romance ensues, and much more. All of these situations can cause positive or negative effects in the social networks we are components of. Once we can map and study the social networks, it allows us to identify and address issues more easily as we gain a vision of situations that are not always clear to Human cognition [2]. However, to identify such situations, it is important that a study of our networks be done and the techniques of social network are analyzed, to make up an adequate toolkit for the task at hand.

The notion of social network and their related methods of analysis have been studied in recent decades. One of the main motivating factors is the analysis of relationships between social entities in various domains of application: terrorist networks [3][4], education [5], scientific social network analysis [6][7][8][9], marketing strategies [10], medicine and epidemics prevention [11][12][13][14][7][15], amongst other areas.

Every day, new applications and studies are produced in many different fields of Human knowledge. Each study has its own variables, relevant information, contexts, and difficulties.

Social networks are not static entities, i.e., they are living entities and undergo constant change. Examples of such change involve the entry or exit of social entities in/from the network, relationships that become weak or strong, relationships that are created or cease to exist, etc. With each new change experienced by the social network under study, other studies should be made, new variables be considered and new inferences be made and, with the growth of available data, the analysis of social networks becomes increasingly complex. For each change, depending on the analysis outcome, steps should or could be taken or suggested to those entitled to take them.

Today, such attitudes are defined based on the analysis done by one or more specialists. These analyses are made based on the knowledge one has on the area and that generally is not available to a non-expert. Thus, this individual sometimes cannot make a decision or, when one can, one
cannot make it in the better manner or, in failing to see the consequences a change to their network can produce, or not having enough knowledge on the social network for its decision. In short, there is a lack of automatic support for the analysis and decision-making in social networks.

A. Motivation

The complexity of social network analysis, often escapes Human cognition, even with the use of computational tools Human: we are not always able to handle such complexity. We need mechanisms to monitor the growth, mutation, and synergy of the social networks in a more automatic and as proactively as possible, to help us work more directly in decision-making, doing so automatically at times and, at others, showing the scenario to the social entity to facilitate decision-making by minimizing Human interference in the analysis. In order to facilitate decision-making by minimizing Human interference in the analysis, we use Autonomic Computing (AC).

Autonomic Computing is an approach to manage computer systems that aims at the minimum use of Human interference and seeks to deal with the complexity of current computer systems.

B. Proposal

The aid of autonomic computing is done through agents that monitor the states of the social network and make decisions to help it achieve the objective it was mapped for. This decision-making is based on rules that must be entered by domain experts. Such rules are processed and the autonomic system can then suggest actions based on the context of the social network.

The use of autonomic agents in the social network is done to make it as efficient as possible, by trying to find and prevent problems and find solutions. In addition to finding problems, it is expected that, with the aid of autonomic computing, there may be a discovery and exploitation of opportunities that allow such relationships.

C. Organization

This paper is organized as follows: Section Two provides a discussion of social network analysis. Section Three addresses Autonomic Computing in more detail. Section Four is devoted entirely to what we call Autonomic Social Networks. Section Five shows our findings on Autonomic Social Network Analysis. And, finally, Section Six offers conclusions and paths for future work.

II. Social Network Analysis

Social networks are alive and present in our everyday lives: we can see people lose their jobs, retire, be promoted, die, win new friends, date, marry, etc. In this context, if we can identify what the social networks are, which we participate in, directly or indirectly (work, study, courses, etc.) and our role in them, we can handle many potential problems and optimize certain situations, such as, for example, searching for a new job [16]. Therefore, analyzing social networks becomes a necessity.

The analysis of social networks consists primarily of identifying social entities and relationships between them and then scanning for situations that normally are not directly shown, such as, for example, formation problems. Social Network Analysis (SNA) can be considered as a set of methods (theoretical and statistical graphs) and tools used to code and analyze social networks and their relationships [13][17], being used in several research fields. Examples of information suitable for analysis include family relationships, social roles (boss of, friend of), actions (dinner with), affective relationships (love, hate), material exchanges (commercial transactions), common behaviors (use of the same clothes) [5].

During the analysis of social networks it is important to have an efficient mechanism to display information from the network. The importance of using a form of representation of the activities in social network analysis can be justified in terms of their own Human cognitive abilities, as social networks are constantly evolving: new information is constantly collected and stored, the network grows at each new contact, etc. Consequently, the complexity of semantic interpretation of the network grows [6].

The first analytical representations of social networks were called Sociograms [18]. In these representations, people were represented by points and relationships by lines connecting them. From sociograms, one could develop a collection of methods, measures and tools, used for the description and analysis of social networks and social structures [19][20][21].

Subsequently, the analysis of social networks began using the notation of graphs to represent them and went to use such theories as a basis and mechanism to facilitate analysis. This type of representation is appropriate for the representation of social networks, as social networks can provide connections from sparse domains, as in trees, until very dense connections, such as in Web networks [6]. The analysis of the graph structure obtained from a social network and the statistical analysis of the specific attributes of nodes can show the analyst individuals, relationships, and clusters of key individuals within the network.

Since then, the analysis of a social network has become an analytical approach with its own theoretical statements and research methods ranging from the whole to the part, from the structure of relations to individuals, from behaviour to attitude. This analysis includes the network as a whole, with all the links containing specific relationships in a defined population, or as personal networks, with links that specific people have, such as their personal communities [16].

In general, there are two main forms of evaluation and study of a social network: the egocentric and sociocentric [22]. In the sociocentric analysis, social networks are studied with an emphasis on all the social entities of the network and possible sub-networks. In this type of analysis the focus is on the structural analysis and social group interaction [23]. In the egocentric case, the focus of the analysis is placed only on one actor in the network. In this case, the focus of the analysis is the social role an individual has in relation to one’s position in the network.

III. Autonomic Computing

Autonomic computing is an approach to manage computing systems that aims at using minimal Human interference [24].

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It emerged as an approach that seeks to deal with current computing systems: increasingly complex and difficult to operate.

As [25] points, the computer industry has spent decades creating increasingly complex systems and, because of that, today, complexity itself is the present problem as the growth inhibits the benefits Information Technology can bring us.

Such difficulty stems from the complexity of their own IT components and their relationships with other components in computer systems, whether they are hardware or software [26]. This situation is further aggravated if we think that, as computer systems evolve into network systems and fully distributed domains, hardware, software or Human failures contribute significantly to system unavailability and prevent their administration. Thus, operating an IT infrastructure is becoming increasingly challenging for IT professionals.

Irving Wladawsky-Berger outlined the solution in an event in November 2001[27] when he said [25]: ‘There is only one answer: Technology needs to manage itself. [...] So that instead of technology behaving in its usual pedantic way and requiring a Human being to do everything for it, it starts behaving more like the ‘intelligent’ computer we all expect it to be, and starts taking care of its own needs. If it doesn’t feel well, it does something. If someone is attacking it, the system recognizes it and deals with the attack. If it needs more computing power, it just goes and gets it, and it doesn’t keep looking for Human beings to step in’.

To deal with these difficulties, autonomic computing sought its inspiration in the autonomic functions of the Human body [28][26][29]. For example, the central nervous system of an individual acts without the need of a conscious activation by a person. It takes care of the vital functions of our body (such as body temperature, blood pressure, etc.) in a way consistent with the various external conditions, prepares the body to execute the activities of the moment, keeps the internal state constant, amongst many other functions.

An example is the work of the central nervous system: it controls the speed with which the heart beats, checks oxygen and blood sugar levels, controls the pupil to regulate the amounts of light, monitors body temperature, breakfast processing, adjusts the breathing rhythm, amongst others.

A. Autonomic System Elements

An autonomic system can be described as having eight key elements or characteristics [28][30][31]: (i) self-knowledge: an autonomic system needs detailed knowledge of itself and that consists of components that have an identity in the system; (ii) self-configuration: an autonomic system should be able to configure and, if needed, reconfigure itself in changing or even unpredictable conditions; (iii) self-optimization: an autonomic system should always try to improve the search for ways to optimize its work; (iv) self-healing: an autonomic system should be able to recover itself from routines and events that may cause malfunction, discovering problems, finding ways to use its resources, or reconfiguring itself while remaining functional; (v) self-protection: an autonomic system should detect and identify threats, protecting itself against attacks and maintaining its integrity and security; (vi) knowledge of its context and environment: an autonomic system should know the environment and context surrounding its activities and act according to them; (vii) it should not be in an proprietary environment: an autonomic computing system should operate in a heterogeneous world and implement open standards, being able to better interact with the various systems; and (viii) it should anticipate optimizations whilst hiding complexity: an autonomic system should not disclose its complexities to its users.

As Miller [32] points, the properties of self-configuring, self-healing, self-optimization, and self-protection are considered basic goals of an autonomic system, and the other ones refer to the way in which the autonomic system will achieve those goals. The basic goals are known as Self-CHOP (self-configuring, self-healing, self-optimizing, and self-protecting).

B. Architecture of an Autonomic System

The architecture of an autonomic system consists of a collection of interactive autonomic elements [33], Autonomic elements can be seen as individual components of a system that contain resources and provide services to Humans or other elements having autonomic behaviour governed by a set of rules defined by a Human or other autonomic element(s). Each autonomic element is responsible for managing its own internal state and behaviour as well as its interactions with other elements that make up the autonomic system.

An autonomic element consists of one or more managed elements and a single autonomic manager that manages and controls the managed elements (Figure 1). In an autonomic system, a managed element can be, for example, hardware or software, a legacy system, an application server, or even individual businesses.

The autonomic manager monitors the managed elements and their external environment, planning and executing actions based on its analysis. This management is achieved through a loop controller known as MAPE-K autonomic loop [34][26][33] described below in greater detail. With the help of this loop, an autonomic system frees Humans from the responsibility of handling the managed elements.

The autonomic loop MAPE-K is used in four major operations: monitoring, analyzing, planning, and executing. All these operations run taking into account the knowledge the autonomic element has of the environment and itself.

The monitoring operation is responsible for collecting details of the managed elements (topological information, metrics, configuration properties, etc.). From the data collected, the monitoring operation tests and determines whether the data collected can be categorized as symptoms that could be examined by the autonomic manager through the analysis operation.

This analysis operation should provide a formal analysis to determine if the symptoms identified by the monitoring operation require some type of action. This operation model often entails complex behaviour (which may involve time analysis, predictions, etc.) that helps the autonomic manager to learn on its environment and, with the results of decisions
made, enables the prediction of future behaviour. To this end, the autonomic manager should have reasoning mechanisms that can be used to store knowledge and also to generate knowledge through learned lessons. Once the symptom is assessed and after it is decided if there is a need to do something about it, the analysis operation relays the necessary changes to the planning operation.

Figure 1 - Autonomic System Structure (adapted from [33])

The planning operation, as its name suggests, seeks to plan how to best carry out the transaction at hand. This selection can only forward the required change to perform or execute a complex workflow of choice on how to best implement the desired changes.

The execution operation is responsible for the execution of the desired changes sought by the analysis operation whose best run was plotted by the planning operation. The action execution may involve the need to change the status of one or more managed elements (for example, perform a lock on the element) and may involve the need to execute one or more actions. These actions are reflected on the managed elements via an effectors interface. This interface allows changes to be made to the managed elements.

The operations mentioned above make their decisions based on shared data stored as knowledge. Examples of information that can make the knowledge base used by managers include autonomic logs, databases, cases, metrics, rules, and others.

IV. AUTONOMIC SOCIAL NETWORKS

With its self-configuring, self-healing, self-optimizing and self-protection properties, autonomic computing is meeting the needs of a more dynamic analysis of social networks. These properties are enabled to each new relevant event that occurs in the system that incorporates autonomic computing. Once activated, they analyze the event and may or may not produce any action.

In this sense, making our various social networks more active to attain one or several goals is an interesting idea, and embeds autonomic features in social networks in order to automate their analysis, to help in our work within them.

Making the social network autonomic consists of embedding intelligence in the social networks and causing it to monitor its condition and environment for the goals set by the individual, making it capable of self-configuring, self-healing, self-optimizing and self-protecting in the situations it may face.

Social networks could monitor events or situations of interest through rules and metrics, analyzing such events and situations based on preset rules, deciding on the best action (if any) to be taken for each recorded event, and then acting on the social network. This action does not mean that social networking will, for example, create new relationships for the individual, but, rather, it may suggest certain actions to the individual, warning about one of a range of possible problems, risks, positive or negative, and finally, on different situations of interest. All of this is done to improve social network design in order to attain its objectives.

Formally, we define autonomic social networks as intelligent networks capable of self-analysis and that can suggest actions to an individual or computer system that owns it, in order to attain one or more defined goals. (Figure 2).

Figure 2 - Autonomic Social Networks Schema

A. Autonomic System Architecture Elements Applied to Social Networks

1) Monitorable Events in Social Networks

Events that may occur in a social network can be monitored for different reasons and, depending on the objectives to be achieved with a social network, these events may be desirable, undesirable, or neutral. Desirable events are those where there is some interest in that to happen, and may lead to situations that facilitate the attaining of the objective proposed in mapping it. Conversely, events can lead to undesirable situations that deviate the social network from your goal. Since neutral events do not interfere at all in the purpose of mapping the social network, they can usually be ignored.

Below are some examples of monitorable events found in social networks.
• Entry of Social Entities: As the name suggests, the entry of new social entities in the network occurs when a new social entity enters it. This event can lead to, for example, an unbalance in the social network;

• Exit of Social Entities: The exiting of entities from the social network occurs when a person leaves the social network (by reason of death, breaks, retirement, etc.). This event can affect the communication between the elements of a social entity or entities, or isolated groups;

• Relationship Creation: Occurs when a new relationship is established between entities in the social network. The creation of new relationships between the entities of a social network can lead to an increase in the minimum distance between points of contact in the network which may be undesirable when one wishes to maintain a cohesive network;

• Elimination of Relationships: Occurs when a relationship no longer exists between certain entities in a social network. When this occurs bonds are broken and it can lead organizations or groups to disconnect from other network entities;

• Strengthening of Relationships: Occurs when one notices a strengthening of the relationship between two entities in the social network. This relationship may represent the strengthening of trade between two nations of the planet or even the strengthening of two nations of the ‘axis of evil’;

• Weakening of Relationships: Occurs when one notices a weakening in the relationship between two entities of the social network. In the case of a decline of a relationship between two companies, it may mean a business operation decrease between them.

The classification of events as desirable, undesirable, and neutral will vary from one scenario to the other. For example, the entry of social entities may be desirable in a social network that contains the fans of a certain football team and may be undesirable in the social network its biggest rival team dwells in.

The events presented here are generic events that can be considered in any social network analysis application. However, applications for specific domains can consider the existence of numerous other monitorable events. For example, in the domain of distance education, students learning a particular content can trigger an action in the social network in which some students with questions can address another member and answer certain questions on the learned content. Likewise, the social network may lead the facilitator (teacher or tutor) to direct one’s focus to teaching students who failed to learn that content.

As we are defining a generic way, here is not a suitable place to study specific monitorable events for each application domain.

2) Actions in a Social Network

Just as there are some monitorable events that may be considered generic, there are also some general actions that can be suggested to those involved. Some examples are the creation or the elimination of relationships, and the strengthening or weakening of relationships. As their names are self-explanatory and as a similar drill was done in the previous section, this section will not provide further explanation on their meaning.

V. AUTONOMIC SOCIAL NETWORK ANALYSIS

To achieve the goals set forth in this paper we are proposing an autonomic framework to analyze social networks whose conceptual architecture can be seen in Figure 3 and is explained in the following section.

A. Conceptual Model

In preparing this conceptual architecture, the fact that social networks are entities that exist by themselves has been widely considered. In it, social networks should be extracted (Figure 3-a) by some automated mechanism (if there is data where there can be some kind of automated extraction) or not (for cases where the social networks are not stored in any computer media, e.g., the social network of a family) and should be stored in a database (Figure 3-b) with a specific format for this purpose. The specific format is set in the generic meta-model shown in Figure 4 and better explained in the next section.

Once stored in a standard format, the autonomic elements can act on the base (Figure 3-c), making inferences based on characteristics analyzed both on the relationship and network levels. In order to assist the analysis, there are several metrics that can be used (inclusiveness, local centrality, shortest path, clustering coefficient, diameter, node degree, degree centrality, closeness centrality, betweenness centrality, amongst others) (Figure 3-d). The usability of each one should take into account the type of analysis and what it wants to from the analysis.

To make their decisions, the autonomic agents make use of a rules basis (Figure 3-e) defined by a domain experts (Figure 3-f) according to information provided by stakeholders (Figure 3-g) in the social network analysis. To monitor agents’ decisions and to change settings or preferences, users should have at their disposal intuitive interfaces that provide control and display functions (Figure 3-h).

In this direction, the domain expert should define what we call the acceptable state of the network. In this state, the social network is considered optimal and no further changes are necessary. To this end, the specialist must select which metrics one wants to analyze, for the network as a whole or for a particular context or group of social entities.

After the statement of the metrics, the analyst should assign weights to them in order to establish the relevance of the metric for his context of analysis. These weights can vary from 10 to -10 where negative values indicate that a particular metric has negative impact on achieving the goals. Thus, we have an objective function of the social network:

\[ F(RS) = \sum_{n=1}^{l} R_n * M_n(RS) \]  

(1)
where: \( F \) is social network objective function; \( RS \) is the social network; \( j \) is the number of metrics selected by the analyst; \( R_n \) is relevance of the \( n \)th metric in the analysis to be made; and \( M_n \) is the function that calculates the value of the \( n \)th metric chosen.

After this definition, the analyst must indicate which events should be monitored in the social network (referred to as symptoms). Examples of such symptoms may be the presents in item A1 of section IV as well as expressions containing metrics (e.g. shortest path > 6).

For each identified symptom and informed by the monitoring operation, an analysis operation checks whether any action should be taken in response to that event. This is done based on the verification of the objective function value, taking into account the change made and comparing it with its original value: if the objective function improves its value, no action is taken. Otherwise, something should be done.

The definition of what should be done is also chosen based on the objective function. For this, the analyst has to choose possible actions to be taken for every possible symptom. For example, the analyst and choose the action that further improves its value (make the objective function value greater than the value of the same function in the initial state of the network).

This action is passed to the planning function which, in its turn, will choose the best way to take action. For this, planning may take into account information from the environment, for example, in an distance learning application it is better to suggest that people contact themselves by email or via a forum.

In addition to the above, the autonomic elements should have mechanisms that allow feedback to be sent via direct interfaces (Figure 3-i) to systems (Figure 3-j) that can use data, information and decisions taken by them. These interfaces...
are important in certain applications and contexts. It may be desirable that the autonomic elements suggest, for example, the creation of new relationships or new contacts, use of environment-specific tools, amongst other things. An interesting example of an application that could make use of this technique is in learning environments. Since there is a student ‘A’ who assimilated a specific content with success, and another student who did not (student ‘B’), the system can autonomously suggest that ‘B’ contacts ‘A’ for information on the content.

Since these suggestions are accepted and network status is changed (Figure 3-k), the database of social networks is updated and autonomic managers can rerun the social network and make new suggestions (if any).

B. Meta-Model

The meta-model has the relationship that can occur between social entities as the central entity. In it, each entity has a valid role for a type of relationship (e.g., husband and wife roles are valid in a relationship of the marriage type). Relationships are obtained from any source (DBLP database [35], historical surveys, and so on) and, as the entities that participate of the relationship may have attributes that identify and characterize them.

Social entities have an associated type (an entity can be either an organization or a person), relationships have roles and types of social entities, beyond attributes and contexts. This data can suffer from ambiguity and, in this sense, the meta-model provides the use of domain ontologies as a means of disambiguation and to give more semantics to the items represented.

Since a single social network can be analyzed in a very broad manner, the concept of context was also represented in the model. The concept of context adopted for this work was presented by Dey e Abowd [36]. According to them, context can be defined as ‘any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between an user and an application, including the user and application themselves’. The adoption of this definition was given by its character, capable of practical implementation in computer systems.

VI. AGENTS WORK ARQUITECTURE

In order to implement the proposed autonomic social networks, a generic architecture based on the work [33] was developed. This architecture consists of a collection of autonomic elements that work on managed elements such as characteristics of social networks such as that represented on the generic meta-model. Each autonomic element can suggest changes to relationship (e.g., aimed at balancing) social network. This is done through suggestions made to social entities that make up the social network. These suggestions may or may not be accepted. Once accepted, the structure and characteristics of the social networking changes and other autonomic elements may perceive such changes through sensors that capture such information and take action, if necessary.

Figure 5 shows two views of the same social network: one complete and another only with social entities that act in research in the Databases area. Moreover, the Figure also shows elements acting in the social network. The action is illustrated by the triangles that starts from each autonomic manager and ends on the social network.

Three types of autonomic elements (Figure 5) were defined: (i) those that work in the social network as a whole, (ii) those that work with visions of the social network and (iii) those that work on specific entities of the network social. The need for three types of autonomic agents becomes justifiable if we consider that there are certain characteristics of a social network that require knowledge of the network as a whole (for example, its structure, bridges, hub centralizers, groups, etc.) and others that need more personal knowledge (e.g., personal interests, values, beliefs, etc.).

For instance, consider a social network made by researchers who hold a common interest in knowledge sharing and collaboration between them. The first type acts on the social networking features considering it as a whole (Figure 5-a). The second type acts on the personal interests of each component in the social network (Figure 5-c). The third type would act on views of the network in order to serve only those interested in a particular area (Figure 5-b).

VII. CONCLUSION

This paper addressed how we are using autonomic computing techniques to improve social network analysis, turning it automatic and proactive. To this, we have discussed social networks and their analysis showing that the analysis could be a strenuous task, with and without automatic assistance. We also discuss autonomic computing theories and showed how it is being applied to social networks, showing a conceptual model that is the basis of the studies, a generic meta-model of the data stored in the database and the initial system architecture.
At this point the technique has shown that its applicability is very broad and many domains can benefit from it. An initial prototype is being developed using free technologies made available in projects over the Web. Many works using the theories have been planned.

A. Current Stage and Future Work

The work is in progress. At the time of writing this paper the authors were working towards a partnership with IBM for the use of the ABLE engine [37][38][39]. The ABLE is a toolkit designed to build multi-agent autonomic systems. It was written in Java and assists in building intelligent agents that make use of machine learning and reasoning mechanisms.

It is hoped that this work is applied as described in [40]. In this work the techniques described above are applied to improve the flow of knowledge between individuals belonging to a scientific social network. It will be implemented in the social network of researchers at INCA (the Brazilian National Cancer Institute). This is an ancillary department of the Brazilian Department of Health involved in the development and coordination of integrated actions to prevent and control cancer in Brazil. In this context some studies are being made to survey and describe the interactions between members of the Institute.

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