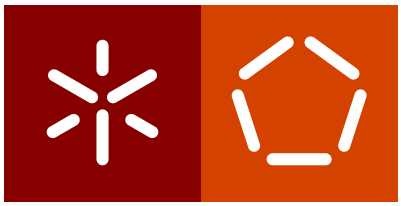

Universidade do Minho
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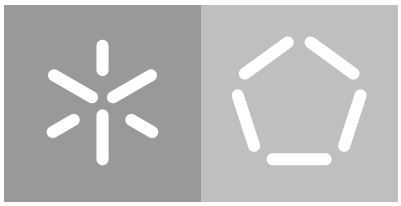
Analysis and Visualization of Dynamic Social Networks

March 2017



Universidade do Minho
Escola de Engenharia
Departamento de Informática

Jorge Caldas

Analysis and Visualization of Dynamic Social Networks

Master dissertation
Master Degree in Computer Science

Dissertation supervised by
Pedro Rangel Henriques
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March 2017

ABSTRACT

*"**You can think of networks as vast fabrics of humanity, and we all occupy particular spots within the network.**" Nicholas Christakis*

This document represents the study developed under the master's thesis Analysis of Visualization of Social Networks, that overlaps two main scientific fields, sociology (more concisely social networks) and computer science, aiming the design and implementation of a system for social network analysis.

First we present and identify the problem and challenge of building a system for social network analysis, we also mention the motivation, research hypothesis and goals. From here we start to search the science foundations for social networks, starting from the very basic theoretical concepts in chapter two, then we travel to the present and present Online Social Networks as the most known application of this science, in chapter 3 we do a more detailed study on Online Social Networks starting from exposing theme in a more generalist way and then narrowing and exploring some of then with more detail. In chapter 4 we cover the analysis theoretical with the tool we want to build in mind, being Social Network Analysis a very broad field we take advantage of our goals to narrow the research on this field, presenting only the concepts and tools that in a certain way built the path for Chapter 5, where we propose the system architecture.

The next steps are more technical, we discuss and prioritize the requirements for our system, we present out technological choices based on a proof of concept built to previous system implementation only for architectural and technological study of viability. Next we present the developed tool, the final results and respective analysis. At the end we focus on discuss the main conclusions of this work, and where could we go from here, we present possible future under different perspectives.

RESUMO

> ***"Podemos ver as redes sociais como vastas fábricas de humanidade, onde cada um de nós ocupa um lugar específico."*** *Nicholas Christakis*

O presente documento representa o estudo desenvolvido sob a dissertação de mestrado de Análise e Visualização de Redes Sociais Dinâmicas, que resulta sobretudo da intersecção de dois ramos científicos, a sociologia e as ciências da computação, com o objectivo de propor o desenho e implementação de um sistema de análise de redes sociais.

Começamos por apresentar e identificar o problema e desafio de construír um sistema para análise de redes sociais, mencionando os nossos objetivos e motivação para o projeto. No segundo capítulo começamos a explorar as fundações científicas sobre redes sociais, apontando os conceitos mais básicos. No terceiro capítulo fazemos uma passagem pelas Redes Sociais Online, começando por fazer um levantamento mais generalista acerca do tema e das redes sociais online, após esta introdução, fazemos um estudo mais detalhado acerca de algumas redes sociais que selecionamos. No seguinte capítulo apresentamos a base teórica da Análise de Redes Sociais, uma área bastante basta e complexa. Por ser uma área de grande dimensão e diversas aplicações, limitamos o seu estudo ao propósito desta dissertação, sendo que o critério para exploração de alguns conceitos terão como base o facto de nos ser útil a sua compreensão para a implementação do sistema, cuja arquitetura apresentamos no capítulo seguinte.

Os próximos passos têm um teor mais técnico, discutimos e prioritizamos os requisitos do nosso sistema, apresentamos as tecnologias com base na contrução de uma pequena prova de conceito que também é apresentada nestes capítulos para fins de validação da viabilidade da arquitectura e das tecnologias escolhidas. Numa fase mais final apresentamos a ferramenta construída e os resultados obtidos, para terminar com uma discussão acerca das conclusões mais relevantes a retirar deste projecto, bem como algumas possibilidades de trabalho futuro.

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1

INTRODUCTION

In this chapter we do an introductory overview on the work being developed along this master's dissertation. This chapter presents the essential introductory topics. First we present the problem and context where this project is framed, then we expose the motivation, followed by the research hypothesis, which concisely describes the possible outcome of this project. Finally we list the goals of this project in a generic and simple way.

1.1 CONTEXT AND PROBLEM

In the mid 1950s sociologists introduced the term *Social Network* (*SN*), that despite being a familiar term for today general public because of the OSNs platforms such as Facebook, Instagram or Twitter, it is a deeper and more mature concept. It was in the 2000s that much of the OSNs we know today start emerging, so it took at least ten years to people to adopt the concept and the new way of living, so today billions of people use these online platforms as channels for socializing, connect with each other and share their daily lives.

From the user's point of view we may consider that all the platforms offer a microscopic perspective from within the network, people have a public profile, and they can visualize their friend's profile (this is a typical scenario that we observe today in the majority of the OSNs), and normally have access to a timeline that displays friends activity. The point is that, to the users of these online platforms, it is not provided a mean to visualize and analyze their network structure in a more abstract and generalized sense, where users are given the opportunity to observe their social network from a macroscopic perspective, and, with that, all the metrics for measuring nodes and relationships within the network.

The problem that is being built in this section resides on general social structure observation and analyzes. This dissertation aims to fill the gap or struggle that online social networks users have in understand their network, how their relationships evolve along the time, what role they play within the network and how can they analyze and visualize their networks based on social properties such as mutual relationships, geographical position, personal tastes and preferences or hobbies.

Within the big data challenges, social network data analysis might be one of the biggest

demands that we face today, because besides of dealing with tremendous amounts of data, we are dealing with unstructured data. The unstructured data derives from the diversity of this platforms known as OSNs, and unstructured data adds complexity to the challenge of analyzing social networks data. The major challenges related with big data and unstructured data comes after the data extraction.

The steps for data analyzes and visualization

Next we present the steps trough data extraction to data visualization, that generally represent the structure and flow of data analysis and visualization systems.

- Data extraction trough social media *Application Program Interfaces (APIs)* or trough web crawlers (also known as web scrappers);
- Saving data, and more importantly know what data to store; in order to have an efficient system that provides a good structure for data analysis, one needs to selected data carefully;
- What to do with the data, what applications the stored data may have, how can the system digest and transform data in order to make it useful or interesting for the end users;
- How to present/show the transformed data, despite the science of visualization represents only a small part of the data scientist work, it has a huge impact on the end user, mainly when targeting a general audience.

1.2 MOTIVATION

As we see in the previous section, social media data analysis represents a major challenge for data scientists in every aspect, since the extraction all the way to the visualization. Despite representing a major technological challenge, social media data analyzes has an additional motivation, that is the massive daily usage in every country across the planet making OSNs an universal tool for communication, such as radio or television but with the technological flavor of the 21st century.

OSNs as we will see along this dissertation, are today a *"digital mineral"* in terms of exploration potential, we do not only pretend to have a generalist perspective of the analyzes of data that flows within this platforms, we will try when appropriate to demonstrate the most narrower applications as possible of analyzing social networks, this applications may go from health analyzes within social structures, to strategic marketing planning supported by the analysis of the already mentioned unstructured data.

1.3 RESEARCH HYPOTHESIS

With this master's dissertation, we aim to prove that a software tool may be designed and implemented in order to actually improve the analysis of social phenomena, allowing not only sociologists but also the public in general to explore with greater detail the connections of individuals within a network, being OSNs the base of analysis for such a tool.

1.4 GOALS

The main goal of this project is to build a useful software tool in the context of social network analysis. Along the process of building and investigating, the following are some of the goals that are also very important to achieve:

- Understand the theory of *Social Network (SN)* in sociology;
- Understand how OSNs came to such a massive use nowadays;
- Perceive the roles of Online Social Networks in society and their potential applications in various fields;
- Study and analyze the most used Online Social Networks, learn how to interact with those systems and how to learn and profit from them;
- Design a system of analysis and visualization that matches the desired goals and requirements;
- Explore new technologies and choose the appropriate tools to build the specified system;
- Implement the system.

1.5 DOCUMENT STRUCTURE

In this section we will preset how this document is structure, and in concisely explain what to expect in each of the following chapters.

We start by exploring some theoretical background on SNs in light of sociology. In Chapter 2 we present some of the history behind SNs, and we review some of the fundamental concepts of SNs.

In Chapter 3 we explore Online Social Network (OSN), this is the *personification* of the SN concept of the 21^{st}. Primarily we present a top level overview on OSNs, where we present many of them and some metrics to compare them (such as number of active and registered

users), then we provide again some historical background followed by the detailed analysis of some selected OSNs, also we talk about OSNs usage among Portuguese people and what impact OSNs had in a recent past and continue to have.

In Chapter 4 we discuss a very broad theme *Social Network Analysis* (*SNA*), in the scope of our project. We talk about *Social Network Analysiss (SNAs)* basic concepts and metrics that are useful for network analysis as well as related scientific related areas. We do an overview on SNAs software tools and libraries.

In Chapter 5 we present an architectural perspective of the project to develop along this master's thesis. We end this document with the conclusion, working plan and future work.

2

SOCIAL NETWORKS IN SOCIOLOGY

Nowadays, it is hard to find something that is not organized as a network, if one tries to understand something about the world around us, then definitely one needs to know something about networks.

Curiously, if we look up the term SN in the Dictionary (2002), we may face the following:

> *"a website or computer program that allows people to communicate and share information on the Internet using a computer or mobile phone"*

But, even if today we automatically think in SNs as websites (or web applications), deep down we know when talking about SNs, we refer to a much more broader term, that said, we may consider a SN as the following:

> *"A social structure made of nodes that are generally individuals or organizations. A social network represents relationships and flows between people, groups, organizations, animals, computers or other information/knowledge processing entities. The term itself was coined in 1954 by J. A. Barnes."* Beal (2016)

One may say that networks work like pipes, and through them things flow, from individual to individual inside the network. Trough networks, big institutions can organize themselves, and actually add value to society despite the large number of individuals.

2.1 ORIGINS OF SOCIAL NETWORKS

> *"The network concept is one of the defining paradigms of the modern era."* Kilduff and Tsai (2003)

The network concept is broadly used across multiple fields of study, including, physics, biology, linguistic, anthropology, mathematics, computer science and more recently computer networks.

But why is the network approach so adopted in such diversification fields? According to Kilduff and Tsai (2003), the answer is because networks allows us to capture the interactions of any individual unit within the larger field of activity to which the unit belongs.

Before reviewing the concept of network (Section 2.2), it is important to talk about it in a sociological perspective.

2.2 SOCIOLOGY PERSPECTIVE

> *"(...) many people attribute the first use of the term "social network" to Barnes (1954). The notion of a network of relations linking social entities, or of webs or ties among social units emanating through society, has found wide expression throughout the social sciences. (...)"* Wasserman and Faust (1994)

The SN concept has been around for many years now, maybe not in the exact format than nowadays, we are familiarized with the "*web way*", in a manner of speaking, but in a more abstract sense, applied in real life within real connections. Wasserman and Faust (1994), refer that this term has first came into discussion in 1954, introduced by Barnes, J.A.

> *"Social relations in Bremnes, Norway, fall into three categories: relatively stable formal organizations serving many different purposes, unstable associations engaged in fishing, and interpersonal links that combine to form a social network and on which perceptions of class are based. In fishing situations, orders are given and obeyed; in the other social settings, consensus decisions are reached obliquely and tentatively."* Barnes (1954)

In the above citation, John Arundel Barnes, does a very well succeed reflection about the relationships of the people from Bremnes (Norway).

The author points out that relations can form organizations for serving a specific purpose, and today we clearly see that the chosen path of SNs and also OSNs, was narrow down SNs to very specific purposes, such as professional networks. So one may say that John Arundel Barnes not only coined the term SN, but also was one of the first who described **interest-based social networks**.

2.3 FUNDAMENTAL CONCEPTS

The concepts listed below are of key importance and are the basis of comprehension of SNs (Wasserman and Faust (1994)).

- *Actor* - It is important to understand the linkages among social entities and the implications of these linkages, these social entities are described as actors. Actors are are discrete individual, corporate, or collective social units.
- *Relational Tie* - Actors are linked to one another trough *social ties*. The type of ties may be extensive, and it describes the nature of the connection. Some example of ties:
  - **Evaluation** of one person by another;
  - **Transference** of resources (business transactions);
  - **Association** (to social event or cause);
  - **Behavioural** interactions (communicating);
  - **Moving** between places or statuses (migration, social or physical mobility);
  - Others may be: physical connection (roads, rivers), formal relations (authority), biological relationship.
- *Dyad* - The most basic relationship that can be established is a dyad, a connection between two actors.
- *Triad* - A relation established between three actors. Many studies included breaking SNs down to small groups (triads), this allowed a more clear conclusion about the transitivity of the connections.
- *Subgroup* - It defines any subset of actors in a SN (conceptually, subgroups come after dyads and triads).
- *Group* - A finite set of actors who for conceptual, theoretical or empirical reasons are treated as a finite set of individuals in which network measurements are made.
- *Relation* - A collection of ties of a specific kind among members of a group is called a **relation** (e.g. a connection in *LinkedIn* is a relation while evaluating our connections of sending them messages are ties).
- *SN* - At last, with the definitions of actor, group and relation, a SN consists of a finite set or sets of actors and the relation or relations defined on them. The presence of relation information is critical and defining feature of a SN.

Next, we present a two more advanced and abstract concepts but still fundamental concerning SNs in the context of this project.

Homophily

In a New York Times Magazine article (Retica (2006)) it is mentioned that the term *"homophily"*, was coined in the 1950s by sociologists and in a more literal sense it means *"love the same"*. This term emerges from the natural tendency we have to link to other individuals that are similar to us.

Quoting the sociologists McPherson et al. (2001), ***"Similarity breeds connection"***, basically similarity is considered a generator of connections among individuals, being the result of this phenomena homogeneous SNs.

The term *homophily* has been cited in light of many different themes, from teenagers choosing friends who drink and smoke similar amounts to theirs, or in explaining how homophily influences the matches of partners in online social dating, this proving that one likes, most of the time, someone like oneself, on or offline (Fiore and Donath (2005)).

From another point of view, this trend could be seen as a threat to diversity and globalization. It is said that diversity can be a synonym of power, when bringing different cultures and different ways of thinking together we could achieve great things, but homophily is already a cemented concept/pattern that sociologists observe among SNs, and maybe we could find ways to battle in favor of diversity, or maybe homophily is a fundamental property in order to structure society.

Heterophily

In order to complete the previous presented concept (*homophily*), we now present the opposite that is *heterophily*, that translates in literally the opposite idea, being *heterophily* the trend of individuals belonging to diverse groups thus connecting with different people.

2.4 Abstraction and Generalization

In a more abstract sense networks are merely abstractions that are originated by the generalization both of individuals, and relationships.

> *"When we study social organization of a simple society, we aim at comprehending all the various ways in which the members os the society systematically interact with one another. For purposes of analysis we treat the political system, the pattern of village life, the system of kinship and affinity, and other similar areas of interaction as parts of the same universe of discourse, as tough they were of equal analytical status, and we strive to show how the same external factors, principals of organization and common values influence these different divisions of social life. "* Barnes (1954)

In the above citation, the author describes a generalist approach on analyzing social networks. The two main characteristics of this approach are **generalization** and **abstraction**. First generalization because we are trying to simplify reality by minifying different kinds of connections (political, affinity etc.), this will allow us to treat networks as part of a world where they can fit in the domain of the exact sciences, being mathematical the way networks express themselves in order to measure metrics and behavior analysis.

Abstraction comes naturally in the way as the process of generalization takes laces, we could see abstraction and generalization as synonym in this specific case, but it also may be seen as a tool to see through the generalization process. Also fitting (at least try) networks and their analysis within the domain of exact sciences, requires the abstraction of the generalization that toke place before. In Chapter 4 we will cover with much more detail the field known as SNAs, that is responsible of deriving conclusions from analyzing social structures.

3

ONLINE SOCIAL NETWORKS

People need to connect other people, and the urge for connection brings to us what today are known as OSNs. These web sites allow us to define a profile as an individual, and to share and visualize content with other individuals in the network, therefore connecting.

> *"We define Online Social Networks as web-based services that allow individuals to construct a public or semi-public profile within a bounded system, articulate a list of other users with whom they share a connection, and view and traverse their list of connections and those made by others within the system. The nature and nomenclature of these connections may vary from site to site.* Ellison et al. (2007)

OSNs have been around for more than a decade now, but these systems have gain world wide popularity since the global adoption of platforms such as Facebook, Youtube or Twitter, which are platforms that are today massively used across all cultures and age groups, and represents a paradigm shift on social interaction that we not yet fully understand.

The earlier referenced OSNs, belong to the top of the most visited web sites in the world, that's because these systems not only represents a new way to keep in touch with friends, but also represents for many, a new way of living, basically we live in network.

In this chapter we are going to explore OSNs, their history, how are these systems being adopted among Internet users, and for some OSNs, a more detailed and deep study will be conducted for they are important objects of study of this master's thesis.

But first, with intent of obtaining a macroscopic perspective of the different OSNs in the Internet, what they offer that makes them different from one to another causing many of the users using multiple OSNs at the same time, we present next a table featuring some of the most used OSNs.

Name	Year of launch	Registered Users	Active Users	Description/Purpose
Facebook	2004	>1 712 000 000	1 712 000 000	**General**. Photos, videos, blogs, apps.
Google+	2011	1 600 000 000	300 000 000	**General**. Google+ is an interest-based social network that is owned and operated by Google.
Youtube	2005	>1 000 000 000	1 000 000 000	Allows billions of people to discover, watch and share originally-created videos. Provides a forum for people to connect, inform, and inspire others.
Qzone	2005	>652 000 000	652 000 000	**General**. It allows users to write blogs, keep diaries, send photos, listen to music, and watch videos. It's only available in Chinese.
Twitter	2006	645 750 000	313 000 000	**General**. Micro-blogging, RSS, updates.
Tumblr	2007	>555 000 000	555 000 000	Microblogging platform and social networking website.
Instagram	2010	>500 000 000	500 000 000	A photo and video sharing site.
LinkedIn	2003	>450 000 000	106 000 000	Business and professional networking.
Sina Weibo	2009	300 000 000	282 000 000	Social microblogging site in mainland China.
VK	2006	249 409 900	100 000 000	**General**, including music upload, listening and search. Popular in Russia and former Soviet republics.
Reddit	2005	234 000 000	120 000 000	Social media, social news aggregation, web content rating, and discussion website.
Vine	**2013**	200 000 000	100 000 000	Short-form video sharing service where users can share six-second-long looping video clips.
Pinterest	2010	176 000 000	100 000 000	The world's catalog of ideas. Find and save recipes, parenting hacks, style inspiration and other ideas to try.
Flickr	2007	112 000 000	92 000 000	Helping people make their photos available to the people who matter to them. Enable new ways of organizing photos and video.
Meetup	**2002**	27 590 000	-	World's largest network of local groups. Meetup makes it easy for anyone to organize a local group or find one of the thousands already meeting up face-to-face. meetup.com (2016)
Couchsurfing	2004	12 000 000	-	Couchsurfing connects travelers with a global network of people willing to share in profound and meaningful ways, making travel a truly social experience. Is commonly used by travelers to find free hosts across the globe. couchsurfing.com (2016)
ResearchGate	2008	>11 000 000	-	Built by scientists, for scientists. Connect the world of science and make research open to all. researchgate.net (2016)

Table 1: Table describing most used OSNs. (statista.com (2016), expandedramblings.com (2016))

Table 1 lists the most used and popular OSNs, **ordered by the estimated number of registered users**. Also notice that, for those OSN where the number of registered users is unknown, we will assume that it is a larger value than the monthly active users represented by the column *Active Users*.

The first obvious comment on the listed OSNs is that general purpose OSNs have more users (social networks with the word *General* in bold), being Youtube an exception, since it is not a general purpose OSNs, neither is focused on individuals, it is build around **social objects**, the videos.

The grey scale in the first column of Table 1 divides OSNs in three groups: the first and smallest, the 1 billion or more users OSNs; the second the OSNs with less than 1 billion users and more then 100 million; finally, the third group, OSNs with less then 100 million users. At this point, we begin to observe that **the narrower purpose OSNs** such as ResearchGate (mainly for researchers) or Couchsurfing (mainly for open minded travelers), **have a smaller number of registered users**, which is expected since the target audience is also smaller.

Other OSNs not listed in Table 1, but still worth mentioning include **Classmates** (helps users finding classmates form kindergarten, primary school, high school etc.) known for being one of the first OSNs, since it was launched in 1995, and **Ask.fm** (allows users to interact with other users asking and answering questions (revealing identity is optional)).

An important note on the listed OSNs in Table 1 is that only Qzone, Vine, Couchsurfing and ResearchGate don't provide any web APIs to fetch data or publish content, while all the others offer a wide variety of web services for developers to consume and use as they please, of course within the terms and policies of use of each OSN.

3.1 History of Online Social Networks

Although the first platform possessing some of the main characteristics that define OSNs, according to Ellison et al. (2007), the first recognizable OSN launched in 1997 as we can observe in the Figure 1. *SixDegrees.com* allowed users to create personal profiles, connect with friends and consult friends of friends lists. The profile feature came from the online dating sites and online communities, while the surfing trough register users in the network and consulting friends was an existing feature in Classmates.com. *SixDegrees.com* was the first to combine these features.

SixDegrees promoted itself as a tool to help people to connect, but in 2000, it became an unsustainable business and the service closed. At the time the creators conclude that *SixDegrees* was a service that was very ahead of its time.

Until 2002 many OSNs have emerged, but still incapable of projecting themselves at a global scale. As we can observe in the timeline of Figure 1 from 2002 and 2005 the *big*

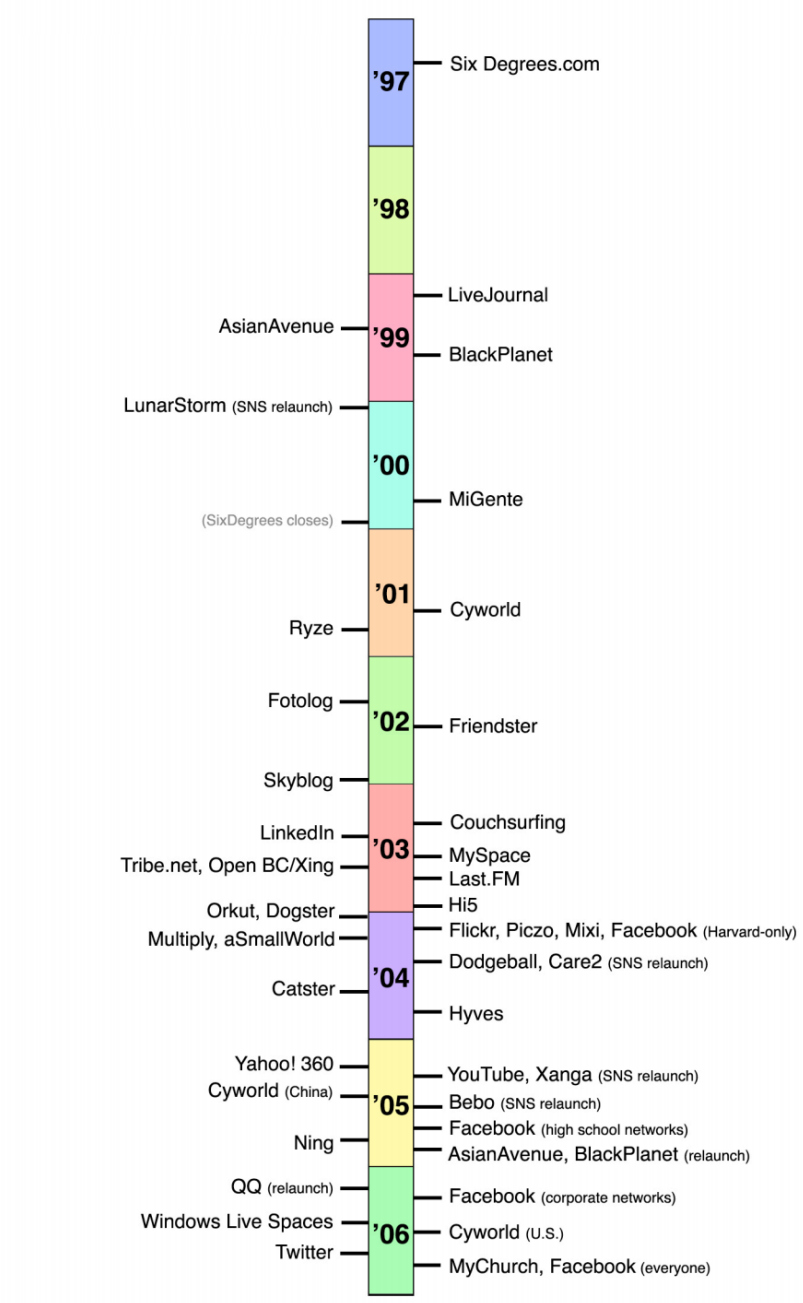

Figure 1: Launch dates of major OSNs. (Ellison et al. (2007))

players came to existence, in these period, OSN such as Friendster, LinkedIn, MySpace, Hi5, Facebook and Youtube were born, shaping the business, cultural and research landscape.

3.2 PORTUGUESE PEOPLE AND ONLINE SOCIAL NETWORKS

From Table 1, we get a good overview on OSNs usage among modern society. In this section we do a deep exploration of the most adopted OSNs by portuguese citizens, and get to compare then with the more global scenario presented in Table 1, also, other interesting facts will be revealed where appropriate.

A recent study, Marktest (2016), revels portuguese relationship with OSNs. This study, has been made by *Marktest Consulting* since 2011, with the goal of know the notoriety, utilization, opinion and habits of portuguese concerning social networks. The study information was collected trough online interviews. The sample was built from 819 interviews from individuals with age between 15 and 64 years, living in Portugal and using OSNs in a daily basis.

Some of the most interesting facts revealed in this study, relative to the participants are:

- 94% has a Facebook account and 43% a Youtube account;
- 21% has abandoned a social network in the past year;
- 27% considers that their dedicated time to social media has increased;
- 67% follows celebrities and 62% follows brands;
- 87% is used to watch videos in social networks.

These are indeed interesting conclusions, but what about the top used OSNs, **the most used are the following (by order): Facebook, Youtube, Google+, LinkedIn, Instagram and Twitter**.

Relatively to Marktest (2016) past studies, Facebook has maintain the top position, maintaining a grow tendency that has been standing out in the past years.

Going back to Table 1, we may now comment the usage of OSNs by portuguese people comparing it to the global scenario. As one may notice Facebook still rules users preferences within portuguese people.

Concerning to global time related usage statistics, according to Marktest (2016), **portuguese spend 91 minutes a day with social networks**, 68% considers that this is the ideal time to spent with social media, despite 1 in each 4 saying that in the past year has dedicated even more time to them. Even if people spent more than one hour and an half in this platforms, the study concluded that **67% of the users that visit OSNs several times a day only 41% does daily publications**.

The prime time for using OSNs is between 8pm and 10pm, being the smartphone the most used device in this time. Also in this short period the featured OSN is Facebook, the majority of the interviewed say that is the most credible site, the one that provides better and useful information, the most interesting and addictive.

3.3 EXPLORING SPECIFIC ONLINE SOCIAL NETWORKS

In this section we are going to explore in greater detail some of the OSNs presented in Table 1. The selection of the social networks was not aleatory, we are going to study deeply the OSNs that gather some important characteristics, that will be of use in the future when we design the system for analyzing and visualizing social networks. First, the OSN must be accessible, this said, one must be capable of extracting information from the platform in order to analyze it. Second, the OSNs should preferably be the most diversified as possible, so that we can draw different types of conclusions deriving from different kind of analysis, for then give proof of the adaptability of the system to different OSNs. Considering the previous comments, these are the following OSNs that we think that as a group, better represents the intentions previously mentioned, so we will cover them with more detail (with no particular order):

- Facebook;
- Instagram;
- LinkedIn;
- ResearchGate;
- Pinterest;
- Twitter.

3.3.1 *Facebook*

Facebook is an OSN, created by Mark Zuckerberg in 2004, which started out by being an exclusive social network for Harvard students, but came later to spread across the country and the globe, having today more than one billion users.

Before diving into details of Facebook's domain, one must first point out some of its general aspects. Facebook basically allows anyone with a valid email address to create a public and personalized profile, we say personalized in terms of displayed content or information such as profile photo, name, work, homeland, education etc. . The next fundamental step is connect with other users, by sending friendship requests to other Facebook users (this are bidirectional relations). The base entity of the network is the user, but entities such as brands, companies can also be part of the platform, appearing normally in the form of page, being a page a public place inside the network with marketing or business related purposes (celebrities, public institutions also use pages as form of appearing in Facebook).

The next parts of this section will clarify the roles of this entities and their way of interact with each other, also other important concepts will be presented.

Domain Model

In this section we explore the domain of Facebook represented in Figure 2 in detail, what are the pieces that conceptually build this platform, and how they relate. The schema in Figure 2 represents a macroscopic perspective among Facebook components and their organization.

There are two entities with bold labels in the schema, this are, **User** and **Post**, being *User* the base entity in the network (the node in the network graph basically), and *Post* the most basic unit of content sharing in Facebook.

Facebook is interesting in terms of data gathering, because despite offering users' basic information and to whom that users are related (*Friends* box), it has a collection of other interesting data such as the family relationships (*Family* box), geographical locations where the user lives, or visited locations (*Locations* and *VisitedPlaces* boxes respectively), and among other things, user information may contain the personal interests that were explicitly inputed by the user (*Likes* box).

In what concerns to user activity in the platform, the *Timeline*, provides all the user Posts chronologically ordered, this is where Facebook dynamism takes place, users are constantly adding content to their timeline, it may be life related events or simply sharing other users posts linking content. The user feed (*Feed* box) represents a global timeline where the user can consult all the posts on his network (this is by default the user's landing page on the platform).

Facebook has, with time, become more then a user profile centralized network, it has invested in expand its horizons, becoming the place where pages of brands, companies, organizations (media, political, non-profitable etc.), or places (cities, monuments, bars etc.) live (*Page/Local* box). This entities that are now cohabiting with users in the Facebook ecosystem, take advantage of the platform and its range to get their updates to most people as possible. The profile for these pages are in many ways different form the user's profile, it also has a timeline, but the about information and other details represent a smaller part of page's profiles, the most important metric for pages is its number of *likes* (*Likes* box), it represents the number of users in the network that follow the page, it might be users that simply have a certain relation with the entity or simply want to keep in touch by regularly receiving these entities updates in their Facebook walls [1].

Other Facebook entities not yet mentioned, are events (*Event* box). These are events inputed in the platform that allow users to keep updated about relevant events happening mainly in their area. Users can tag the event as *interested in*, showing their friends the will of participating in some event, or they can simply reject the event. Users also can confirm participation on events showing their network that they will be present. Events keep three

1 Facebook wall an area where users can see the posts of their friends and/or liked pages, in a chronological order

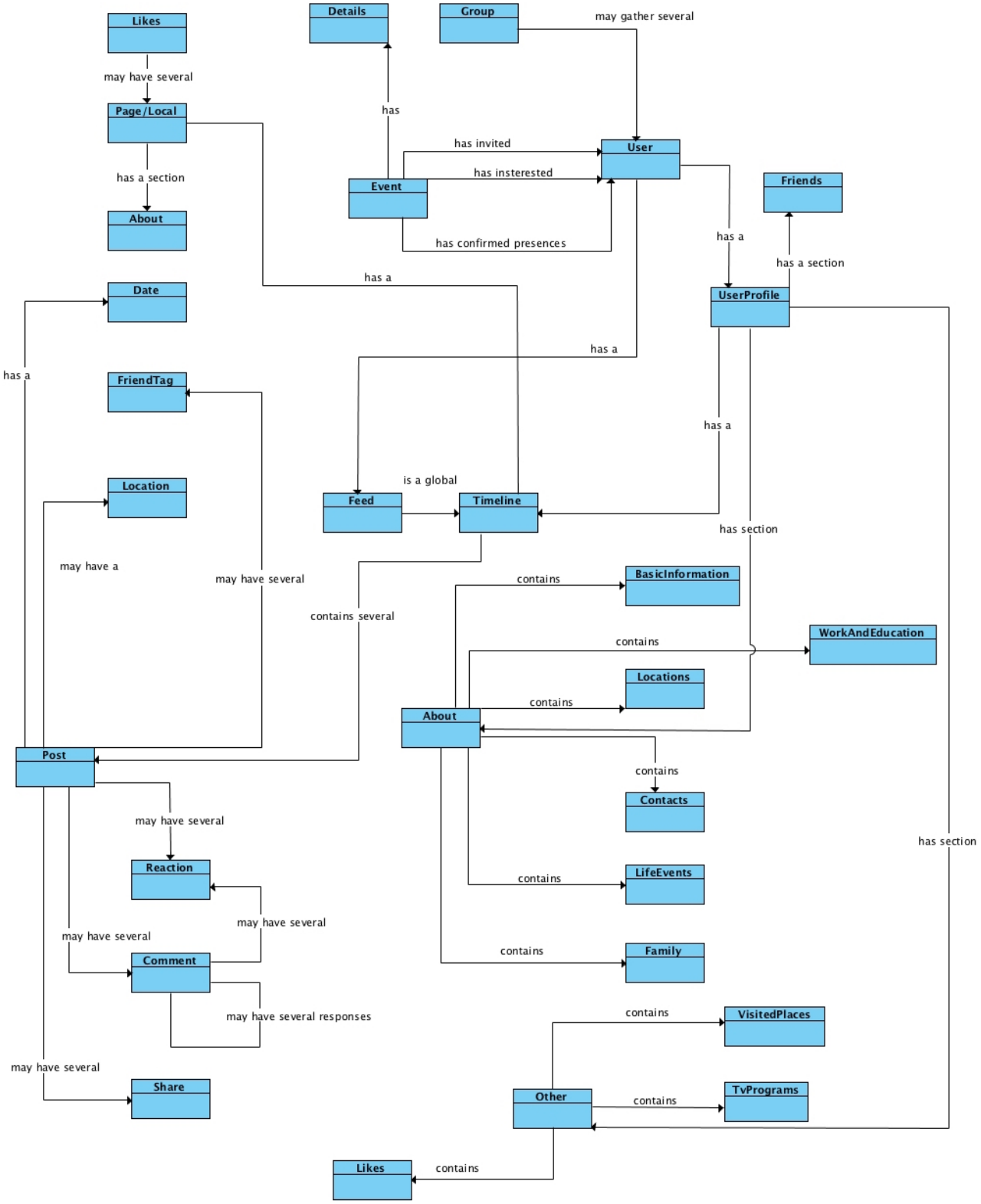

Figure 2: Facebook domain model schema.

separated counters for users, they count the number of invited users, number of interested users and number of confirmed users (these relations are expressed as links between the *Event* box and the *User* box).

In Facebook is also possible to join groups of users, this groups may be public or private, and they generally are focused on a specific matter, or gather users from one same institution or organization (e.g. Facebook group of students of the University of Minho). Having this feature of groups, clustering users by they interests one may say that groups, some way, transform Facebook in a *"multi interest-based OSN"*.

Facebook Graph API

Facebook has today several software *kits* for developers to interact with the platform in the most diversified and imaginable ways. Facebook developers offers a range of variated software products that vary from monetization programs, that focus on how to make users profit from Facebook, Analytics to developers who have their apps embedded in the Facebook platform understand their audience and the performance of their apps, etc. (developers.facebook.com/products/ (2016)).

In this master's thesis context, the relevant software that Facebook has available is the Facebook Graph API. This API basically allows developers to collect information from Facebook such as posts, photos, videos, pages etc. According to developers.facebook.com/docs/graph-api/common scenarios (2016), the common scenarios for using the Graph API are the following: determine whether two people are friends on Facebook; publishing new status and updates, uploading content (photos, video etc.); sharing links. But in this project what we seek is build the most biggest and detailed network as possible, with analysis and visualization purposes in mind.

For building the network fetching users friends information is crucial, this was possible until Facebook Graph API v2.0 (trough the router */me/friends*), one could actually retrieve friends information and build a network from there. From v2.0 on, to achieve what was explained before, one must request a special permission called **user_friends** from each user. The permission **user_friends** is no longer included by default in every login. This change breaks down the possibility of gather Facebook information via its Graph API, this said, we need in the future to look up alternative paths to extract data from Facebook.

3.3.2 *Instagram*

> *"Since the beginning, Kevin has focused on simplicity and inspiring creativity through solving problems with thoughtful product design. As a result, Instagram has become the home for visual storytelling for everyone from celebrities, newsrooms and brands, to*

teens, musicians and anyone with a creative passion." https://www.instagram.com/about/us/ (2016)

Similarly to Facebook we are going to explore Instagram in the same way. Instagram was originally developed by Kevin Systrom and Mike Krieger, and launched in 2010, only for iPhone devices. Within a year Instagram was able to gather around 10 million of users. Later, in 2012 Facebook acquire Instagram for approximately 1 billion dollars.

As already mentioned in Table 1, Instagram does not belong to the group of general purpose OSNs, instead, Instagram specially focused on photo and video sharing, building a global community that shares more than 95 million photos every day.

According to https://www.instagram.com/about/us/ (2016), since the very beginning Instagram was a very simplistic platform, being this characteristic reflected on its domain model.

Domain Model

Figure 3 represents the domain model of Instagram, and as we can observe, simplicity its the essence of this platform, since this diagram is far more a realistic representation of Instagram than Figure 2 is a representation of Facebook, and this may be why Instagram is so massively adopted by users on the Internet, because it goes directly to the point, focusing mainly on sharing activity, offering a real easy and simple user experience.

Now concerning to the domain model, we can see that a user and its profile (*User* and *UserProfile* boxes) are very simple entities, because a user's profile is only its biography (*Biography* box), relationships (*Followers* and *Following* boxes) and the user's posts, that despite being chronologically ordered, do not intend to form any kind of timeline such as Facebook, instead it represents more the concept of a wall with frames hanged on it.

In Instagram the landing page, represents a timeline (*Timeline* box) with posts from users we follow. Regarding to posts (*Post* box), one can comment posts (*Comment* box), but one cannot react or respond to comments (this preserves simplicity even more, for nested comments represent a complex part of OSN such as Facebook), and react to them by the *like* reaction (*Like* box).

Instagram API Platform

In consequence of a simple domain, Instagram API Platform, provides simple and useful end points for programmatic publishing, and for network discovering, as far as concerning to this project, the late utility is more of interest. Instagram allows to get users, their relationships and also the media shared content (posts).

Similarly when exploring Facebook Graph API, we now found also very intimidating

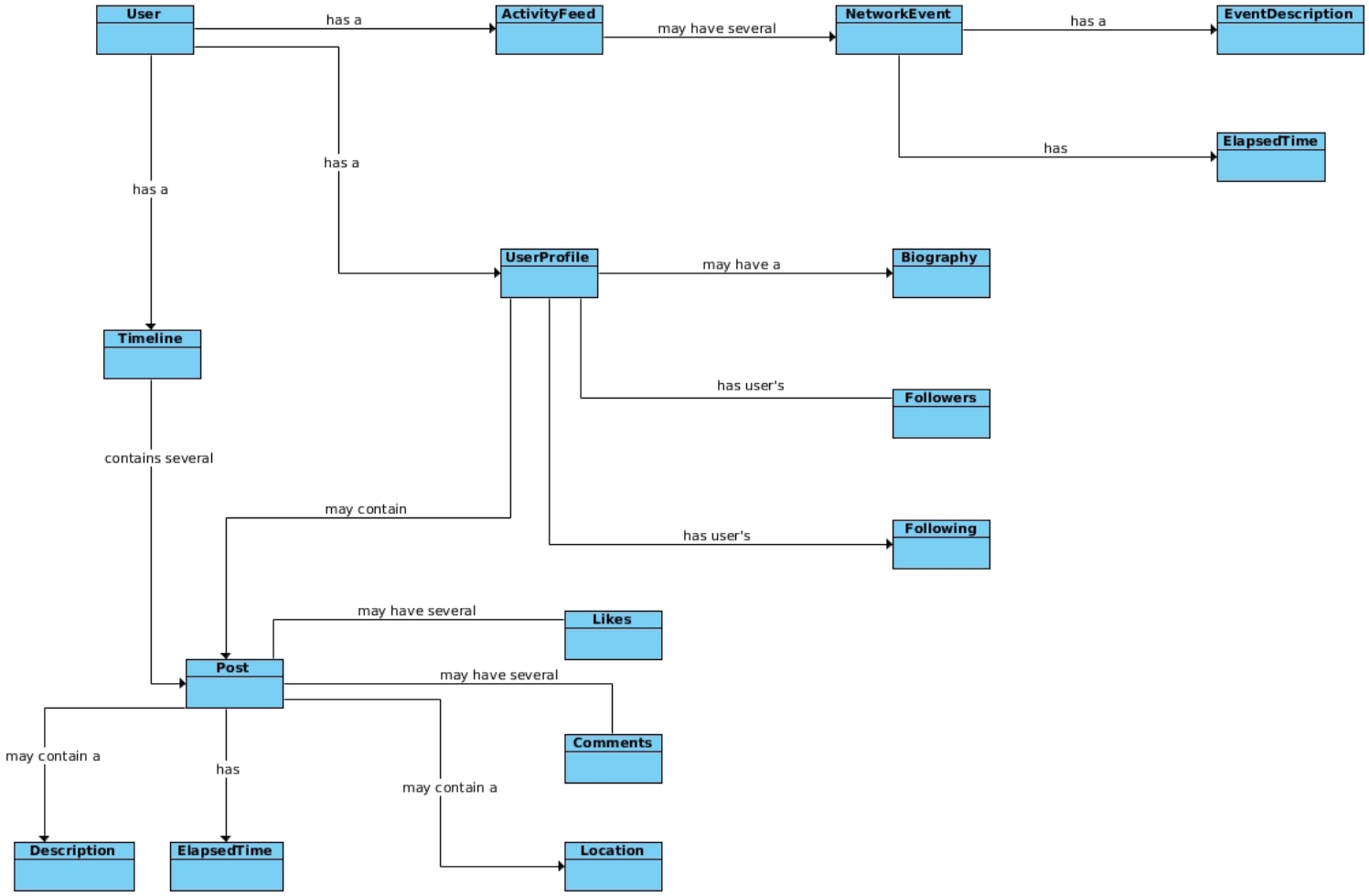

Figure 3: Instagram domain model schema.

restrictions for the purpose of this project, this restrictions include limited rate of 500 API requests per hour, and end point specific limitations that allow only to perform 30 requests per hour to getting users' relationships data. (https://www.instagram.com/developer/limits/ (2016))

3.3.3 *LinkedIn*

Moving on to the next OSN we now have LinkedIn. According to https://press.linkedin.com/about linkedin (2016), LinkedIn was launched officially on May 5 of 2003, and by the end of that month, the network had already more than 4500 members. In 13 June of 2016 LinkedIn was acquired by Microsoft in an all-cash transaction valued at $26.2 billion (Guardian (2016)).

LinkedIn is an OSN that has a very narrow purpose, which is connecting professionals around the globe to make them more productive and successful.

Domain Model

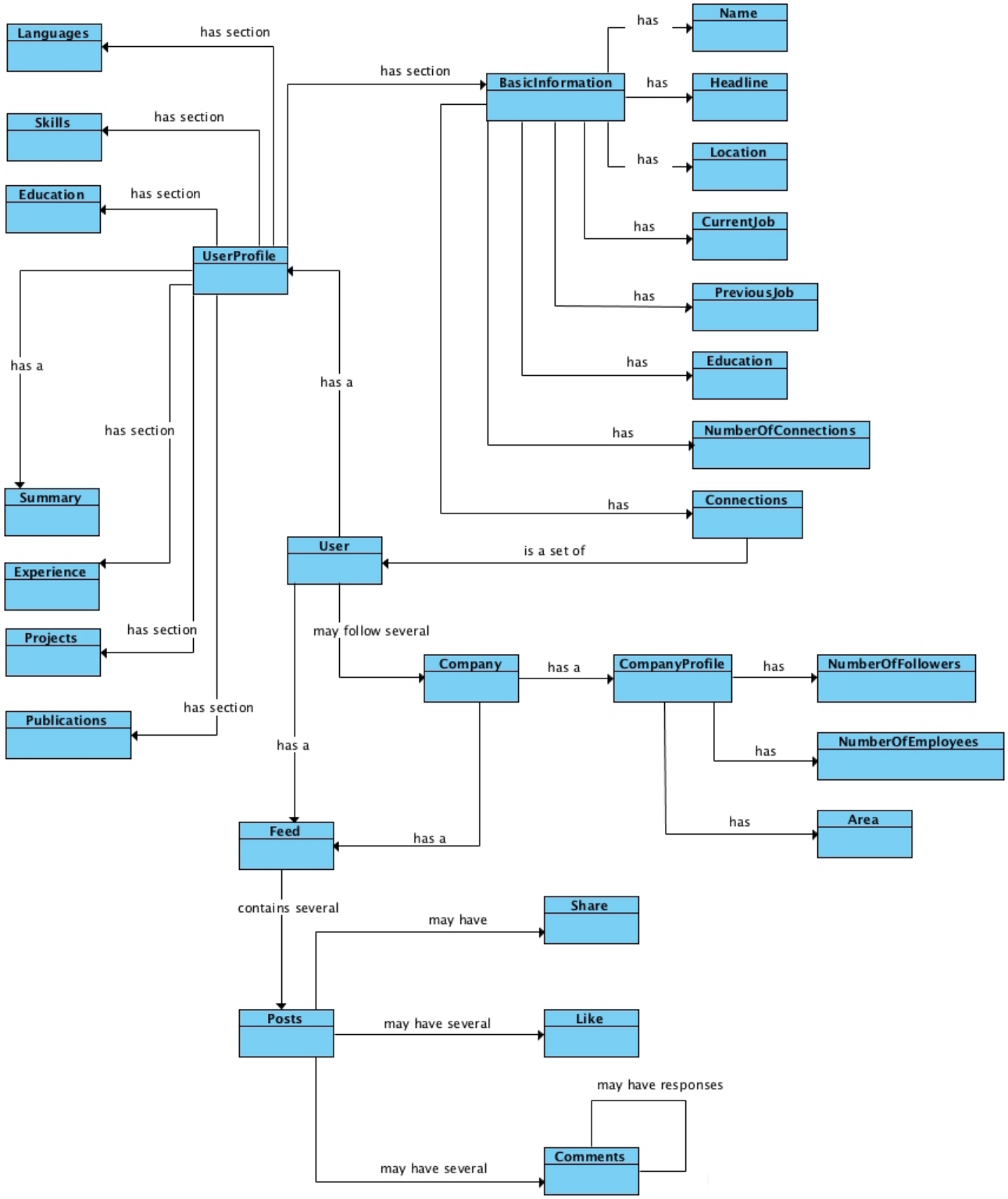

Figure 4: LinkedIn domain model schema.

Being a more purpose oriented OSN and focused on the professional world, makes LinkedIn platform more complex, even with a simplified representation of the domain model, as we can observe in Figure 4 it is schema [2] far more complex that Instagram, having more or a similar complexity comparing to Facebook.

In LinkedIn the user profile (*UserProfile* box) is very rich in terms of what is important for building an individual professional image (profile), starting by one individual's basic information (*BasicInformation* box) that has information like name, location and current and/or previous jobs. Then the user profile has several sections with very specific purposes such as professional experience (*Experience* box), languages (*Languages* box) or education (*Education* box), all this summed up give a very precise perspective of an individual's "professional appearence". At the bottom of the profile we have along with the professional recommendations and connections, the skills or expertise section (*Skills* box), this is one of the most attractive features in the LinkedIn platform. Skills in LinkedIn are a tagging system that allow user's to expose their expertise trough their public profile and then receive feedback on them according to their ability on that specific skill, this is a very important and promising feature for matching user's profiles with job positions requirements.

LinkedIn's main entities are not only users, the industry is massively represented in this network too. Companies may have a company profile (*Company* and *CompanyProfile* boxes) where they present the company, containing basic information such as number of people following the company number of employees (giving the idea of the company dimension) and the area where the company fits (pharmaceuticals, technology etc.) (*NumberOfFollowers*, *NumberOfEmployees* and *Area* boxes respectively).

Other important concept of LinkedIn is the user feed where the user can chronologically consult a series of posts produced by their connections or by companies that their follow.

LinkedIn API

LinkedIn provides a REST API (https://developer.linkedin.com/docs/rest api (2016)), but still similarly to the OSNs we been studying its very limited. In what concerns to data retrieval LinkedIn only allows the consult of basic profile data, this is the data retried from the LinkedIn interactive REST console:


```
{
"firstName": "Daniel",
"headline": "Graduate Front-end Developer at Blip.pt",
"id": "k_yk8W37WH",
```


2 In the schema presented on Figure 4, much of the platform complexity was simplified in order to produce a simple domain, and to narrow down this analysis to the core components and concepts of LinkedIn.

```
"lastName": "Caldas",
"siteStandardProfileRequest":  {
  "url": "https://www.linkedin.com/profile/..."
}
```


As we can see from the above data sample, we only could fetch some data properties, that would not bring value in terms of network analysis.

3.3.4 *ResearchGate*

> *"Founded in 2008 by physicians Dr. Ijad Madisch and Dr. Sören Hofmayer, and computer scientist Horst Fickenscher, ResearchGate today has more than 11+ million members. We strive to help them make progress happen faster."* researchgate.net (2016)

ResearchGate is an OSN built specifically for scientists, with the goal of easing the task of collaborative research around the globe. ResearchGate strikes to connect the world of science and make research open to all.

Domain Model

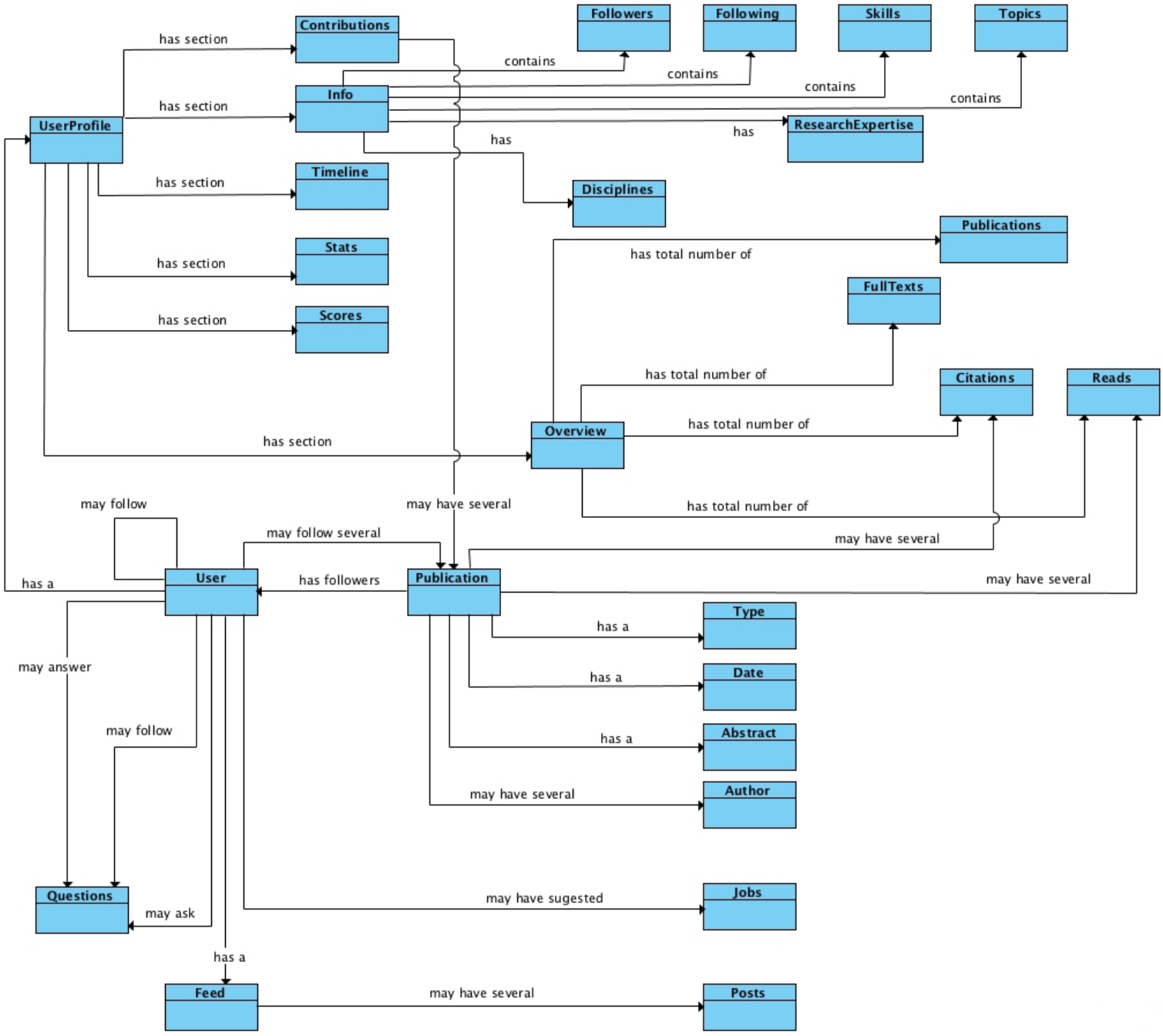

Figure 5: ResearchGate domain model schema.

Data Dictionary

Some terms on the schema presented in Figure 5 may be quite ambiguous due to the the specificity that they represent. In order to make the schema fully legible and before diving

into the domain model analysis, we present first, a small data dictionary detailing the terms one may found more ambiguous:

- **Scores** - This term represents a collection of metrics that evaluate the performance of a user based on his contributions and research experience. The user has also associated a global score;
- **Topics** - Topics represent the user's scientific areas of interest, ResearchGate uses topics to provide personalized suggestions;
- **Disciplines** - Represent more broad areas of the user education, expertise and interest;
- **Type** (*Type* box connected with the *Publication* box in Figure 5) - A type classifies a publication, this said, a publication may be an article, a book, a thesis a conference paper etc. .

Domain Model Analysis

ResearchGate is a peculiar OSN that despite having connections between individuals, it has alongside connections between individuals and scientific publications, making the publication (*Publication* box) a social object, playing the same role that videos play in Youtube for example.

Like LinkedIn the user profile (*UserProfile* box), is very detailed and builds up a very clear image of the researches work, positions and areas of interest. The relations among users are bidirectional, following the followers/following (*Followers* and *Following* box) strategy like other OSNs such as Instagram or Twitter. Very simillarlly to LinkedIn, a user's profile has a skills (*Skills* box) section, where skills are expressed in the form of tags, the tag description is far more specific than LinkedIn tags, that may some times acquire very abstract or high level descriptions (e.g. Technology Information). In ResearchGate tags have are very specific and are normally related with the user topics (*Topics* box) or disciplines.

Publications play along with the user a main role in ResearchGate. Normally publications have associated a type (already explained in the data dictionary section), a date, an abstract and may have one or more authors. The main metrics for Publications rating are the number of reads (*Reads* box) and the number of citations (*Citations* box) of that publication. The publications may also be followed by users that may have interest on particular publications.

Other concept of ResearchGate that raises the collaborative spirit among users, living up to the values that originated the platform, is the questioning system (*Question* box). Users may ask each other specific questions and have them answered by an expert on a specific scientific area, this opens up the possibility of having the best experts on a specific matter giving their opinion, thus the possibility of obtaining the *"best possible answer in the globe"*.

ResearchGate users' receive open jobs suggestions based on their profile, also user's have a post where they receive activity notifications of the people or publications that they are following.

API

Today ResearchGate does not provide any API for accessing its data or for any kind of interaction with the platform.

3.3.5 *Pinterest*

According to Pinterest (2016), Pinterest **is the world's catalog of ideas**. Created by Ben Silbermann, Paul Sciarra and Evan Sharp and launched in 2010, Pinterest is a simple but yet very original OSN, instead of aiming for connecting people like Facebook or LinkedIn, it aims for inspire people trough new ideas.

Domain Model

Data Dictionary

As one may notice from Figure 6, Pinterest introduces very particular concepts that may lack explanation, that is why we present first a small data dictionay before going trough the analysis, as we did with ResearchGate on a previous section:

- **Pin** - A Pin is the basic unit of Pinterest, it represents an idea of some user, presented in some context (the board context), and it is presented to us with a picture;
- **Board** - As the name suggests, a board is a collection of pins. Boards are created from users to other users, and normally present pins within some context (e.g. travels, technology, food etc.). In Pinterest boards may be followed by other users;
- **NumberOfPinedTimes** - This entity is not entirely a Pinterest entity, instead it represents a relevant metric introduced to measure pins popularity, and it refers to the act of saving pins. Pins that are presented to the users may be saved (or *"pinned"*), and the number of times that users have saved a particular pin is expressed in Figure 6 by the box *NumberOfPinnedTimes*;

Domain Model Analysis

Pinterest introduces new concepts forming a very original OSN, because it's very different from others that we analyzed previously. Just as we seen in ResearchGate, where the domain model is build around a social object (the scientific publication), with Pinterest we

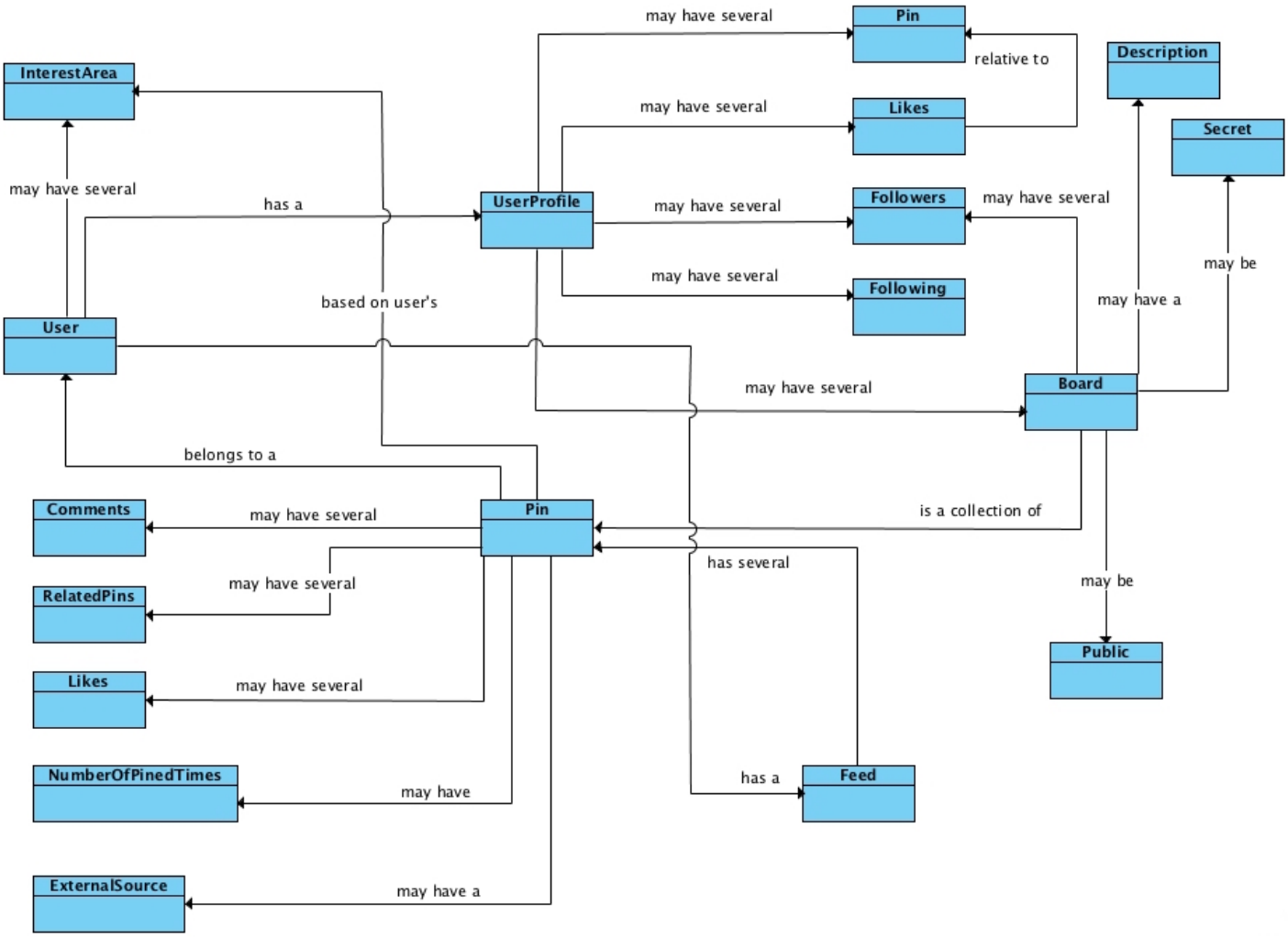

Figure 6: Pinterest domain model schema.

have a similar scenario, where the concept of the platform is built around a different social object the Pin (*Pin* box), which also as a grouped perspective introduced by a group or collection of pins that are the boards (*Board* pin). Pinterest is basically a set of pins aggregated in boards that are explored in the platform accordingly to the user's interests.

Simmilarly to other networks (e.g. Instagram) Pinterest also has direct unidirectional connections between users that adopt the concept of *"follow/following"* (*Followers* and *Following* boxes). As user's can follow publications in ResearchGate, Pinterest users may follow boards, being then notified if some pin is added to that specific board.

In what concerns to Pins, they may be commented by users (*Comments* box), they also may be targeted by likes as posts in Facebook (*Likes* box). A particular point concerning to Pins is that they can have a explicit external reference, for instance, if some image is extracted by some other web site or from other OSN they can be explicitly referenced, and that same reference appears at the top of the pin along with its title (*ExternalSource* box).

Pinterest was the traditional concept of feed, but in this case, the feed represents a completely different concept compared to other OSN. First the content of the feed (pins) is not related with users we follow on the network, is instead related is our personal interests (*InterestArea* box) and second, they are not presented according to a chronological order, and visually they do not follow the standards of typical timeline/feed design, instead the different pins displayed on some user's feed, form some kind of board or catalog, like the ones people use to hang in walls and pin post-its on it.

Pinterest API

According to Developers (2016), Pinterest provides a REST API for developers interact with the platform. The data restrictions follow Facebook politics, where the application that integrates Pinterest API can only fetch data for authenticated users. Pinterest provides endpoints to interact with users, boards and pins. Concerning to the requests limitation, Pinterest offers a 60 minute sliding window where 1000 requests can be made by unique user token.

3.3.6 *Twitter*

One OSNs that frequently is bring to discussion for being more of a *"news content generator"* is Twitter. Twitter is another of must most used OSN listed in Table 1, is basically a social networking microblogging service that allows their users to broadcast short posts (short because they're maximum size cannot exceed the 140 characters) called tweets. Twitter was created in March 2006 by Jack Dorsey, Noah Glass, Biz Stone, and Evan Williams, gaining fast worldwide popularity, Twitter has today more then 300 Million users according to Table 1.

Unlike many other social networks that have private or semi-public profiles with restrict policies concerning to exterior access to information within the network (examples of this kind of OSNs may be LinkedIn or Facebook), Twitter default settings are public, making tweets spread more effectively across all social media, this particularity makes Twitter one of the most *"barrier-free*" OSNs. Of course that despite unregistered people may read tweets they cannot interact with them as Twitter users by linking, comment or *"retweet"*[3] them.

3 The act of retweet consists and share some existent tweet originated by another user.

Domain Model

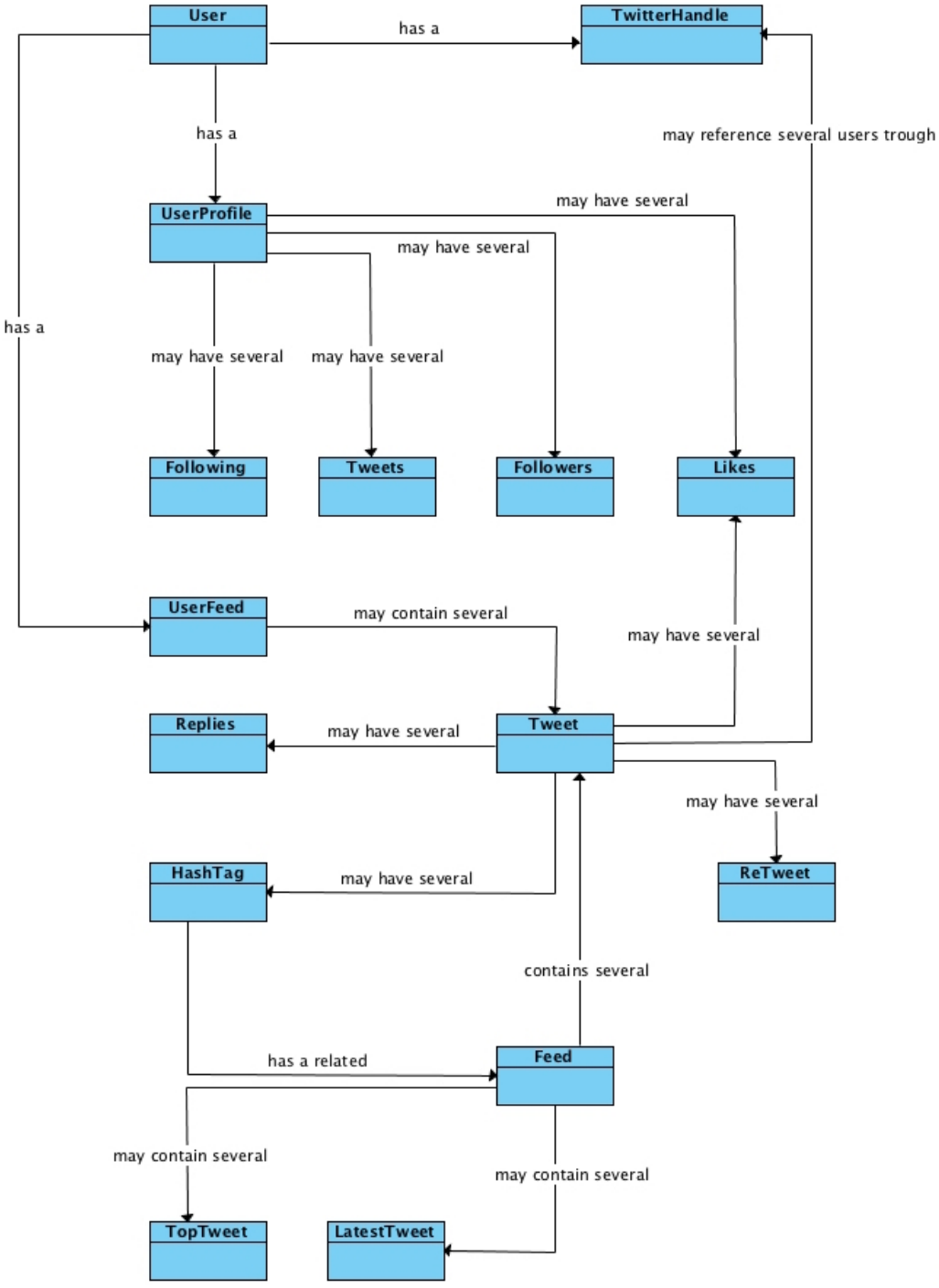

Figure 7: Twitter domain model schema.

Domain Model Analysis

In Figure 7 on may observe a very concise representation of the Twitter domain. Despite being a very minimalist OSN concerning to data properties and relationship complexity, Twitter has some very semantically strong features that brand the platform, being those features used among other well known OSNs such as Facebook. We are referring specifically the hashtag ((*HashTag* box) and the (*TwitterHandle* box), but let us first introduce some of the more basic features.

As usual in these kind of platforms, Twitter's users posses a user profile (*UserProfile* box) that as attached to it some properties and user metrics such as number of followers, number of tweets, number of other users the user is following, and number of likes the user has obtained across all his or her tweets (*Followers*, *Tweets*, *Following*, *Likes* boxes respectively).

The tweet is the basic unit of Twitter, is trough tweets that information flows in Twitter. Also tweets may have several comments, and they may be *retweeted*. Now back to hashtags and twitter handles. Hashtags is in some way how these chaos of unstructured tweets gain some semantic value, in order to a group tweets according to a specific matter. Hashtags may in many cases be misleading, because users start to adopt hashtag to express sentiments or simply describing a tweet pushing back to the already mentioned unstructured chaos. Twitter handles are the same as tags in Facebook they serve as a mean to mark a specific twitter user, a twitter handle may be used in a comment or in a tweet leading directly to the respective user's twitter profile.

Twitter API

Similarly to other OSNs, twitter provides a REST API to fetch users data such as profile data, tweets or user's followers. Restrictions are felt again this API is very limited providing a 15 minutes window for making http requests.

Other data sources

As more and more of OSN appear to be closing doors to data availability even when for research purposes one may want to search for alternative data sources to feed the system that we intend to build along this project. Projects as KONECT (Kunegis (2013)) provide large data sets of networks collected online so that researchers may perform all types of operations and experiments on that data. This kind of alternatives are very valuable in terms of network analysis even for real time data analysis systems that may in a more immature phase of the project benefit from this data sets.

> *"KONECT (the Koblenz Network Collection) is a project to collect large network datasets of all types in order to perform research in network science and related fields, collected by the Institute of Web Science and Technologies at the University of Koblenz–Landau."* Kunegis (2013)

3.3.7 *Summary*

In this section we have explored with some detail six of the OSNs listed in the Table 1. In this analysis we followed a similar approach for analyzing each OSN, adding only an additional step for the more domain specific OSNs, that were ResearchGate and Pinterest, which was building a small data dictionary in order to ease the interpretation of the domain model schema.

From the analysis we may draw some generic conclusions concerning the domain of each OSN. Despite the differences and specifics of each platform, all them sum up to the basic primitive concepts of social networks, that are **actors** and **relational ties** between them, which form **subgroups** originating **groups** that build the network. This being the high level conclusion for our analysis, there are other patterns that emerge when analyzing different OSNs like the **user profile** that is a key element characteristic of this platforms and **feeds** (or **timelines**) that represent a standardized way of communicating events within a OSN.

3.4 How Online Social Networks Have Changed The World

Social media have clearly shifted the way we communicate and we perceived the world, simply putting it, nowadays with social media one can say that social media is responsible for *"everyone talking to everyone about everything all of the time"*.

According to Duggan (2015), 62% of the entire adult population in on social media. As an example of events that were clearly influenced by social media, we have the presidential campaign of Barack Obama in the United States, started in 2007 and ended in 2009, Barack Obama had as his campaign technological adviser Chris Hughes, co-funder of Facebook, who played a crucial role in the camping trough online social media. The outcome of the election of 2009 could have been very different without the online social media.

According to Farida Vis (2016), a very interesting reflection is made on how social media impact the world, and the six major drawn conclusions are the following: **across industries, social media is going from a *"nice to have"* to an essential component of any business strategy**; **social media platforms may be the banks of the future**, as example we have the bank customer profiling trough social media in order to get a loan; **social media is shaking up healthcare and public health**, because information is spreader *at the speed of light* trough social media, this means less struggle to achieve public health and well

being awareness; **social media is changing how we govern and are governed**, with OSNs public participation has grown and everyone can participate in their opinion making people voices louder, bringing more credibility to the democratically system implemented by many governments across the planet; **social media is helping us better respond to disasters**, as the health public awareness improved trough social media information propagation speed, so did improved the response of governments and institutions to disasters such as natural disasters, in countries that may have not the services or infrastructure to respond to some catastrophes, making social media and crucial component to raise awareness across the globe, that have impact in help mobility, or fund raising for supports the damages made by certain disaster; **social media is helping us tackle some of the world's biggest challenges, from human rights violations to climate change**.

If we look particularly to the most globally used OSN, as reported by Elgot (2015), there are pointed out *"seven ways Facebook has changed the world"*, we are going to point and comment out some of the more relevant. **Facebook has changed the definition of friend**, if back there having a dozen of friends was already a very large number of relationships, with Facebook the new limit was raised up to the hundreds or thousands of friends, the concept was given a completely new meaning, since we don't need to know a person face to face so that one becomes friend with the other, one simply needs to click the *"add friend"* button, and it does not matter if it is one's neighbor or some other person on the another side of the planet; **We care less about privacy**, *"if you are not paying for it, you are the product"*, means that we are not paying for using Facebook or any other OSNs, this said we must retain that these online platform profit from our information and from our interactions, but even being the major of the users aware of this situation, that doesn't seems to bother anyone; **Facebook has created millions of jobs – but not in its own offices**, for example the marketing industry suffer a revolution since the raise of the social media, there are jobs for people to manage business and brands profiles on OSNs it's also a new way to approach customers, as we have seen previously with banks; **Facebook has been the tool to organize revolutions**, protests and awareness campaigns are raised inside facebook, this is related to the political influence and awareness capacity that we previously have pointed out in this same section.

Now switching to the negative aspects of not only Facebook but OSNs and social media in general. Very strong campaigns were raised against social media, for instance, *"The Anti-Social Network"* a short film depicting a life of an adult which as become obsessed with social networking at the point he starts to break boundaries between his real life and his virtual one. Strategically or ironically this campaigns use social media to spread the word.

We have seen that social media had a great deal of impact in society, what about our bodies? There are numeral studies on this matter, focusing on finding the true negative impacts of OSNs on our personal health. According to Lin et al. (2012), scans to brains of

people how excessively use social media, point out that there is a clear degradation of white matter similar to people who are addicted to substances such as drugs or alcohol, in the regions that control emotional processing, attention and decision making, because social media immediate reward (instant feedback) with very small effort, this causes the brain rewire itself make us to desire this stimulations Berridge and Robinson (1998). Another common situation among OSNs users is the idea of multitasking, the felling that one is able to being productive in some task while browsing on social media. Well according Ophir et al. (2009) users who heavily use social media are more susceptible to interference from irrelevant environmental stimuli, leading this users to perform worse on a test of task-switching ability, because they were not able to filter out interferences.

4

SOCIAL NETWORK ANALYSIS

Social Network Analysis (SNA) is the study of how people are connected to each other, basically it studies a set of relations among a set of entities, these entities may be individuals, organizations, or even countries.

The common analysis procedure consists in mapping the network and then creating metrics to characterize the network. Then one tries to figure what is the structure of the network and why does it have that structure. SNAs is also about looking at the individuals inside the network and where are those individuals located.

4.1 FUNDAMENTAL CONCEPTS FOR NETWORK ANALYSIS

According to Wasserman and Faust (1994), the concepts listed below are of key importance to understand SNAs.

- *Actor* - SNA is concerned with understanding the linkages among social entities and the implications of these linkages, these social entities are described as actors. Actors are discrete individual, corporate, or collective social units.
- *Relational Tie* - Actors are linked to one another trough *social ties*. The type of ties may be extensive, and it describes the nature of the connection. Some example of ties:
  - **Evaluation** of one person by another;
  - **Transference** of resources (business transactions);
  - **Association** (to social event or cause);
  - **Behavioural** interactions (communicating);
  - **Moving** between places or statuses (migration, social or physical mobility);
  - Others may be: physical connection (roads, rivers), formal relations (authority), biological relationship.

- *Dyad* - The most basic relationship that can be established is a dyad, a connection between two actors.
- *Triad* - A relation established between three actors. Many studies included breaking SNs down to small groups (triads), this allowed a more clear conclusion about the transitivity of the connections.
- *Subgroup* - It defines any subset of actors in a SN (conceptually, subgroups come after dyads and triads).
- *Group* - A finite set of actors who for conceptual, theoretical or empirical reasons are treated as a finite set of individuals in which network measurements are made.
- *Relation* - A collection of ties of a specific kind among members of a group is called a **relation** (e.g. a connection in *LinkedIn* is a relation while evaluating our connections of sending them messages are ties).
- *SN* - With the definitions of actor, group and relation, a SN consists of a finite set or sets of actors and the relation or relations defined on them. The presence of relation information is critical and defining feature of a SN.

4.2 GRAPHS THEORY

Graphs are typically the base of representation of social structures. This mathematical approach maps with extreme convenience social networks. Nodes are individuals, and edges are relationships. Despite looking a quite simple approach, there is a very strong theoretical background that is of basilar importance for interpreting social networks. In the next sections we will explore how graph theory and network analysis coexist in order to provide more formal metrics for analyzing network structures and provide information about each node within the network.

4.3 NETWORK ANALYSIS OVERVIEW

In this section we intent to explore the scientific concepts behind network analysis, always trying to map them to reality, so only the core and applicable concepts will be explored in this section, namely:

- ***Power Laws*** - Power laws or power law distribution, represent in general a dependency relationship between two quantities. In SNs, power law distribution describes a particular trend in the evolution of the number of relationships of individuals within a network;

- ***Centrality Measures*** - Centrality measures aim to answer the following question ***Which vertices are important?***. In a SNs, an actor centrality measures the actor's interactions with other individuals;

- ***Link Analysis*** - Link analysis is a well known term form web search engines, popularized by the Page Rank algorithm. In SNs, link analysis measures individuals connections, such as identifying strongly connected nodes, absorbing nodes or even cycles inside networks;

- ***Community Detection*** - Community detection is related to clustering in social networks. Normally when analyzing SNs we aim for detecting communities (groups) that express similar ideas in matters such as politics, music or philosophy. Community detection is a far more abstract concept than geographical clustering, despite we often found it in OSNs such as Facebook, that the two concepts are tightly coupled;

- ***Spread of Information*** - Spread of information consists in a set of metrics that classify the propagation of the information within a network. Considering a Facebook post by a newspaper, it would come in hand to know, where was the starting point of that post, how many individuals it reaches, in which sub-networks the information was propagated, what were the entry points of for that sub-networks, how fast the information got to the individuals, these are some of the concerns relating to spread of information;

- ***Social Learning*** - Social learning consists in the change of behavior or beliefs based on direct observation of other individuals. Considering again a Facebook post by some random individual A, and consider an individual B that shares (*'re-posts'*) the individual's A post. If one detects a pattern in this kind of interaction, one may say that individual B is learning from individual A (imitating, mirroring).

Some of the previous listed concepts represent metrics for analyzing networks, thus requiring a more detailed explanation. In the next sections we will focus one the most fundamental metrics that will be relevant for further reference in this document. [1]

4.4 RELEVANT METRICS FOR NETWORK ANALYSIS

These are crucial metrics that will be referenced within integral components of our system (that we will propose in the next Chapter 5). We will use these metrics to add value to analysis features that we will provide to the end user. For that we must first address this

1 At this point, and being network analysis basic concepts being covered it is normal that we interchangeably use the terms actor, node or vertices for denoting the same things

concepts with a smaller granularity in terms of what they represent and also in terms of what can they offer us.

4.4.1 *Centrality*

Centrality if often mixed with node degree. Despite node degree being in fact used for centrality calculations, these metric have some variations that are worth to take a close look, in order to understand the different perspectives from where we can observe a particular node in a particular network.

Degree Centrality

Degree of a node is equal do the his number of adjacent nodes (or simply the number of first degree connections). So basically what do we get from this metric? When normalized the node degree value tells us the level of direct interaction of an actor with other actors within a network.

Closeness Centrality

Closeness centrality tells us how close an actor is to all the other actors in the network (not only with his first degree connections).

This metric is considered a sophisticated measure of centrality in network theory. It is defined as the mean geodesic distance (i.e., the shortest path) between a certain vertex v and all other vertices reachable from it. This concept is normally associated to geographic distances, being actors closeness mapped to reality. Still there are abstractions that compute this value not considering nodes as geodesic markers (politaktiv.org (2011)).

Betweenness Centrality

This measure reflects the number number of shortest paths going trough a particular actor. **Nodes that occur in many shortest paths** between other nodes in the network have a higher betweenness centrality, basically takes into account the connectivity of the nodes' neighbors, giving a **higher value for nodes which bridge clusters** (politaktiv.org (2011)).

Eigenvector Centrality

This measure is based on the following statement:

> ***"Importance of a node depends on the importance of its neighbors."***

Eigenvector centrality (politaktiv.org (2011)) measures importance of a node within a network. This measure assigns relative scores to all nodes, then if a node is connected to a

high scored node it has a bigger increment to its score then when connected to a *low scored* node. One of the most famous variants of eigenvector centrality is the Google's PageRank algorithm (Brin and Page (1998)).

Page Rank

PageRank algorithm (Brin and Page (1998)) was thought as a way to rank online content (online sites) in order to discover what sites are important and really worth to consult. The algorithm sums up a score for every node (web site), this score is in some way proportional to the number of times a site is cross referenced (linked by other web site), gaining higher score, on the other hand when a site links to other that has a high score it loses score, meaning that is a less important site.

4.4.2 *Clustering and Community Detection*

Represents the value of tendency for certain nodes to form a cluster. Normally actors within a network tend to aggregate when having some simple characteristic in common such as living in the same city, working in the same place or event frequenting the same gymnasium.

A common approach for detecting communities is trough graph clicks (subset of vertices of an undirected graph where all vertices are connected between each other), being the normalized clustering coefficient a high value when the network consists in a set of disjoint clicks.

4.4.3 *Node Dominance*

Dominance may be related with betweeness centrality but it focus particularly on node reachability. One may say that a node $v1$ dominates a node $v2$ if $v2$ needs to go trough $v1$ to reach a certain node $v3$.

4.5 SMALL WORLD PROBLEM

This principle of *small-world phenomenon* is based on the idea that all human beings are connected by **short chains of acquaintances**. The pioneer of this work was Stanley Milgram (Travers and Milgram (1967)).

Six Degrees of Separation

The concept of six degrees of separation is an extension of the small world problem. In the sequence of what we state before, the six degrees of separation materialize the previous concept in six interconnections for some individual to reach any other one. Six degrees of separation gained a particularly strong relevance, when a play was written in the 90's portraying the concept.

4.6 NETWORK VISUALIZATION

Network visualization may be considered as a science by itself. In the context of this project we will not look further into network visualization, we will instead in further chapters (more technical chapters) reference advanced visualization technologies that will help us on the tool implementation serving as a fundamental complement to social network analysis.

4.7 SOCIAL NETWORK ANALYSIS SOFTWARE

> *"(...) more sophisticated graphics capabilities should make exploratory studies using visual displays of networks more fruitful. One should be able to display actor attributes and nodal or subgroup properties (such as expansiveness, centrality, or clique membership) along with the graph. (...)"* Wasserman and Faust (1994)

4.7.1 *Software Tools*

Next we present some relevant software tools on SNAs.

4.7.2 *Structure*

The program Structure Pritchard Lab (2000) is a free software package for using multilocus genotype data to investigate population structure. Its uses include inferring the presence of distinct populations, assigning individuals to populations, studying hybrid zones, identifying migrants and admixed individuals, and estimating population allele frequencies in situations where many individuals are migrants or admixed.

4.7.3 *Gephi*

Gephi Bastian et al. (2009) is a tool for keen data analysts and scientists who want to explore and understand graphs. Like Photoshop™ but for graph data, the user interacts with the representation, manipulates the structures, shapes and colors to reveal hidden patterns. The goal is to help data analysts to make hypothesis, intuitively discover patterns, isolate structure singularities or faults during data sourcing. It is a complementary tool to traditional statistics, as visual thinking with interactive interfaces is now recognized to facilitate reasoning. This is a software for Exploratory Data Analysis, a paradigm appeared in the Visual Analytics field of research.

4.7.4 *UCINET*

UCINET 6 Lin Freeman (2002) for Windows is a software package for the analysis of social network data. It was developed by Lin Freeman, Martin Everett and Steve Borgatti. It comes with the **NetDraw** Borgatti (2002) network visualization tool.

4.7.5 *SocNetV*

Social Network Visualizer Kalamaras (2004) is a cross-platform, user-friendly application for the analysis and visualization of Social Networks in the form of mathematical graphs, where vertices depict actors/agents and edges represent their relations.

With SocNetV you can construct social networks with a few clicks on a virtual canvas or load field data from various social network file formats such as GraphML, GraphViz, Adjacency, Pajek, UCINET, etc.

Furthermore, you can create random networks using various random models.

4.7.6 *NetworkX*

NetworkX Hagberg et al. (2013) is a Python language software package for the creation, manipulation, and study of the structure, dynamics, and functions of complex networks. NetworkX relevant features are listed below:

- Python language data structures for graphs, digraphs, and multigraphs;
- Many standard graph algorithms;
- Network structure and analysis measures;
- Generators for classic graphs, random graphs, and synthetic networks;

- Nodes can be "anything" (e.g. text, images, XML records);
- Edges can hold arbitrary data (e.g. weights, time-series).

4.8 Real World Applications

Here we will present some of the real world applications of SNAs with special attention for developed projects with a similar focus to this master's dissertation, and other tools of OSNs that cross many fields of studies. Two examples of projects with similar focus to this master's dissertation are:

- ***Vizster*** (Heer and Boyd (2005)) - Visualizing online social networks. A visualization system for playful end-user exploration and navigation of large-scale online social networks.
- ***Project Palantir*** (Facebook (2008)) - This is an impressive tool that displays the rate of interactions on Facebook across the globe.

5

SYSTEM ARCHITECTURE PROPOSAL

Before diving into the architectural details of the system, we first present a state of the art summary, that concisely describes what is the positioning of this project in light of the previous explored SNAs tools that we presented in Chapter 4, and also considering the OSNs that we study in Chapter 3.

Specifically regarding the SNAs tools, we will comment some of them, some of their useful features and overall comments to what may lack on this tools that this project may target, in order to differentiate and not only *"reinvent the wheel"*.

5.1 SIMPLICITY

Aside of **Vizster** (Heer and Boyd (2005)), the majority of the previously presented tools such as Gephi Bastian et al. (2009) or Social Network Visualizer Kalamaras (2004), are very complex tools with very heavy interfaces, that have a big learning and are meant for users that have particular advanced knowledge in SNs and SNAs. The tool to be developed could also serve for less expert users, providing a set of core basic functionalities (e.g only allow users to load and visualize they're networks), and then, allow the user to build complexity from there enabling and disabling other features.

5.2 ACCESSIBILITY

All the software that we presented above exists in the form of desktop applications. This applications need to be downloaded, and installed in a compatible machines (sometimes with dependencies on other software that is not installed by default). Nowadays almost every application is web based, this allows users to access them every where trough a browser, making web apps a solution that is Operating System and device agnostic. This said, building a web based social networks analysis tool could be a way of tackle the accessibility of such tools.

A web based application, it's good for sake of accessibility but in another hand it is a

performance culprit when it comes to performance. This is a decision to take into account, but always having in mind that tackling performance it's not the main goal this master's thesis, also, the mentioned tools are mature projects that are highly performant and are capable of rendering huge networks.

5.3 Online Social Network (OSN) integration

Social Network Visualizer Kalamaras (2004), allows to *scrap* web sites to build networks, but for this feature relays only on links to build the network (it blindly scraps recursively some url to build the network). By allowing the user the power to the user to analyze networks that are directly reporting they're social network status would be a differentiation factor from the other tools, and would certainly be a more meaningful and valuable analysis for the end user.

5.4 drawing accurate conclusions

As we state before when talking about simplicity, the mentioned SNAs tools provide generic metrics on networks such as network density or actor centrality. The values outputted from this tools are the result of running generic formulas and algorithms against some networks, so its very common for current SNAs researchers to be worried about the size of the network, being their focus on **quantitive analysis**.

In a hypothetical analysis scenario where some researcher has a network with a few thousand nodes, **what is the meaning of his assumptions when analyzing the network**? Since this is a pure quantitive analysis the numbers will seem reasonable for the given network, but this will not allow him to extract contextual conclusions, because in this case analyzing data form Facebook or analyzing data from LinkedIn will sound just like the same, because deep down it all comes down to the network. A better approach for drawing conclusions would be to have a mixture between **quantitive analysis** and **quality analysis**, the tool could do some content and context analysis to help the end user to get a more meaningful conclusion rather than just simple metrics.

5.5 system positioning and tools comparison

In this section we will make a high level comparison between the software tools presented in Chapter 4. In Table 2 we can observe the tools classification based on some pre defined metrics that well show the positioning of the proposed system, these metrics are:

- **Availability (Desktop or Web)** - Whether the tool available trough a desktop application or a web application;
- **Complexity (Low, Moderate, High)** - Whether the tool has very complex features that require expertise to be used, also we may consider the learning curve for using the tool with efficiency;
- **Performance (Low, Medium , High)** - Whether the tool is performant, if it computes metrics with velocity and if it renders dense graphs without struggle;
- **Network Editor (Yes, No)** - Whether the tool allows network editing, such feature allows adding nodes and edges to existing network or event creating new networks from scratch;
- **OSNs Integration (Yes, No)** - Whether the tool is able to integrate data analysis of OSNs.
- **Contextual Analysis (Yes, No)** - By contextual analysis we do not mean that the user will not be aware of the network context, our contextual analysis has a strong meaning, it represents the capacity that the system demonstrates (or not) to be aware of the context of the network and providing metrics with a specific meaning.

Tool	Availability	Complexity	Performance	Network Editor	OSNs Integration	Contextual Analysis
Structure	Desktop	Moderate	Medium	Yes	No	No
Gephi	Desktop	Moderate	Good	Yes	No	No
UCINET	Desktop	High	Very Good	Yes	No	No
SocNetV	Desktop	Low	Medium	Yes	No[1]	No
Our system	Web	Low	Low	No	Yes	Yes

Table 2: Software tools comparison and our system positioning.

As we can observe in Table 2 our system has essentially three differential factors, that are: web availability; OSNs integration; contextual analysis; being the trade off for such gains the system performance. When describing our system compared to the other tools we want to be able to have a web tool that has a complexity level similar to SocNetV.

5.6 System Architecture

Now, after building up our aiming for this project, we now present a more concrete image of the overall system. In Figure 8 we present an abstract system architecture.

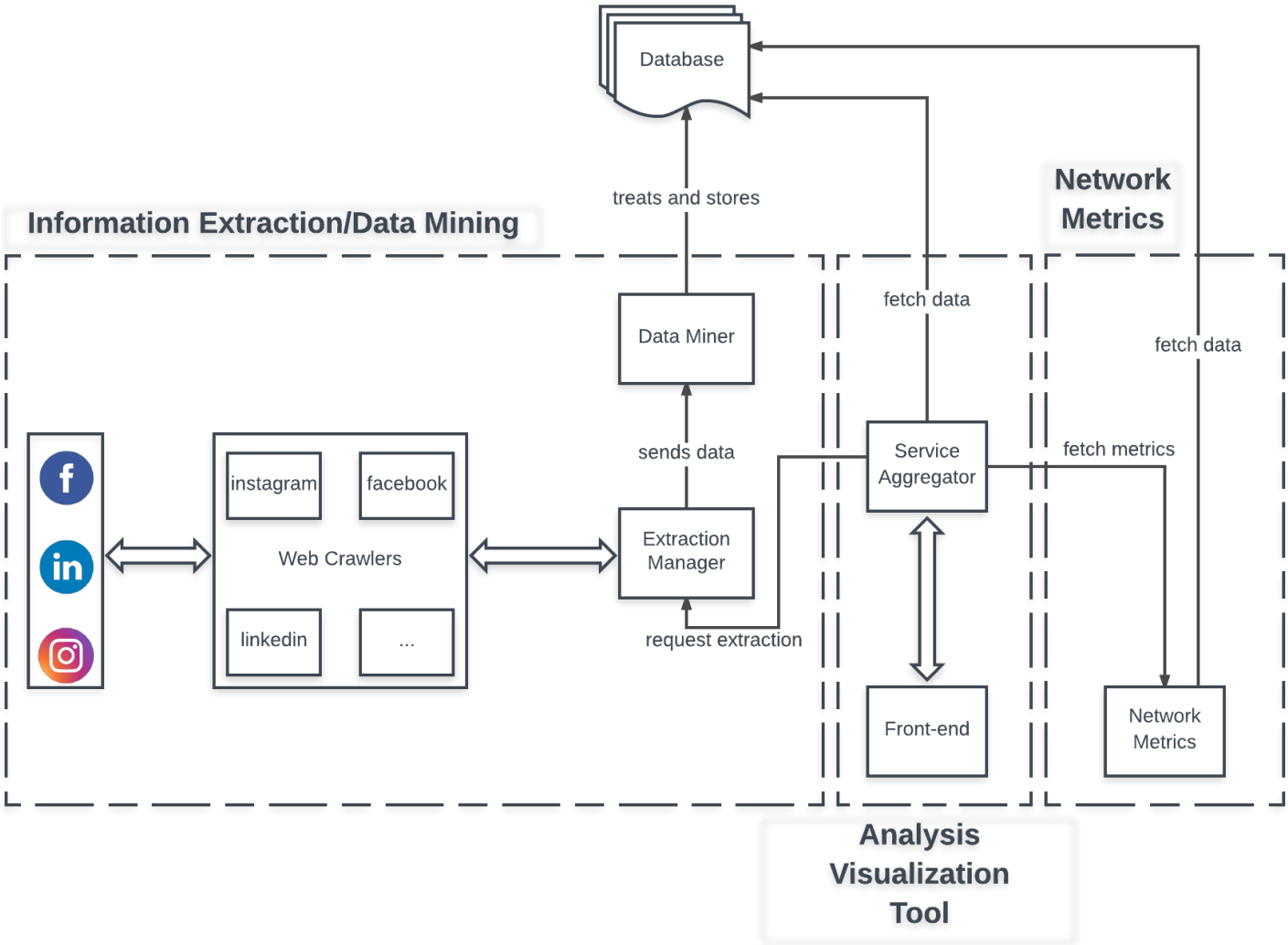

Figure 8: System architecture proposal.

5.6.1 *General overview*

As the interaction of the software components may be clear from the diagram, the role of each module is not clear by simple diagram observation, an underlying explanation of each component is needed in order to understand the system.

We will follow a *top down* approach for explaining the system architecture. First let us be clear about the two main and distinct parts of the system:

- ***Information extraction and data mining*** - All the other components are built for extracting information from existent databases, or from OSNs (through the **Web Crawler**) and store information being information properly treated before stored;

- ***Network metrics*** - This module acts as a isolated component that is dedicated to perform calculations and algorithms on stored networks. It will feed metrics as requests by other components;

- ***Analysis and Application/Visualization*** - The tool that directly interacts with the end user is composed by a **Service Aggregator** that fetches data from a database, requests extractions to the application back-end and runs calculations and algorithms on top of stored networks as the user requests by interacting with a **Front-end** that provides the visualization and interaction features.

5.6.2 *Detailed Components Description*

The components presented in Figure 8 more detailed explanation, next we look more carefully into each on of the components.

- ***Online Social Network (OSN)*** - This are the object of study, the source of information that the systems will process and analyze;

- ***Web Crawler*** - The **Web Crawler** consists in a set of modules for crawling each one of the OSNs (*fb-extraction* and other modules);

- ***Extraction Manager*** - This module consists in a wrapper for extracting information from social networks, and allows extraction orchestration spreading extraction processes along multiple hosts, so that we can mitigate the slowness of web crawlers and extraction process in general;

- ***Data Miner*** - The data mining process assures that we store a well defined data schema that describes in the more simplified way the state of the networks;

- ***Database*** - The database is where we store our data. It is not represented by the *classical cilindro* because it resembles relational databases, and the possibility of using non relational databases such as document databases, grows strongly within the project, and the reason is the unstructured data that we will be storing into our database. We also plan on feeding some data trough already existing databases, instead of crawling data from OSN. This databases may be provided from projects that we already mentioned in this document (Section 3.3.6), such as Kunegis (2013). This data would be accessed through the **Data Miner**, or a new module could be constructed exclusively to feed this data to our database;

- ***Network metrics*** - These module fetches data directly from the database in order to perform network operations that may be heavy. Isolating this component will allow

logic separation from the service aggregator and will allow a separated infrastructure deploy, so that we may have dedicated computer resources on network metrics calculations;

- ***Service Aggregator*** - Ideally this component application will read the already normalized information from the database, run SNAs calculations and algorithms against the stored networks, and request data to the back-end (the Information extraction and data mining super component). The Service aggregator is also responsible for communicating with network measures component in order to fetch metrics about a given network as the user requests to access it;
- ***Front-end*** - The front-end will render the networks to the user, and will allow the user to interact with the network; these interactions will be defined in the requirements specifications.

6

SYSTEM REQUIREMENTS

In this chapter we will specify with detail the system requirements and particular features to be implemented. The requirements will be divided in two major sections.

First we will describe what tasks the Back-end of the system should perform in order to provide all the data and tools for supporting the system Front-end. Then with the end user in mind we will define the tool requirements from the user point of view. For aggregator that is part of the Front-end no requirements will be specified since this component will only bridge requests from the Front-end and the Back-end or will eventually fetch data directly from the database.

6.1 SOCIAL NETWORKS PRIORITIZATION

Before diving into the requirements we first will review our OSNs preferences regarding information extraction and the interest we have in analyzing this specific networks.

First we want to analyze **Facebook** because it is the more general purpose network, the more popular and the more used thus allowing us to derive more interesting conclusions since the resultant graphs will be more realistic having a more concrete social structure representation. Second we want to analyze **LinkedIn** because it also widely used and the only one that specifically focus on professional worldwide networking, generating different kinds of graphs and understand how companies and professionals are interacting online. Analyzing LinkedIn may also introduce an interesting analysis that is merging information from Facebook and analyzing friendship networks within professional networks.

Having two networks embedded in the system proves that we can analyze social networks in general since we have more then one and with different purposes, but since the system is designed to simply accommodate new networks simply adding a new extraction module should the major part of the work to integrate a new OSNs, this said we could eventually also implement some extra modules to the remaining OSNs listed in Chapter 3.

6.2 BACK-END

As seen is Figure 8, our Back-end is essentially composed by essentially two parts: **web crawlers/extraction modules**; **extraction manager** and the **data miner**, we will write the requirements for each one of the components. We will not prioritize this requirements (as we will do in the next section for the Front-end requirements) because **all listed requirements are essential for the overall system usefulness**.

6.2.1 *Web crawlers*

Each web crawler (or extraction module) must fulfill common requirements that are listed below [1]:

1. Web crawlers should be able to login with an user account (an *entry point*);
2. Web crawlers should be able to navigate trough the pages of a given OSNs;
3. Web crawlers must be capable of performing "human" interactions such as click and scroll;
4. Web crawlers should be able to output a pre defined (agreed and formally defined in the next section) data schema, covering eventual exceptions due to privacy limitations;
5. Web crawlers must be able to perform user extraction with second order depth, from the user entry point perspective (this means that we want to extract user's friends and friends of friends information);
6. Extraction modules should provide a global extraction method where extraction parameters can be passed from the outside reducing or amplifying scope of extraction as specified from the outside (e.g. under given circumstances we may only need to extract the friends' list or the basic information like name, city and birth date);
7. Extraction modules must be available to the data miner trough a web API in order to allow remote and distributed extraction. The web API must wrap all the different supported OSNs being each one accessible trough a different path within the same web API. The extraction web API required specifications are presented next:
   - **GET /api/v1/extraction/{osn}** - should return a confirmation message signalizing that API is up and ready for receiving requests;
   - **GET /api/v1/extraction/{osn}/{user_id}** - should perform full extraction of the user with the *user_id* in the *osn* ;

1 These requirements are agnostic to the OSNs context

- **POST /api/v1/extraction/{osn}/{user_id}** - should receive a set of and set of options, that parameterize the extraction and reduce the scope of the extraction for a given *user_id* within some *osn*.
- **POST /api/v1/extraction/{osn}/** - same as the previous but instead of performing extraction for a given *user_id*, performs it to a set of *user_ids* performing multiple extractions;
- In API version 1 **osn** must be one of the following: **facebook**, **linkedin**;
- **user_id** is a string that uniquely represents the user within a specific OSN.

6.2.2 *Extraction Manager*

Below are the extraction manager requirements [2]:

1. Orchestration of extraction processes scattered trough various hosts: one should be able to define a list of hosts and the number of extraction processes that each host should handle;
2. Chunk an entry point (that is a set of user identifiers within the OSNs) in order to delegate different users to different hosts;
3. Call the extraction endpoints according to the OSNs from where we need to extract data;

Extraction pipeline

Being listed above the requirements for each component we will now draw the specification of what is the expected workflow for data extraction, in Figure 9 we design a pipeline that tries to reflect with maximum detail, the listed requirements. The diagram will not cover the data mining process that is responsible for normalizing data and store it. This diagram is exclusively focused on how we pretend that data extraction is achieved in order to mitigate the slowness of web crawlers.

As we can see from Figure 9 we aim to follow a very straight forward process in order to extract information. First we provide an entry point for a given OSNs (the user the web crawlers will use to log in into the social platform), and a hosts files that describes the resources available for extractions, this is intended to be simply a list of hosts (ip addresses) that have the extraction web API running and awaiting for extraction requests.

Next each extraction API instance is responsible for handling a session of some web crawler instance and waits for it to return data so it can give it back to the extraction manager.

2 Again, these requirements are agnostic to the OSNs context

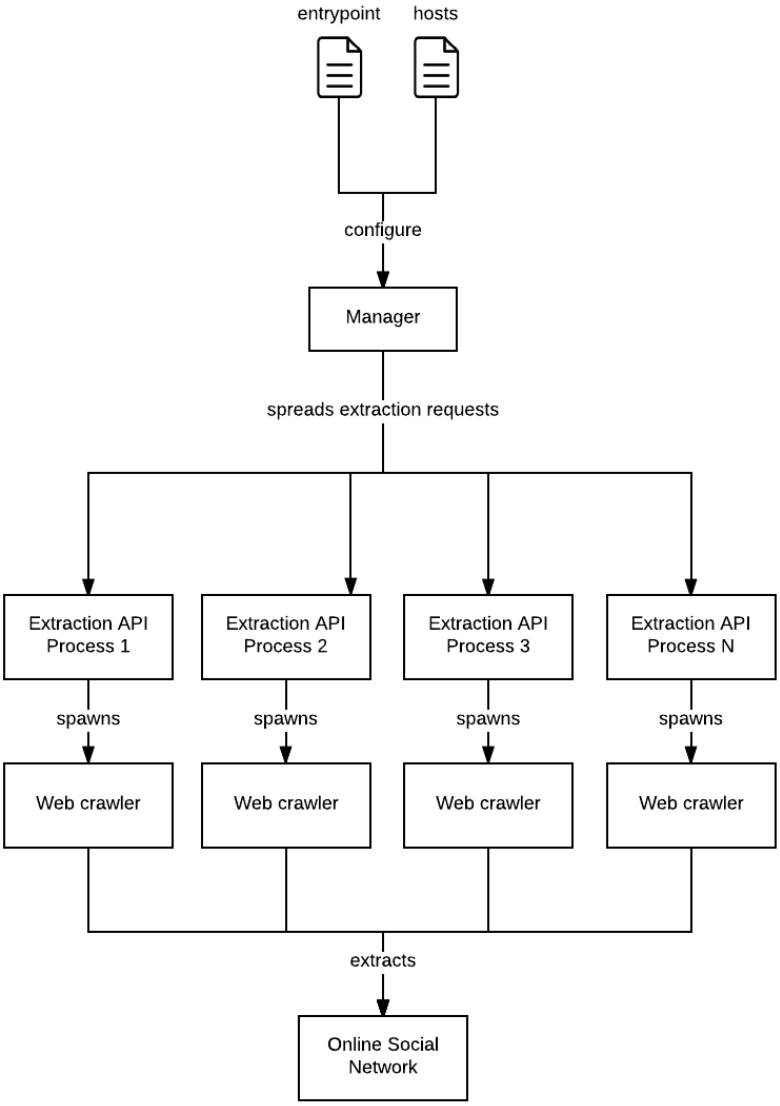

Figure 9: Extraction pipeline diagram.

6.2.3 *Data miner*

The data miner simply assures some data treatment before storing it on the database, that said there is a very narrow requirements list for this component:

1. Receive extraction data and normalize the fields that may need some treatment giving as result a normalized data structure;
2. Store normalized data in the database;
3. Assure that the data schemas (these are presented in the next section) are well defined.

Data schemas

Defining data schemas in earlier stages of system specifications will allow us to develop the Front-end and the Back-end simultaneously, we must for that consider that the only source of true when it comes to data structures is a well agreed contract between both parts. The data miner will assure that the next presented schemas are stored in the database. For convenience reasons we will describe the data structures with a JSON like notation.

Facebook data structure

```
{
    "livesIn": {
        "id": {string},
        "description": {string}
    },
    "life_events": {
        {string}: [{string}]
    },
    "birthDate": {string},
    "likes": {
        {string}: {string}
    },
    "friends": [{string}],
    "relationships": {
        "civil_status": {
            "id": {string},
            "description": {string}
        },
        "family_members": [
```

```
            { "id": {string}, "relationship": {string} }
        ]
    },
    "from": {
        "id": {string},
        "description": {string}
    },
    "name": {string},,
    "gender": {string},
    "age": {number},
    "posts": [
        {
            "timestamp": {string},
            "description": {string},
            "author": {string},
            "reactions": {
                "likes": {number},
                "laugh": {number},
                "sad": {number},
                "angry": {number},
                "surprise": {number}
            },
            "comments": {number},
            "shares": {number}
        }
    ]
}
```

LinkedIn data structure

```
{
    "id": {string},
    "name": {string},
    "headline": {string},
    "from": {string},
    "summary": {string},
    "experience": [
        {
            "company": {string},
```

```
        "position": {string},
        "duration": {
            "count": {number},
            "unit": {string},
            "from": {string},
            "to": {string}"
        }
    }
],
"education": [
    {
        "institution": {string},
        "course": {string},
        "startYear": {number},
        "endYear": {number}
    }
],
"skills": {
    {string}: {number}
},
"languages": {
    {string}: {string}
},
"projects": [
    {
        "name": {string},
        "date": {string},
        "description": {string}
    }
],
"groups": [
    {string}
],
"following": [
    {string}
],
"connections": [
    {string}
```

```
    ]
}
```

6.2.4 *Network metrics*

In this section we will list the requirements for the module that is responsible for calculating metrics upon our stored networks. This component must provide a web API in order to access all the algorithms and metrics calculations that the service offers.

1. The API must be able to calculate strongly and weakly connected components;
2. The API must be able to calculate the clustering coefficient (including average and maximum) and transitivity for a given network;
3. The API must be able to calculate the average neighbor degree;
4. The API must be able to calculate centrality measures, these include:
    a) Degree centrality;
    b) Closeness centrality;
    c) Betweenness centrality;
    d) Eigenvector centrality;
5. The API must be able to compute node importance trough the page rank algorithm;
6. The API must be able to calculate the isolated graphs within a certain network;
7. The API must be able to calculate the shortest path between two nodes;
8. The API must be able to run dominance algorithms agains a certain network;

6.3 FRONT-END

The Front-end is actually where the majority of the requirements work is, since we need to go into detail of how the user will interact with the tool, we must decide how that interactions will be drawn so that the tool can actually be what it was meant to, also bear in mind that these represent the tool requirements, what the user actually will able to see.

6.3.1 *Requirements Prioritization*

For simplifying the prioritization process we will use the **MoSCoW** method that is a simple method to define what requirements are more important for the system overall functionality,

allowing us to focus on the very essential requirements for getting a functional product [3].

Next we present the MoSCoW method as it is defined in requirements engineering.

- ***M**ust* have requirements are critical requirements that are part of the identity of the product, they must by all means be implemented;
- ***S**hould* have requirements are definitely important, but they are not critic to the product definition, and they are not time critic as well having the possibility of being included in later stages of the implementation. Some times these requirements may have another ways of satisfying the customer;
- ***C**ould* have requirements are indeed the *nice to have* requirements, being often left outside of the first deliver, but seen as very valuable to the future of the product in later stages of the product time line;
- ***W**on't* have requirements that are agreed to not be included in the first deliver of a project, this does not excludes the possibility of including them in later stages of the project. *Won't* requirements may be seen as future work.

The requirements will be listed by groups (sections) that aggregate common requirements or features. Each requirement will have a classification according MoSCoW method.

6.3.2 *Network configuration and construction*

In this requirements group we present a set of requirements that represent the operations that allow the users' to get theirs network build.

1. **[MUST]** The user must be able to register available OSNs accounts in the system;
2. **[MUST]** The user must be able to order the build of its network with depth I or II where:
   a) Depth I - Builds network with user and user's friends;
   b) Depth II - Builds network with user's friends and friend's of friend's.
3. **[MUST]** The user must be able *blacklist* from the network nodes with a minimum or maximum number of connections;
4. **[MUST]** The user must be able to choose for each network node which details will be extracted within a given OSNs [4]:

3 In this section we will tend to user some terms often find in requirements engineering that may seem a bit off topic, still we find that this is the more objective way for describing our prioritization method

4 Despite these flags being activated by the user, for privacy reasons some information will not be available, the web crawlers will never extract these kind of data

a) **Facebook**:
   i. *Relationships* - If this flag is checked, relationships will be included;
   ii. *Personal* details - If this flag is checked, personal details will be included;
   iii. *Life events* - If this flag is checked, life events will be included;
   iv. *Likes* - If this flag is checked, user's likes will be included;
   v. *Posts* - If this flag is checked, most recent posts will be included.

b) **LinkedIn**:
   i. *Experience* - If this flag is checked, experience will be included;
   ii. *Education* - If this flag is checked, education will be included;
   iii. *Skills* - If this flag is checked, skills will be included;
   iv. *Languages* - If this flag is checked, languages will be included;
   v. *Projects* - If this flag is checked, projects will be included;
   vi. *Groups* - If this flag is checked, groups will be included;
   vii. *Connections* - If this flag is checked, connections will be included.
   viii. *following* - If this flag is checked, following will be included.

5. **[MUST]** The system must give feedback on the extraction status.
6. **[SHOULD]** The user must be able to *blacklist* nodes specific from being extracted and consequently rendered on the user's graph;
7. **[SHOULD]** The system must clearly warn the user about the impacts that extracting some kind of data (e.g. extracting complete list of user's likes on Facebook) could have on extraction time and consequently on render network time (these could be expressed via label warnings in the user's interface);
8. **[COULD]** After the first extraction all the extracted nodes must be marked as extracted, being the user able to extract the missing properties for some given nodes;

6.3.3 *General interactions and display*

These requirements express general behavior of the tool, and some display features.

1. **[MUST]** The system must be able to render a graph using the information provided by the aggregation service;

2. **[MUST]** The system should be able to automatically identify communities by painting nodes belonging to the same community by same the color and providing information about the community such as *"People that studied at School X"* or *"People that live in Lisbon"*;
3. **[MUST]** The user must be able to perform text search and filter or highlight the nodes that match the text query.
4. **[MUST]** The user must be able to drag and drop the graph to any place on the graph render area;
5. **[MUST]** The user must be able to zoom in and zoom out the network so that he his able to explore specific parts with more detail;
6. **[SHOULD]** The system should be able to automatically deactivate heavy graph animations if a large graph is being rendered;
7. **[SHOULD]** The user should be able to choose activate animations despite these have been deactivated by the system for sake of graph interactions performance;
8. **[COULD]** The user should be able to enable and disable *fisheye distortion* alike effect;
9. **[WON'T]** The user must be able to perform a hive plot of his network;
10. **[WON'T]** Double clicking on a empty zone should perform a smooth zooming effect on that are.

6.3.4 *Node interactions*

Here we describe interactions at the node level.

1. **[MUST]** Along side the node a label with the node name or id should be displayed;
2. **[MUST]** The user must be able to activate highlight functionality for more interactive node consulting. This functionality will highlight the node and his first degree connections, clarifying relations within very dense clusters;
3. **[MUST]** When the user clicks a node a side panel must be opened, this panel should display the following:
   a) Should contain all node user's available information;
   b) Should allow the user to perform calculations on that specific node;
   c) Should allow user to request extraction of more information on that node (e.g. if the list of user's likes wasn't extracted this option should be available);

   d) Should offer the user all the metrics already mentioned the previous network metrics section 6.2.4.

4. **[MUST]** The user must be able to drag and drop the node to some place else in the screen and the node should be fixed in that place (being the rest of the graph automatically rearranged);

5. **[SHOULD]** The user can pick color and size of his nodes within the network;

6. **[SHOULD]** When the user mouseover a specific node relevant information should be displayed when possible, such as: name, age, address, number of connections;

7. **[COULD]** The user can pick color and size of specific pre selected nodes within the network;

8. **[COULD]** Right clicking on some node should open a context menu that provide options to the user such as:
   - Opening the users' profile in the current OSNs;
   - Change the node symbol (e.g. if it is a circle the user might want to make the node a triangle instead).

9. **[WON'T]** Double click on some node should make the node grow and stand out comparing remaining nodes.

6.3.5 *Link interaction*

Links are not only visual node connectors, these also possess characteristics and metrics that can be consulted.

1. **[MUST]** User may choose to render the graph links with semantic thickness, if the user checks this flag the link thickness should be proportional to the number of common connections between two given nodes, indicating strongly connected individuals;

2. **[SHOULD]** When the user performs a mouseover on some link, the link itself should be highlighted as well the intervenient nodes;

3. **[COULD]** When the user performs a mouseover on some link, relevant information about the link should be displayed such as number of interactions between the two nodes, or number of common connections.

6.3.6 *Bulk operations*

The user may select a set of nodes with a selection box, allowing him to perform bulk operations on nodes, such as:

1. **[SHOULD]** The user must be able to collapse dense clusters in one single node (all nodes would be replaced by a bigger node, not necessarily representing a community);
2. **[SHOULD]** The user must be able to group nodes in communities based on specific OSNs property (e.g. such as page likes on Facebook or skills on LinkedIn);
3. **[SHOULD]** Check what are the connections that the selected nodes have in common;
4. **[COULD]** All the metrics that can be consulted in node interaction must also be available in bulk interactions so that the user may compare metrics among a set of nodes;
5. **[WON'T]** The user must be able to paint all selected nodes same color;
6. **[WON'T]** Check what are the preferences (in Facebook it would be the *likes*, in LinkedIn would be the companies they follow) that the selected nodes have in common.

6.3.7 *Statistic analysis*

The system could also provide some statistics on the user's network.

1. **[MUST]** The user must be able to visualize geographical network distribution;
2. **[MUST]** The user must be able to rank nodes by various metrics such as node centrality;
3. **[SHOULD]** The user must be able watch rankings such according to social interaction (e.g. on Facebook we may have a rank by number of reactions to user's posts while in LinkedIn we can have a rank of must recommended user's on particular skills).

6.3.8 *Other operations*

These are other operations that differentiate for the other groups of requirements and do not fit any particular requirements bucket.

1. **[MUST]** The user must be able to download his network in standard graph formats: Trivial Graph Format (TGF) and GraphML so that it could be imported to other SNAs tools such as Gephi or SocNetV (see Chapter 4 section 4.6);
2. **[WON'T]** The user should be able to enter an edition mode where he appends new nodes to the social structure.

6.3.9 *Specific OSNs requirements*

As we previously mentioned in Chapter 5, one of the main value propositions of building such a tool is to offer contextual analysis, specific inferences driven by system awareness regarding the OSNs that we are analyzing.

Facebook specific requirements

Below we list requirements that are Facebook specific:

1. **[MUST] Sentiment analysis** - The user must be able to see a metric on each node that describe sentiments such as happiness or sadness, this will be simply the result of the mapping and extraction of reactions to user's posts giving us an overall idea of the user sentiments without involving any natural language processing or other complex processes;
2. **[COULD] User activity** - By analyzing timestamps on user's posts we will provide a metric that describes user activity;
3. **[WON'T] Link Analysis for user social interaction** - When clicking on links in the graph the user must be able to tell the degree of interaction between two nodes (this interaction metric should derive from the number mentions or posts in user's posts).

LinkedIn specific requirements

Below we list requirements that are LinkedIn specific:

1. **[MUST] Human resources discovery** - As companies struggle to find people with particular skills, it might in some cases be a matter of how to reach certain nodes in the network. The user must be able to find individuals with particular skills on the network but also the *shortest path* to that individual, as well as the point of contact a third individual that is a first degree connection with the target and that could serve as proxy to reach that person;
2. **[COULD] Carrear history** - It could be useful to see a particular career path for a specific user (we could call it a user career diagram);

3. **[WON'T] Carrear development** - Because nowadays people tend change jobs more frequently, the user could be able tell from the network general behavior, that users' from a certain company tend next to go to some particular companies.

7

SYSTEM SPECIFICATIONS

Here we present the system specifications such as which technologies we use in each component by drawing a new architecture diagram that specifies what technologies are used in each part of the system.

7.1 IMPLEMENTATION FIRST STEPS

In this section we will describe out approach towards the implementation of the system, we will describe the process since the requirements definition to the technological choices, some challenges and implementation details.

For gathering requirements we simply defined two groups, the first, the system Back-end has essential base functionalities, we focused only on the essential without scoping or prioritizing, all the collected requirements are in the progress of being implemented, these include web crawling modules, data mining for some data treatment and an extraction manager that allows remote calls of parameterized (granular) extractions. In the system Front-end we followed a different approach by collecting a larger group of requirements that consist mainly in user interactions with the tool, allowing us to narrow down the essential features based on requirements comparison. So at the end we sum up a few *must have* requirements that define the system identity an reflect the principles on which the project was designed upon (accessibility, simplicity, OSNs integration and contextual analysis).

From here we built a simple *proof of concept* that demonstrates the most basic of the workflow, this consists in a few steps that we next list:

- **Back-end** - Extract users from a OSNs (for this particular case we used Facebook as source);
- **Service Aggregator** - Aggregate the extracted users in a graph respecting front end data contract;
- **Front-end** - Rendering a graph on the browser, allow simple interaction of node data display on the user mouse click.

Aside note

As one may noticed in the previous list, for sake of objectivity we skipped the implementation of some pieces in the architecture, namely, the network metrics api and the data mining process, these will only be included in the full implementation, because for the current proof of concept we labeled this components as complements (this may be seen as add ons or plugins that added to proof of concept will bring the project to life).

7.1.1 *Proof of concept results*

These steps previous listed steps prove that the designed architecture produces the expected results, furthermore we also conclude in an empiric way what are the best tools and technologies that better suite the project requirements.

Figure 10: A *screenshoot* of our first proof of concept.

In in the Figure 10, we can observe a network being rendered, this represents the friendship network of a given user. Since there is an entry point user, if we let him in this network

we would obtain a egocentric network that could not depict all the surrounding relations in these small society. What we did was remove this node order to obtain more clarity to observe the network. At the Figure 10 we also can see the interaction of clicking on a certain node and displaying the node information.

7.2 CHOOSE OF TECHNOLOGIES

Having the requirements been defined and a small proof of concept being developed as we seen in the previous section, we are now able to present our technological choices and provide some context on how we came to these conclusions.

7.2.1 *Database technologies*

(**MongoDB**(Home page (2009)), **Neo4j**(Developers (2012)))

Relational databases are one of the complex and advance technologies that we have today. We have been building our applications on top of this technologies with very strict rules that allow our data to remain coherent trough applications lifetimes. Databases engines such as MySQL, PostgresSQL and SQL Server are good live examples of the relevance of this technologies. Meanwhile, applications have grown not just in size but also in complexity, the *web era* came, and with it the need for tools that allow us to manage unstructured data. Other alternatives to relational databases have emerged, this are today known as **non relational databases** (also known as NoSQL databases). These are database engines that better allow us to store unstructured data or store data in a non relational way. The most suitable NoSQL database in the context of this project are graph databases such as **Neo4j** that allows to think on data structures as graphs in the the more purest form. Also engines such as **MongoDB** (a document oriented database, will give us more flexibility allowing us to have replicated data documents stored in a primary database and then migrate them into a graph database.

7.2.2 *Back-end technologies*

(**Flask**(Ronacher (2015)), **Python**, **NetworkX**(Hagberg et al. (2013)), **PhantomJS**(Hidayat (2013)), **Selenium WebDriver**(Documentation (2013)), **XPath**(Clark et al. (1999)))

The main language that will supports our back-end is Python, this conclusion came very naturally since Python is one of the most used programming languages in the data science field along with others such as R or Java. We choose Python for two main reasons:

Data extraction and XPath and PhantomJs selenium driver (SEE THIS BETTER) Network Analysis with Networkx Library

Flask as a simplist framework for building our web APIs such as extraction and

7.2.3 *Middleware technologies*

(**NodeJS**(Home page (2017)), **Python**)

Python should do as well, but since we may want to agelize... We may use modern platforms such as NodeJS that are very well known for building scalable network applications.

7.2.4 *Front-end technologies*

(**HTML**, **Javascript**, **CSS**, **D3.js**(Bostock (2012)))

Additionally we may add an MVC modern web library such as ReactJS if needed.

In terms of visualization the main Front-end library is D3.js that brings many visualization features out of the box that will help us on network representation and graph interaction (in the proof of concept we used D3 for rendering the network).

7.3 IMPLEMENTATION ARCHITECTURE

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7.4 IMPLEMENTATION DETAILS

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7.4.1 *Extraction and data mining*

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7.4.2 *Network metrics*

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7.4.3 *Front-end and service aggregator*

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BIBLIOGRAPHY

John Arundel Barnes. *Class and committees in a Norwegian island parish*. Plenum New York, 1954.

Mathieu Bastian, Sebastien Heymann, Mathieu Jacomy, et al. Gephi: an open source software for exploring and manipulating networks. *ICWSM*, 8:361–362, 2009.

Vangie Beal. Webopedia definition for social network, 2016.

Kent C Berridge and Terry E Robinson. What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Research Reviews*, 28(3):309–369, 1998.

Stephen P Borgatti. Netdraw: Graph visualization software. *Harvard: Analytic Technologies*, 2002.

Michael Bostock. D3. js. *Data Driven Documents*, 492, 2012.

Sergey Brin and Lawrence Page. The anatomy of a large-scale hypertextual web search engine. *Computer networks and ISDN systems*, 30(1):107–117, 1998.

James Clark, Steve DeRose, et al. Xml path language (xpath) version 1.0, 1999.

couchsurfing.com. Couchsurfing about page, 2016.

Neo4J Developers. Neo4j. *Graph NoSQL Database [online]*, 2012.

Pinterest Developers. Pinterest developers page. https://developers.pinterest.com/, 2016. Online accessed 29 October 2016.

developers.facebook.com/docs/graph-api/common scenarios. Facebook developer graph api, 2016.

developers.facebook.com/products/. Facebook developer products, 2016.

Cambridge Dictionary. Cambridge dictionaries online, 2002.

Selenium Documentation. Selenium webdriver. *Selenium HQ, Feb*, 2013.

Maeve Duggan. The Demographics of Social Media Users. http://www.pewinternet.org/2015/08/19/the-demographics-of-social-media-users/, 2015. Online accessed 29 October 2016.

Jessica Elgot. From relationships to revolutions: seven ways Facebook has changed the world. https://www.theguardian.com/technology/2015/aug/28/from-relationships-to-revolutions-seven-ways-facebook-has-changed-the-world, 2015. Online accessed 29 October 2016.

Nicole B Ellison et al. Social network sites: Definition, history, and scholarship. *Journal of Computer-Mediated Communication*, 13(1):210–230, 2007.

expandedramblings.com. Social media statistics, 2016.

Facebook. Project palantir. https://www.facebook.com/video/video.php?v=37403547074&ref=nf, 2008. Online accessed 5 December 2016.

Alejandra Guzman Farida Vis. 6 ways social media is changing the world. https://www.weforum.org/agenda/2016/04/6-ways-social-media-is-changing-the-world/, 2016. Online accessed 29 October 2016.

Andrew T Fiore and Judith S Donath. Homophily in online dating: when do you like someone like yourself? In *CHI'05 Extended Abstracts on Human Factors in Computing Systems*, pages 1371–1374. ACM, 2005.

The Guardian. LinkedIn bought by Microsoft for $26.2bn in cash. https://www.theguardian.com/technology/2016/jun/13/linkedin-bought-by-microsoft-for-262bn-in-cash, 2016. Online accessed 22 October 2016.

Aric Hagberg, Dan Schult, Pieter Swart, D Conway, L Séguin-Charbonneau, C Ellison, B Edwards, and J Torrents. Networkx. high productivity software for complex networks. *Webová strá nka https://networkx. lanl. gov/wiki*, 2013.

Jeffrey Heer and Danah Boyd. Vizster: Visualizing online social networks. In *IEEE Symposium on Information Visualization, 2005. INFOVIS 2005.*, pages 32–39. IEEE, 2005.

Ariya Hidayat. Phantomjs: Headless webkit with javascript api. *WSEAS Transactions on Communications*, 2013.

MongoDB Home page. Mongodb. *NoSQL Database [online]*, 2009.

NodeJS Foundation Home page. Nodejs. *Node.js JavaScript runtime*, 2017.

https://developer.linkedin.com/docs/rest api. Linkedin developer docs, 2016.

https://press.linkedin.com/about linkedin. Linkedin about page, 2016.

https://www.instagram.com/about/us/. Instagram about page, 2016.

https://www.instagram.com/developer/limits/. Instagram developer page, 2016.

Dimitris V. Kalamaras. Socnetv. http://socnetv.org/, 2004.

Martin Kilduff and Wenpin Tsai. *Social networks and organizations*. Sage, 2003.

Jérôme Kunegis. Konect: the koblenz network collection. In *Proceedings of the 22nd International Conference on World Wide Web*, pages 1343–1350. ACM, 2013.

Fuchun Lin, Yan Zhou, Yasong Du, Lindi Qin, Zhimin Zhao, Jianrong Xu, and Hao Lei. Abnormal white matter integrity in adolescents with internet addiction disorder: a tract-based spatial statistics study. *PloS one*, 7(1):e30253, 2012.

Steve Borgatti Lin Freeman, Bruce MacEvoy. Ucinet software. https://sites.google.com/site/ucinetsoftware/home, 2002.

Marktest. Os portugueses e as redes sociais, 2016.

Miller McPherson, Lynn Smith-Lovin, and James M Cook. Birds of a feather: Homophily in social networks. *Annual review of sociology*, pages 415–444, 2001.

meetup.com. Meetup about page, 2016.

Eyal Ophir, Clifford Nass, and Anthony D Wagner. Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences*, 106(37):15583–15587, 2009.

Pinterest. Pinterest about page. https://about.pinterest.com/en, 2016. Online accessed 29 October 2016.

politaktiv.org. Social network analysis - theory and applications. *politaktiv [online]*, 2011.

Stanford Pritchard Lab. Structure software. http://pritchardlab.stanford.edu/structure.html, 2000. Online accessed 5 December 2016.

researchgate.net. Researchgate about page, 2016.

Aaron Retica. Homophily. http://www.nytimes.com/2006/12/10/magazine/10Section2a.t-4.html, 2006. Online accessed 5 November 2016.

Armin Ronacher. Flask (a python microframework), 2015.

statista.com. statista, global social media ranking, 2016.

Jeffrey Travers and Stanley Milgram. The small world problem. *Phychology Today*, 1:61–67, 1967.

Stanley Wasserman and Katherine Faust. *Social network analysis: Methods and applications*, volume 8. Cambridge university press, 1994.