



TÉCNICO
LISBOA

**HOMOPHILIC SELF ORGANIZING FEATURE MAPS:
FINDING TOPICS ON SOCIALY CONNECTED DATA,
USING SOCIAL NETWORK RELATIONS**

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Dissertação para obtenção do Grau de Mestre em
Engenharia de Redes de Comunicações

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Acknowledgments

Remember that your parents have paid for the last 20 something years of your studies and that your advisor had to read this document.

Abstract

Clustering is a widely used technique in data analysis. In this thesis, a generic algorithm used for clustering is modified in order to enhance the value of socially connected entities.

To achieve this, we present RubySOM. A framework for easy construction of custom Self-Organizing Maps. With it, it is possible to dynamically change multiple parts of the algorithm, making it an extremely flexible solution to create, train and run custom implementations of the algorithm.

With RubySOM, a relational aware version of the SOM algorithm was created in order to better identify topics on the social network twitter.

Keywords

topic detection, twitter, self-organizing maps, classification, clustering

Resumo

Palavras Chave

detecção de tópicos, twitter, mapas auto organizados, classificação, agrupamento

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List of Acronyms

SOM	Self-Organizing Maps
NLP	Natural Language Processing
U-Matrix	Unified Distance Matrix
TF-IDF	Term Frequency–Inverse Document Frequency
LDA	Latent Dirichlet Allocation
TDT	Topic Detection and Tracking
VSM	Vector Space Model
IR	Information Retrieval
ML	Machine Learning
ANN	Artificial Neural Network
MDS	Multi Dimensional Scalling
PCA	Principle Component Analysis
URL	Uniform Resource Locator
JSON	JavaScript Object Notation
CSV	Comma Separated Values

1

Introduction

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1. Introduction

With the evolution of social network websites like Facebook and Twitter, the amount of pertinent content about a specific issue is increasing dramatically, which calls for new ways to make sense and catalog this data. The usage of social networks for branding quality and on-line marketing is specially compelling since 19% of all tweets [14] and 32% of blog posts [27] are about brands or products. Nevertheless, finding topic sensitive information on social networks is extremely complicated due to the fact that documents have very little content, slang vocabulary, orthographic mistakes and abbreviations. Asur, Sitaram and Huberman [2] successfully predicted box-office revenues by monitoring the rate of creation of new topics based on debuting movies. Their work outperformed some traditional market-based predictors.

Thus academic and enterprise worlds started looking at Machine Learning for new ways to achieve revenue or simply explore and discover patterns in data. As a consequence, the Machine Learning course at Stanford is the one with more students enrolling in the year of 2014 ¹ with more than 760 students enrolled.

Using unsupervised Machine Learning (ML) Le et al. [21] was able to achieve 81.7% accuracy in detecting human faces, 76.7% accuracy when identifying human body parts and 74.8% accuracy when identifying cats. He used a 9-layered locally connected sparse auto-encoder with pooling and local contrast normalization on a large dataset of images (the model has 1 billion connections, the dataset has 10 million 200x200 pixel images downloaded from the Internet). This dataset was trained using model parallelism and asynchronous SGD on a cluster with 1,000 machines (16,000 cores) during three days. Even though the amount of computing power used in this project was of several orders of magnitude, it is remarkable how an unsupervised algorithm could achieve such results.

Even though a lot of solutions have arisen in order to automate real time searches, topic categorization and many other data intensive tasks are still done manually. Twitter still uses humans to deliver ads to trending queries, states Edwin Chen's Data Scientist responsible for ads quality at Twitter. On his blog post ², Edwin Chen describes the process of delivering real time ads to trending queries at Twitter. The main problems that arise in the Twitter platform in order to identify rising topics are:

- The queries people perform have never before been seen, so it is impossible to know beforehand what they mean.
- Since the spikes in search queries are short-lived, there's only a short window of opportunity to learn what they mean.

This means that when an event happens, people immediately come to Twitter in order to know what is happening in a determined place. Twitter solves this issue by monitoring which queries

¹<http://www.forbes.com/sites/anthonykosner/2013/12/29/why-is-machine-learning-cs-229-the-most-popular-course-at-stanford/>

²<http://blog.echen.me/2013/01/08/improving-twitter-search-with-real-time-human-computation/>

are currently popular in real time, using a Storm topology ³. After the queries are identified, they are sent to a Thrift API ⁴ that dispatches the query to Amazon's Mechanical Turk service ⁵ where real people will be asked a variety of questions about the query.

Social Media Analytics is another raising topic that draws from Social Network Analysis [17], ML, Data Mining [37], Information Retrieval (IR) [31], and Natural Language Processing (NLP). As stated Melville et al. [27], 32% of the 200 million active bloggers, write about opinions on products and brands, while 71% of 625 million Internet users read blogs and 78% of respondents put their trust in the opinion of other consumers. In comparison, traditional advertising is only trusted by 57% of consumers. This kind of data drives companies to Social Media Analytics as a way to know what people are saying on the web about their companies and products. This new worry has brought to life a lot of new startups like Sumal⁶ or ThoughtBuzz⁷, but also solutions from the old players like IBM⁸ and SAS⁹

Its also important to notice that in the last few years Data Science/Analysis has been a trending topic, mostly due to the fact that big dot-com companies have been having high revenues by exploiting user specific information in order to deliver ads and sell products. Not surprisingly that if you look that in the top ten ebooks sold by O'Reilly throughout 2013, four are about data science ¹⁰.

1.1 Motivation

Clustering analysis has been widely used throughout the times, from its first occurrence in England, where John Snow was able to map a wider amount of people infected with cholera to a well in the center of London. Nowadays the applications are endless, and fields where it is applied are quite vast.

Specifically with a greater amount of people describing events around them, and their lives on social media, it is increasingly more challenging to categorize this data, due to its sparsity and volume.

However, data generated on social networks, have more information than simply written text, on a tweet, or a photo published on Facebook. Data generated in social network is connected by entities, and these entities tend to be closer to other entities with the same kind of interests [26]. In this thesis we will explore how a clustering algorithm can be altered in order to add social relevance to its fed data. By focusing on using an unsupervised learning technique based on

³<http://storm-project.net/>

⁴<http://thrift.apache.org/>

⁵<https://www.mturk.com/mturk/>

⁶<https://sumall.com/>

⁷<http://www.thoughtbuzz.net/>

⁸<http://www-01.ibm.com/software/analytics/solutions/customer-analytics/social-media-analytics/>

⁹<http://www.sas.com/software/customer-intelligence/social-media-analytics.html>

¹⁰http://shop.oreilly.com/category/deals/bestoforeillydotd.do?code=DEAL&cmp=tw nabooks videos info-authornote_best_of_2013

1. Introduction

neural networks named Self-Organizing Maps (SOM) [19] in order to detect topics in Twitter posts, by using the Social Network users as base neurons for clustering. After the network is trained, it will be possible to categorize tweets in real time.

1.2 Objectives

The main objective of this project is to find topics on tweets by contextualizing the social network involving the person that authored the tweet in the clustering process.

We start by building a dataset, in order to train the SOM, that will later classify each future tweet that arrives on the network without further delay.

After creating the dataset, we will try to find clusters of topics using the default SOM approach, converting each tweet to Vector Space Model (VSM). After analyzing the results from the default SOM approach, the algorithm will be changed in order to give relevance to the fact that there is a relationship between authors of tweets.

1.3 Contributions

The main contributions of this work are as follow:

- A method to enhance topic discovery on data with small text corpus and high social significance.
- A framework to easily edit multiple parts of a SOM algorithm, by passing high order functions as configuration.
- To develop highly customizable infinite tweeter crawler that preserves the social network.

1.4 Dissertation outline

Explain how did you organized your thesis.

2

Background

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2. Background

In this section, we will start by generally describing what clustering is and how it works. We will then outline how SOM [19] perform, which is the document clustering algorithm used on this thesis.

2.1 Document Clustering

Document clustering is an optimal division of documents into categories without prior knowledge of the data that is being organized, based only on the similarity between them. Due to the fact that no prior knowledge of the data has to be known, document clustering is labeled as Unsupervised ML [11].

Liu et al. [23] asserted that document clustering can be used in a variety of Computer Science fields, such as:

- Natural Language Preprocessing.
- Automatic Summarization.
- User preference mining.
- Improving text classification results.

There are two main types of document clustering: hard clustering and soft clustering. In hard clustering, one document can only belong to one cluster, while in soft clustering one document can belong to multiple clusters.

The clustering process usually works as described in Figure 2.1. In the first step, a data set must be provided with the documents to be clustered. The second step is where non relevant words are removed from the documents, to improve clustering quality [15].

The third step is characterized by converting the keywords of each document into vectors. The most common model used for this task is VSM. In VSM, each vector dimension represents one detected keyword and each document is represented by the vector of keywords in the feature space. This process is illustrated in Figure 2.2 and works in the following way:

- **First step:** string tokenization, and token selection. In this case, stop words and repeated words will be removed.
- **Second step:** string to VSM conversion. Each different word will correspond to a position in the array, and its value will correspond to the number of occurrences.

There are many clustering algorithms. In the following section we will describe the particular case of the SOM algorithm, the solution used in our work.



Figure 2.1: Text clustering main framework [9]

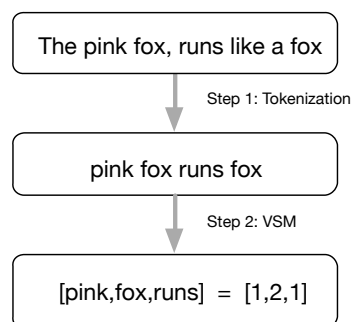


Figure 2.2: Text tokenization and transformation to Vector Space Model.

2.2 The Self-Organizing Map

SOM are a two layer recurrent Artificial Neural Network (ANN) that has the desired property of topology preservation, thus mimicking the way the cortex of highly developed animals brains work. SOM allow cluster visualization of multi-dimensional data, similar to methods such as Multi Dimensional Scalling (MDS) [20] and Principle Component Analysis (PCA) [13] .

Baão et al. [3] described the basic idea behind SOM as a mapping between input data patterns into a n-dimensional grid of neurons, or units. That grid is also know as the output space, as opposed to the initial space — input space — where the input patterns reside. An illustration of both spaces can be seen in Figure 2.4.

SOMs work in a similar way as is thought the human brain works. Analogously to the human brain, SOMs also have a set of neurons that, through learning experience, specialize in the identification of certain types of patterns. These neurons are responsible for categorizing the input patterns for which they are responsible to identify. Nearby neurons will be organized by similarity, which will cause similar patterns to activate similar areas of the SOM. With this topology preserving mapping, the SOM organizes information spatially, where similar concepts are mapped to adjacent areas. The topology is preserved in a sense that, as far as possible, neighborhoods are preserved throughout the mapping process. Output neurons are displayed in an N dimensional grid, generally rectangular, but other structures are possible, such as hexagonal or octagonal. The grid of neurons, in the output space, can be divided in neighborhoods — where neurons responsible for the same kind of input reside. In SOM, neurons will have the same amount of coefficients as the input patterns and can be represented as vectors.

Before describing the algorithm, it is important to define two key aspects of the SOM: the learning rate and the quantization error. The learning rate is a function that will be decreased to converge to zero. It will be applied to winning neurons and their neighbors in order for them to move toward the corresponding input pattern in progressively smaller steps. Quantization error is the distance between a given input pattern and the associated winning neuron. It describes how well neurons represent the input pattern. The radius of the neighborhood around the winning neuron is also particularly relevant to the topology of the SOM, deeply affecting the unfolding of the output space as stated by Baão et al. [3].

SOM training is always subject to some variability due to multiple causes, like the sensitivity of initial conditions, convergence to local minima and sampling variability [6].

No general formula exists to minimize quantization error [6] . In order to achieve a minimal value, the number of neurons, value of neurons and order of the input data is randomly changed. Multiple SOMs are trained and the one with the lowest mean quantization error is chosen.

In order to know how well a neuron maps to all the input patterns it represents, the average of the quantization error can be used(Eq. 2.1). On the equation, $d_{i,n}$ is an input pattern that is

represented by the neuron w . Each neuron represents an arbitrary number n of input patterns, that group of input patterns is represented as $D_{i,j}$.

$$\varepsilon(w) = \frac{\sum_{i=0}^n \|w - d_i\|}{n}, d_i \in D, \forall n \quad (2.1)$$

Algorithm 1: Self-Organizing Map [19]

Data: Input patterns $X = \{\vec{x}_1, \dots, \vec{x}_N\}$, number of iterations t_{max} , neighborhood function $\sigma(t)$, learning rate $\epsilon(t)$

Result: Trained map and clustered input patterns

Randomly initialize neurons, $w_i \in \mathbb{R}^D, \forall i$

for $t = 1$ **to** t_{max} **do**

```

    Randomly draw an input pattern,  $\vec{x}_d$ 
1    $p = \arg \min_i \{\|\vec{x}_d - \vec{w}_i\|\}$ 
2    $\vec{w}_i = \vec{w}_i + \epsilon(t) \cdot h_{ip}(t) \cdot (\vec{x}_d - \vec{w}_i), \forall i$ 
3    $\sigma(t) = \sigma_0(\sigma_f/\sigma_0)^{t/t_{max}}$ 
4    $\epsilon(t) = \epsilon_0(\epsilon_f/\epsilon_0)^{t/t_{max}}$ 
5    $t \leftarrow t + 1$ 

```

The learning phase is characterized by the Algorithm 1, which works the following way:

- **On line 1:** neuron closer to the input pattern is selected. The euclidean distance (Eq. 2.2) is generally used.

$$Dist = \sqrt{\sum_{i=0}^n (V_i - W_i)^2} \quad (2.2)$$

- **On line 2:** the winning neuron (p) previously selected on line 5 is updated, in order to better represent the input pattern — this process is represented on Figure 2.3. Also, all other neurons inside a specific radius will also be updated — this process is described in Figure 2.4. Each neuron is updated with a different rate of influence determined by how far away it is from the winning neuron, which is defined by the neighborhood influence function $h_{ip}(t)$, the Gaussian (Eq. 2.3) is often used.

$$h_{ip}(t) = \exp - \frac{|\vec{a}_i - \vec{a}_p|^2}{\sigma^2(t)} \quad (2.3)$$

- **On line 3:** the size of the radius will be updated.
- **On line 4:** the learning rate is updated.
- **On line 5:** the number of iterations is incremented.

In order for the algorithm to converge, the learning rate and the radius of the neighborhood need to decrease at a given rate. This process can be seen on line 3 and 4, respectively .

2. Background

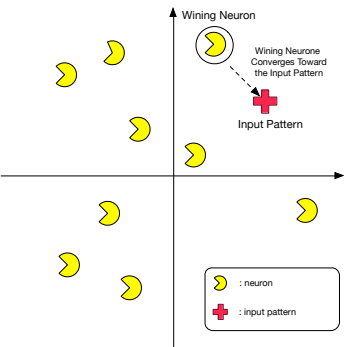


Figure 2.3: Winning neuron converging at learning rate

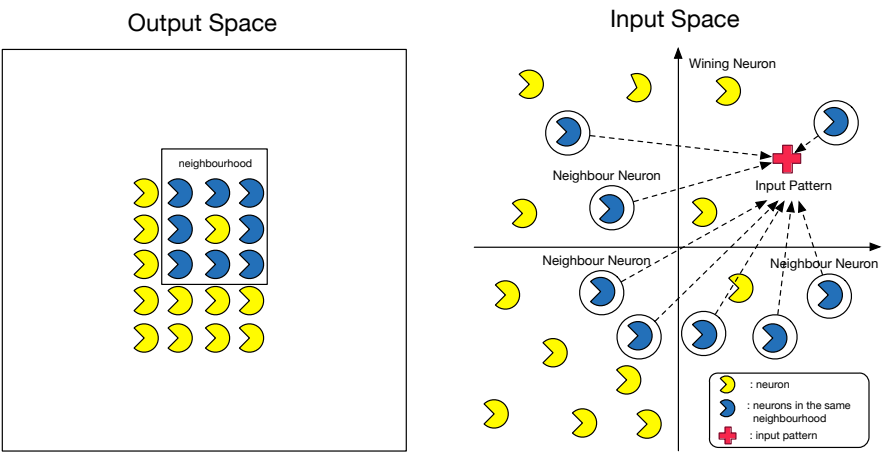


Figure 2.4: On the left the output space neighborhood, on the right the neighbors of the winning neuron converging in the direction of the input pattern

The prediction phase can start after the model is learned. On the prediction phase, new input patterns can be quickly assigned to the SOM, without need to apply the learning rate to the winning neuron and his neighbors. In other words, only line will run. Due to the fact that the input pattern will be assigned to the cluster that is mapped by the nearest neuron. Thus, it is very easy and fast to classify new data now. As stated by Liu et al. [23], the advantages of using SOM are: data noise immunity, easy to visualize data, and parallel processing.

In order to visually interpret the result of the SOM, Unified Distance Matrix (U-Matrix) method may be used [3]. The U-Matrix is a representation of the SOM, in which, the distance between neurons is represented in a gray-scale where the darkest colors represent the farthest distance and the lightest colors the closer neurons. One way to compute the U-Matrix is described in 2.

The U-Matrix algorithm (Alg. 2) is composed by four main cycles, which work in the following way:

- **Cycle 1:** On line 1 neurons are added to the empty matrix, in order to be able to calculate the distance between them.
- **Cycle 2:** From line 2 to 4, we are calculating the distance between adjacent neurons, and adding the distance to the empty position between them. On line 2 and line 3 we are looking for neurons horizontally and vertically, respectively. On line 4 we are looking for neurons on the diagonal. The diagonal calculus is more complex due to the fact that we need to calculate the lower diagonal to the current neuron, and average it with the upper diagonal of the neuron immediately below it.
- **Cycle 3:** At this stage the matrix is full of the distances between neurons, theoretically nothing else would be needed to be calculated. But it still has neurons residing on the matrix which need to be removed. On line 5 we substitute all neurons with an average of the distances surrounding them.
- **Cycle 4:** Finally all the values on the matrix are substituted by colors on a black to white scale. Bigger distances between neurons are represented with darker colors while smaller distances are represented with lighter colors. This conversion is done on line 6

An example of an U-Matrix can be seen in Figure 2.5(b).

2. Background

Algorithm 2: U-Matrix

Data: $W = \{\vec{w}_{0,0}, \dots, \vec{w}_{n,n}\}$ are the trained neurons
 $D_{i,j}$ be the input patterns represented with neuron $w_{i,j}$
 U is an empty matrix with size $2n - 1, 2n - 1$

Result: U-Matrix

```
/* Initialize  $U$  by adding the trained neurons */
for  $\underline{w_{ij} = w_{00}}$  to  $\underline{w_{n,n}}$  do
1  |  $U_{i*2,j*2} \leftarrow w_{i,j}$ 
/* Calculate the distance between every adjacent neurons, and apply it to the
   square between them */
for  $\underline{i = 0}$  to  $\underline{U_{max}}$  do
  | for  $\underline{j = 0}$  to  $\underline{U_{max}}$  do
    | if  $\underline{l + 1 < m} || \underline{j + 1 < m}$  then
2  | |  $U_{i+1,j} = \|u_{i,j} - u_{i+2,j}\|$ 
3  | |  $U_{i,j+1} = \|u_{i,j} - u_{i,j+2}\|$ 
4  | |  $U_{i+1,j+1} = \frac{\|u_{i,j} - u_{i+2,j+2}\| + \|u_{i+2,j} - u_{i,j+2}\|}{2}$ 
    | |  $j \leftarrow j + 1$ 
  |  $i \leftarrow i + 1$ 
/* Substitute the neurons for an average of surrounding distances */
for  $\underline{i = 0}$  to  $\underline{U_{max}}$  do
  | for  $\underline{j = 0}$  to  $\underline{U_{max}}$  do
5  | |  $u_{ij} = avg(Adj[u_{ij}])$ 
    | |  $j \leftarrow j + 1$ 
  |  $i \leftarrow i + 1$ 
/* convert the distances to color */
WHITE = 255
BLACK = 0
 $u_{max} \leftarrow max(U)$ 
 $u_{min} \leftarrow min(U)$ 
for  $\underline{u_{ij} = u_{00}}$  to  $\underline{u_{n,n}}$  do
6  |  $U_{i,j} \leftarrow (1 - \frac{u_{i,j} - u_{min}}{u_{max} - u_{min}}) * WHITE$ 
```

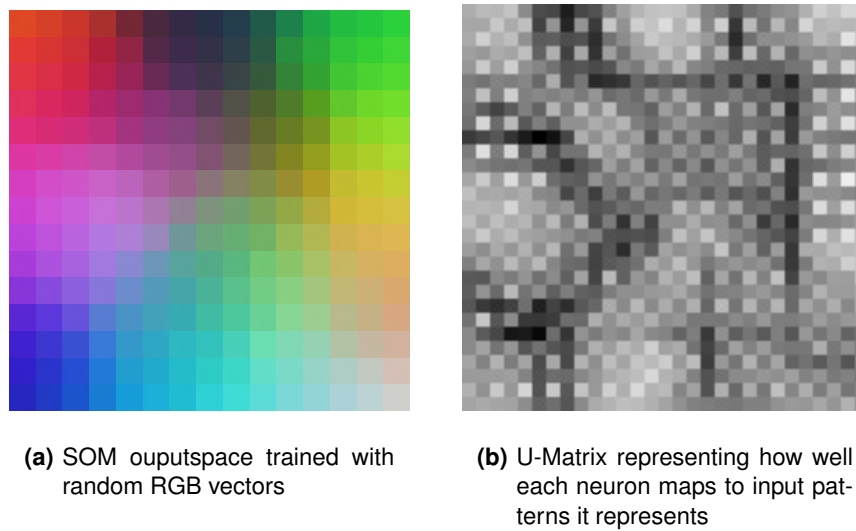


Figure 2.5: U-Matrix and SOM output space, computed after 300 epochs of training, with 1500 random input patterns representing an RGB color.

3

State of the art

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This section provides insight of work done in several research areas that are related to the project. In section 3.1, work done using SOM maps will be described. Section 3.2 and 3.3 are dedicated to data clustering and to data mining specifically on Twitter ¹.

3.1 Self-Organizing Maps

SOM are used in a wide area of applications, from authentication systems [9] through network intrusion detection [32] and speech recognition and analysis [18]. In this section we highlight some of their applications.

3.1.1 The Geo-SOM

The Geo-SOM, by Bação et al. [3], applies the first law of geography “Everything is related to everything else, but near things are more related than distant things.” [35] to the SOM algorithm. In this case, the winning neuron is chosen in a radius defined by the geographic-coordinates of the data, forcing units that are close geographically to be close in the output space.

The algorithm works by defining a variable k which is used as a “geographical tolerance” that forces the winning neuron to be geographically near the input pattern. When $k = 0$, the winning neuron is forced to be the unit geographically closest to the input data, whilst k increases, the tolerance for data with further geographic coordinates, increases as well. k is a geographic radius applied in the output space. When the radius exceeds the size of the output space, every unit is eligible to be the winning neuron, and therefor, we have a regular SOM.

The selection of the winning neuron is done in two steps. First, geographic neurons inside the tolerance k with the input data as a center are selected. Only after that, comparisons are made with the rest of data present in the input data. The representation of the Geo-SOM can be seen in Figure 3.1, where the units considered for the best match are defined by a sort of geographic radius defined by k , whilst in the original SOM, the winning neuron could have been any of the units presented on the figure.

The Geo-SOM approach to the alteration of the default SOM algorithm is specially interesting due to the fact that this thesis objective is also to give relevance to data patterns that are not located in the same space as the trained data. In a way, what we are trying to achieve is similar to the work by Bação et al. [3] but changing the geographic relevance in data by a social relevance.

3.1.2 Detecting Hidden Patterns on Twitter Usage

Cheon and Lee [8] analyzed hidden patterns in the usage of twitter. In their study, they started by collecting data from the twitter API of different kinds of topics like “2009 Iran Election” and “iPhone 3.0 OS launch”. They made multi level signal extraction, not only from information directly

¹<http://www.twitter.com>

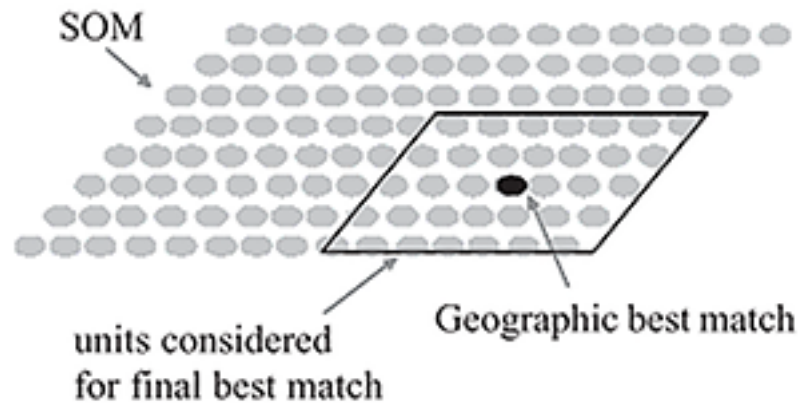


Figure 3.1: Geo-SOM structure, where the units considered to be the winning neuron are constrained by the geographic coordinates of the data, from Bação et al. [3]

present on the tweet, but also by cross referencing with other social websites and with the twitter user profile information. The signals retrieved from the social network can be seen in Table 3.1.

Table 3.1: Twitter Signals

Twitt Corpus
Tweet Size
Replies
Re-tweets
Hashtags
Presence of URIs and Type of linked content
Type of Device
Tweet Location
Twitter Profile
Account Age
Gender
Country
frequency of posts
Friends to followers ratio
Number of customizations
External Sources
Other Social Network Accounts
Type of website

Parece me interessante descrever quais as características diferenciadoras dos clusters. By applying a SOM, they could find four demographical clusters during the Iran 2009 Election. The first cluster was characterized by young web-based Iranians, with twitter accounts not older than three months with a high frequency of replies. The second cluster was mainly compound of web users from Iran accounts older that three months. The third cluster had Iranian users with mobile

clients with large texts clearly trying to raise awareness. The fourth and final cluster represented the users around the world trying to raise awareness about the issue by sharing tweets with URIs. Looking at their analysis about the topic "2009 Iranian Election", it is clear to see that it was possible to describe the type of users represented in the social network and the way they interact with it.

On the iPhone 3.0 OS launch, it was possible to find three main clusters. The first cluster was characterized by male users, accounts older than 90 days, coming from countries where the iPhone is marketed, with high adoption of social media clearly representing the target market of the iPhone or its customers. The second cluster had new accounts with higher rate of followers to followees, high frequency of posts per day, presence of URI linking to technology blogs or websites, no country or gender specified meaning that this cluster was clearly composed by news aggregators and technological news websites. Inside the second cluster, there was a sub-cluster of Japanese users which represents the high rate of iPhone adoption in Japan. Finally, the third cluster was clearly spammer accounts that were eventually deleted after a couple of months, characterized by popular social connections, posting more than fifty tweets a day with external URIs and the accounts were not older than a day or so.

In conclusion, it was possible to detect Twitter usage patterns, and specifically, detect spammers before they were banned from the social network.

3.1.3 WEBSOM

Honkela et al. [12] developed a new approach to automatically order arbitrary, free from textual, document collections, using two different SOMs. The first SOM is called word category map and its used to find words that have similar meaning, while the second SOM, called document map, is the one actually used to cluster the documents.

The WEBSOM was not based on keywords and boolean expressions, instead, words with the same meaning are encoded in a word category map (Fig 3.2(a)), where placement and frequency in documents is taken into account. This way it is possible to remove words with similar meaning — greatly reducing the VSM size making it possible to train the document map in a scalable way.

3.2 Topic Detection and Tracking with Clustering

Allan [1] defined Topic Detection and Tracking (TDT) as: "TDT research begins with a constantly arriving stream of text from newswire and from automatic speech-to-text systems that are monitoring selected television, radio, Web broadcast news shows. Roughly speaking, the goal of TDT is to break the text down into individual news stories, to monitor the stories for the events that have not been seen before, and to gather stories into groups that each discuss a single news topic".

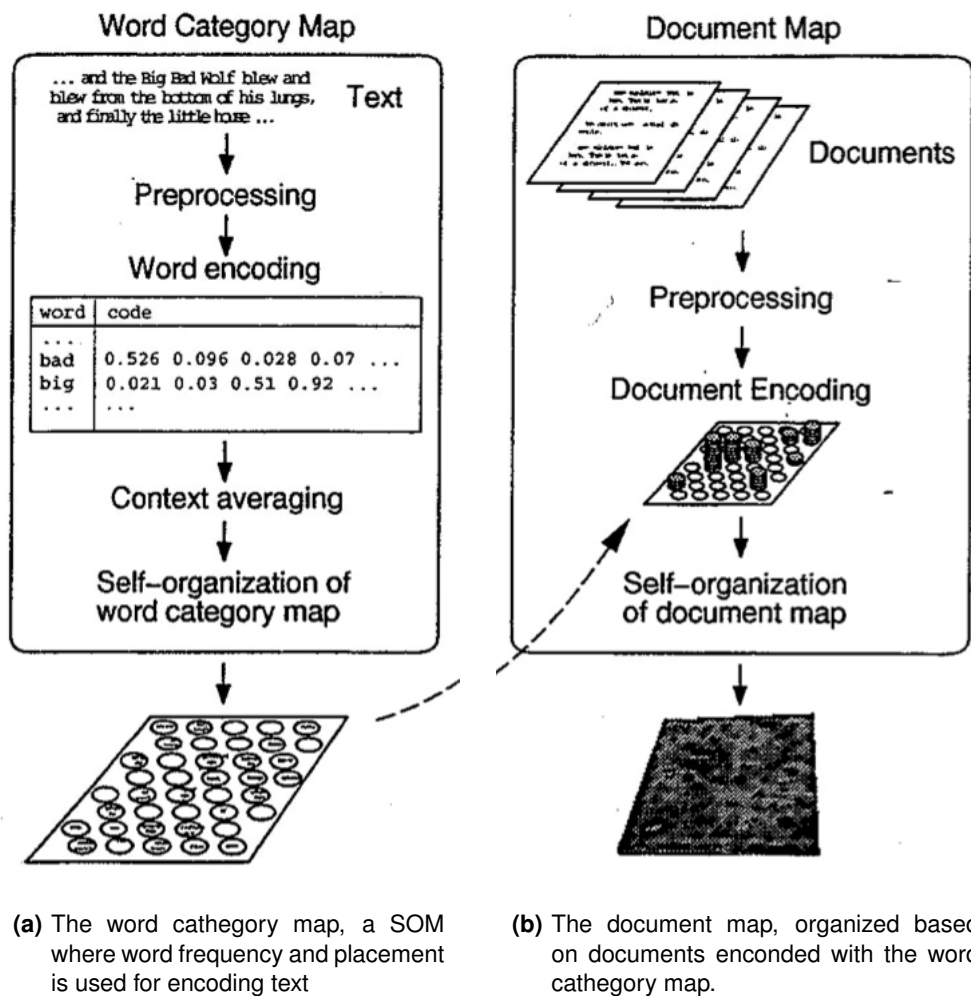


Figure 3.2: Basic architecture of the WEBSOM method, from [12]

Nowadays, due to the rapid adaptation of people to always be on-line, through the usage of cellphones on the move, desktops at work and even TV at home, the increase of user generated content has increased tremendously in latest years. In 2006, 35% of on-line adults and 57% of teenagers created content on the Internet², which in "Internet Years" was ages ago.

The challenge of TDT is evermore focused on online generated documents, and in new forms to be able to track and categorize all the information that is continuously being generated. Many TDT techniques have been proposed, a significant amount of them rely on the Term Frequency–Inverse Document Frequency (TF-IDF) [4]. Because tweets are very small, often with typos or slang words, and because the same tweet might be written in multiple languages, TF-IDF is not particularly adequate for topic detection on twitter. In this subsection, we will take a look at multiple methods of topic detection in general, and also specifically on the Twitter social network.

3.2.1 Topic and Trending Detection

Cataldi et al. [7] proposed a new technique for emerging topic detection that permits real-time retrieval of the most emergent topics expressed by a community on Twitter. Their work applies the PageRank algorithm [29] to the users follower/followee relationship, in order to find the most influential users on the network. Then, the most trending topics are calculated, by relating social influence, word co-occurrence and time frame. In the end, an interface was created where it would be possible to navigate, through hot topics in a given time frame. Topic labeling was not automatic and was implicit by the time frame of an event.

Weng et al. [36] also used the PageRank algorithm to find the most influential twitter users on a certain topic. However, using a different approach, they represent each twitter user as a bag of words comprising of all the tweets that they have posted, and applied Latent Dirichlet Allocation (LDA) [5] in order to find topics in which users are interested in. Finally, it was possible to prove that follower/followee relations on twitter are not just casual, but that people actually follow other people to whom they have some resemblance or common interest. This concept is called homophily and will be further explored on this thesis.

3.3 Twitter Data Mining

In this subsection, we will focus on work done on the Twitter social network in order to leverage insights on how the public data available from the website can be explored.

3.3.1 Tweets Implicit Data

Tweet retrieval and analysis is a double edged problem. On one side, the tweet is really small, which makes it almost impossible to retrieve any actual sense from it. On the other hand, the

² Data source: <http://www.pewinternet.org/Presentations/2006/UserGenerated-Content.aspx>

3. State of the art

Table 3.2: Tao et al. [34] tweet characteristics hypothesis versus influence

Hypotheses	Influence of Features
Syntactical	
Tweets that contain hashtags are more likely to be relevant than tweets that don't	Not Important
Tweets that contain an URI are more relevant than tweets that don't	Important
Tweets that are replies to other tweets are less relevant	Important
The longer the tweet is the more relevant it is	Not Important
Semantic	
The more the number of entities the more relevant a tweet is	Important
Different types of entities are of can have different amount of interest to a give topic	Important
The greater the diversity of concepts mentions in a tweet the more likely for it to be relevant	Important
The relevance of a tweet is determined buy its polarity	Important
Contextual	
The lower the temporal distance between a query and the creation of a tweet the more relevant the tweet is	Not Important
The more the number of tweets created by a user the more relevant one of his tweets will be	Not Important

amount of tweets generated per day is around 140 million³, which means that it is very hard to do a deep analysis of the semantics and content of individual tweet, and that only the more appropriate signals should be evaluated. For this reason, Tao et al. [34] evaluated how the multiple signals that could be retrieved, directly or indirectly, from the tweet corpus could mean that a tweet is relevant for a determined topic. In their work, they present premises that seem intuitively true and proves they actually are relevant through a comparison of multiple precision and recall values. Their results on feature comparison are summarized in Table 3.2. The first column consists of all the made hypothesis categorized by type, and the second column tells if the data used actually influenced in precision and recall results. Tao et al. [34] also compared results, of topic characteristics, concluding that distinction between local and global events as well as temporal persistence proved to not be relevant on relevance prediction.

McCreadie and Macdonald [25] also approached the issue of having very little content on tweets in order to categorize them, and tried to solve the problem by applying the content of linked URIs into the tweet body in order to improve precision and recall. The best fitting approach was using Field-Based weighting, where for each tweet a new document is created, which contains two fields: the terms in the tweet and the terms in the linked document. Afterwards a learning to rank algorithm called PL2F [24] is used against the dataset from "Trec Microblog2011" in order to find the best weighting. With this model they were able to improve precision in an order of 0.9, over only analyzing the text contained in the tweets.

³<https://blog.twitter.com/2011/numbers>

3.3.2 Tweeter Natural Language Processing

Using standart NLP tools on tweets has been extremely unreliable, due to the fact that microblogging text tends to be full of abbreviations, emojis and smiles . Recently, Owoputi et al. [28] published a NLP library, specific for twitter. As shown in Figure 3.3, ARK Tweet NLP can tag words that are only used in social networks. The tagger was built using maximum entropy Markov model, where a tag is assigned to a word based on the entire tweet text, and the tag assigned to the word to its left. Owoputi et al. [28] state that the tagger has a 93.2% accuracy. By using NLP tools, it is possible to reduce the dimension of VSM space by only choosing words that are relevant, like common nouns, hashtags and proper nouns. This will not only yield better results by removing tweets that have no content, and therefor, cannot be categorized, but will also increase performance during training due to the reduced dimensions caused by less use of words.

ikr	smh	he	asked	fir	yo	last
!	G	O	V	P	D	A
name	so	he	can	add	u	on
N	P	O	V	V	O	P
fb	lololol					
^	!					

Figure 3.3: Tweet automatically tagged with ARK Tweet NLP. ! stands for interjection, while V stands for verbs and D for determiner. The full table of tags can be found in [28].

3.3.3 Rapidly Changing Trends

Due to the real time nature of Twitter, using typical retrieval model, that relies on term frequency models like Okapi BM25 or language modeling cannot be applied, as stated by Lin and Mishne [22]. The study of topic endurance on the social network proved that topics are presented in bursts of queries and mentions. In addition the typical usage of twitter for search is not the same of Google. When users are searching on twitter, they want to find out what is happening in that moment, meaning that classification techniques based on past events cannot respond this kind of problem. As stated by Lin and Mishne [22], this problem has not yet been solved at Twitter (or anywhere else at the time of writing this report), and issues a new kind of data analysis approach that was not taken into consideration in the past.

This effect of rapidly changing topics and queries based on real time events was named "Churn", and can be clearly seen in Figure 3.4.

By including social features into clustering algorithms, it might be possible to discover interesting rising topics to a specific specific user, by categorizing them through a trained SOM.

3. State of the art

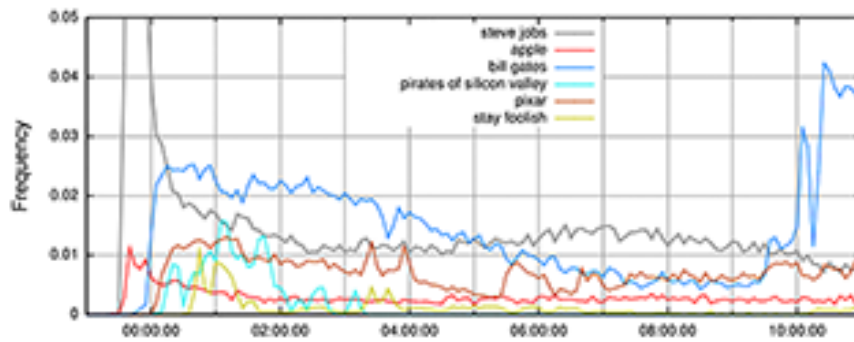


Figure 3.4: The Churn effect: Frequencies of queries related to Steve Jobs death over a 12 hour period in 5-minute intervals, normalized to the total number of queries in the interval. At its peak, the query “steve jobs” reaches 0.15 (15% of the query stream); Graph taken from [22]

3.4 Summary

Ending section summarizing the chapter is typically a good idea.

Ensure that the next chapter starts in a odd page

4

Clustering Tweets with Self Organizing Maps

Contents

4.1	Introduction	24
4.2	Twitter Data	24
4.3	SOM	26
4.4	Homophilic SOM Definition	27

4. Clustering Tweets with Self Organizing Maps

```
1 {
2   "_id" : { "$oid" : "4fa14bc97e5617025fb14787" },
3   "text" : "RT @FastCoDesign: A Paintbrush That Works On The iPad
4           http://t.co/eWjEZAgA (@sensubrushman)",
5   "id_str" : "197701817864421376",
6   "coordinates" : null,
7   "in_reply_to_screen_name" : null,
8   "in_reply_to_user_id" : null,
9   "possibly_sensitive" : false,
10  "favorited" : false,
11  "in_reply_to_status_id" : null,
12  "source" : "<a href=\"http://www.flipboard.com\" rel=\"nofollow
13            \">>Flipboard</a>",
14  "possibly_sensitive_editable" : true,
15  "contributors" : null,
16  "retweet_count" : 0,
17  "truncated" : false,
18  "in_reply_to_status_id_str" : null,
19  "geo" : null,
20  "in_reply_to_user_id_str" : null,
21  "entities" : { Entities Object },
22  "user" : { User object },
23  "retweeted" : false,
24  "id" : 197701817864421376,
25  "place" : null,
26  "created_at" : "Wed May 02 14:59:21 +0000 2012" }
```

Figure 4.1: JSON representation of a Tweet.

4.1 Introduction

4.2 Twitter Data

Twitter is a social network website and mobile app, where users are able to share whats on their mind with less than 140 characters. Due to its limitations, twitter users started to adopt their own kind of language on the social network, sharing shortened Uniform Resource Locator (URL), and tagging topics with a word preceded with an hashtag – # – became so popular, that it was eventually implemented into twitter itself. Nowadays it is possible to monitor events through hashtags selections and links shared on the mobile app are automatically shortened.

With the rise of smartphones and decent prices for mobile Internet access, and people becoming always online, GPS coordinates where also added to tweets. In fact a tweet nowadays has a massive amount of information, as can be seen in Figure 4.1.

There are two main ways to gather data from twitter: Crawl twitter HTML pages and scrap the intended information, access through the twitter API.

Crawling web pages is done through the analysis of HTML documents generated by twitter servers. Due to specific semantic rules, it is possible to gather almost all information that is

possible to have access through the twitter API. Even though writing an HTML crawler is not particularly complex, specially through the usage of open source tools like nokogiri ¹ or beautiful soup ², Twitter specifically asks to not be crawled in some parts of their URL, as can be seen in Figure 4.2.

Basically the restrictions that twitter asks on his robots.txt, only allows for search results, and hashtag searches to be monitored, which is pretty limiting.

```
# Every bot that might possibly read and respect this file.
User-agent: *
Allow: /?lang=
Allow: /hashtag/*?src=
Allow: /search?q=%23
Disallow: /search/realtime
Disallow: /search/users
Disallow: /search/*/grid

Disallow: /*?
Disallow: /*/followers
Disallow: /*/following

Disallow: /account/not_my_account

Disallow: /oauth
Disallow: /1/oauth
```

Figure 4.2: Twitter robots.txt piece where it is possible to see what should and shouldn't be crawled

When accessing twitter through their API, authentication is required as since version 1.1. The authentication mechanism at hand, is used to limit the amount of information users can gather from twitter. The API itself is divided in the streaming – used for subscribing directly to twitter public, user or site streams – and REST – used for programmatic access to read and write to the twitter API.

The streaming API is extremely useful for building dataset based on keywords ,searches and entities. Since their API limit is based on levels, and the default level lets an endpoint track up to 400 words, and 5000 user ids as long as the amount of tweets streamed to the endpoint doesn't surpass the 1% of the total amount of tweets Twitter is currently streaming. Although, if some wrong terms are monitored, the amount of spam crawled can be huge, specially when monitoring public entities or trending hashtags.

The REST API can be used to get all information that is available on twitter by the time the request is sent. REST API limits are much greater than the ones applied at the streaming API. The basic rules are 15 minutes windows per endpoint where 15 requests can be made. There are some exceptions to these rules and those can be found on twitter documentation ³

Due to the amount of specificity allowed by the REST API, it is better suited to create datasets that mimic the way twitter data is interconnected, like getting users and their followers, as well as

¹<http://www.nokogiri.org/>

²<http://www.crummy.com/software/BeautifulSoup/>

³<https://dev.twitter.com/rest/public>

4. Clustering Tweets with Self Organizing Maps

their tweets.

4.2.1 Crawling Twitter for Social Relations

When trying to find clusters of topics with SOM, integrating the social network in the output space the need for a dataset which had the social connections between the authors of the tweets arose.

Given the fact that the social relations were required, we opted for making a crawler based on the REST API. Due to the fact that twitter API rate limits would be achieved with some ease, the crawler should be prepared to achieve this maximum amount of requests per 15 minute window and wait for fifteen minutes.

Also, at a given time, the crawler should be able to serialize its state in order to be able to resume crawling in case it has to stop at any given worldly circumstances.

4.3 SOM

4.3.1 Clustering Tweets

In order to use SOM to cluster tweets, first the tweets need to be converted into VSM. Given the fact that tweets are often misspelled, with slang words and are written in multiple languages the VSM tends to become pretty large with relative ease.

In order to reduce the amount of different words that could have the same meaning, or no meaning at all the following rules were applied:

- Only English tweets were used during clustering.
- URLs are removed. Since most of them are minimized little information can be taken from them without domain translations.
- Numbers are removed.
- All letters are down cased.
- Runs of a character are replaced by a single character.
- Words smaller than 3 chars are discarded.
- Stop words are removed.
- The tweet text is stemmed.

By applying these rules the VSM is greatly reduced without destroying major relevant words. More information about VSM reduction can be found on chapter X.

Since tweets are very small and have an average of only 10 14 words, there is no need to store term frequency on the VSM, only a binary count is made.

Converting tweets from text to VSM can be done in two different approaches: cumulative approach, where the VSM is being built at the same time that the tweets are read, and as soon as a new term is found, it is a new position is added to the VSM matrix. The second way relies on scanning all words present in the dataset in order to first build the VSM, then iterate through all tweets and mark them as ones and zero's if they occur in the tweet text.

After the **SVM!** (**SVM!**) is filled with tweets, it can be feed to the SOM and training can start. It is important to notice though that since a destructive process was done to minimize the size of the **SVM!** if we want to read the tweets associated to clusters after the SOM training, some extra mechanisms must be implemented. **write about the NLP and how it fits in all of these**

4.3.2 Extensible SOM Library

When researching ways to extend the SOM algorithm, in order to add social features to the learning process. I found that the number of SOM libraries was not very extense. Even though, programing languages often used in ML and Data Mining, such as Python or C++, have their how implementation of the SOM algorithm. I've found that most of these libraries are made in such a way to be extremely fast, in order to take as much advantage from the hardware they are running on as possible. They often lack the modularity needed to adapt the SOM algorithm to specific problems.

The SOM algorithm has been changed many times in order to better categorize data with specific features, for example Geo-SOM was described in Subsection 3.1.1, the Growing Hierarchical SOM [30], the time adaptive SOM [33], the Ontological SOM [10], and the list goes on. . .

In order to create the homophilic SOM, described in Section 4.4 we first created a SOM framework that is easy to extend due to be fully object oriented, scripted — even though it can be compiled to run on the JVM — and without C extensions.

4.4 Homophilic SOM Definition

The default SOM algorithm has no idea whatsoever of the social connections between the tweets, it simply looks at the binary vectors that represent sentences and assigns it to the most similar neuron.

In order to better categorize socially connected data, we propose some alterations to the SOM algorithm in order to make it aware of the social connections between the tweets, and therefor better represent the homophilic behavior present on social networks.

4. Clustering Tweets with Self Organizing Maps

4.4.1 Output Space

The output space is the zone on the SOM algorithm where the neurons reside. It works like a cortex where neurons are scattered in a geometric fashion, generally a square. The output space is generally initialized with random values, with a relatively high learning rate, and also a relatively high number of epochs. The algorithm is made this way in order to be able to identify any type of data that can be represented as vectors.

First we will try to change the output space to better resemblance the social network. In order to do this, the squared grid that defines the output space was changed by the social network connections, and the neurons, are represented by a social network user. This changes are applied in the following way:

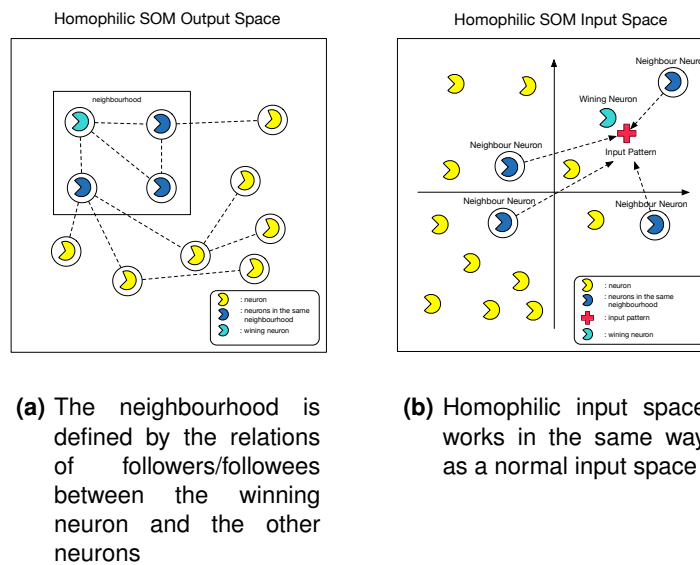


Figure 4.3: Homophilic SOM output and input space during the learning phase.

- Each neuron is comprised of the text from all the tweets that he authored.
- Each neuron has a unique id, and stores the ids of his followers and followees that are present in the output space.
- During the learning phase, the radius will be defined as the maximum number of hops separating the winning neuron and followers/followees of followers/followees.

4.4.2 Learning Phase

Like in the default SOM the learning phase is where the output space is trained in order to organize the input data into clusters. Since this algorithm is specific to categorize tweets using social network features, the learning rate, radius and number of epochs used can be greatly reduced in order for the algorithm to converge. The learning phase operates in the following way:

- The distance between the input pattern and all the neurons is calculated. The neuron closest to the input pattern is considered the winning neuron.
- When the winning neuron is selected, he and his social neighbors within k hops, update their representations in the input space, and move closer to the input pattern. The Gaussian function (Func. 2.3) is also used in here in order for the neighbors that are closer to the input pattern be significantly more influenced by the input pattern, while the neurons further away are less influenced.
- This process is repeated for a predefined number of epochs. While the number of epochs increases, the learning rate, and number of hops that defines the neighborhood decreases in order for the algorithm to converge.

Just like the default SOM algorithm, after the map is trained, input patterns can be fast assign to the nearest neuron since the neuron positions in the output space are no longer updated.

4.4.3 Visualizing Neuron Representation Quality

The homophilic SOM has an output space that doesn't relate to any kind of geometric figure, due to this fact it is not possible to visualize the clusters formed using U-Matrix. In order to solve this problem we propose an alternative way to visualize SOM that instead of focusing on the distance between the neurons on the output space – like the U-Matrix – it focuses on the mean quantization error between each neuron and the input patterns it is mapped to. We named this method Q-Matrix (All. 3) due to its similarity to the U-Matrix but using the mean quantization error.

The algorithm works in the following way: for each neuron in the grid, we find the quantization error between it and all the input patterns it represents. Afterwards we calculate the average between all the quantization errors associated to the neuron, and add it to the Q-Matrix. After this process is applied to all neurons, all quantizations errors are converted to a color that is directly proportional to the amount of the mean quantization error.

Even though we used the Q-Matrix algorithm to find the best clusters on the Homophilic SOM where each neuron represents a cluster. The Q-Matrix can be applied to the default SOM algorithm in order to easily visualize neurons which don't represent well their input patterns. An example of a Q-Matrix can be seen in Figure 4.4

4. Clustering Tweets with Self Organizing Maps

Algorithm 3: Q-Matrix

Data: Input patterns $X = \{\vec{x}_{0,0}, \dots, \vec{x}_{n,n}\}$,

Trained neurons $W = \{\vec{w}_{0,0}, \dots, \vec{w}_{n,n}\}$

let $D_{i,j}$ be the input patterns represented by neuron $w_{i,j}$

Result: Q-Matrix

let Q be an empty matrix of size $n * n$

for $i = 0$ to W_{max} **do**

for $j = 0$ to W_{max} **do**
 $q_{i,j} \leftarrow avg_quant_error(w_{i,j}, D_{i,j})$

/* convert the distances to color

*/

$WHITE = 255$

$BLACK = 0$

$q_{max} \leftarrow max(Q)$

$q_{min} \leftarrow min(Q)$

for $q_{ij} = q_{00}$ to $q_{n,n}$ **do**

$Q_{i,j} \leftarrow (1 - \frac{q_{i,j} - q_{min}}{q_{max} - q_{min}}) * WHITE$

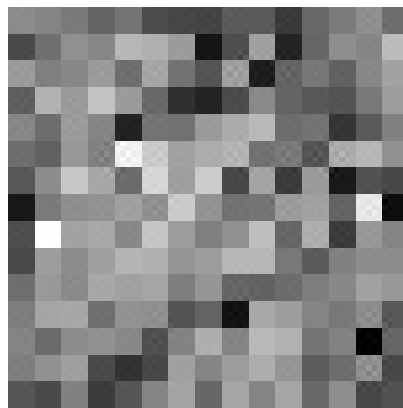


Figure 4.4: Q-Matrix calculated after 300 epochs of training a default SOM algorithm to identify colors. By looking at the matrix it is very easy to see which neurons are not representing their associated input patterns well – in black – and in white the ones that have very little quantization error and therefore are good at representing their input patterns

5

Evaluation Metrics

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5. Evaluation Metrics

```
1 karmadabaghi,A Paintbrush That Works On The iPad @sensubrushman
```

Figure 5.1: CSV representation of a Tweet. The username is present in the first column and the tweet text on the last.

5.1 Clustering Tweets with Self-Organizing Maps

5.1.1 Twitter Dataset

As can be seen in Figure ?? no information about the social relations of the user which emitted the tweet are present. Therefore in order to retrieve the social network in which a user is contained, it will be necessary to connect to the Twitter API. Crawling twitter is discussed in further depth in Chapter ??.

In order to better understand the dataset at hand, all the JSON files were converted into CSV in a way to reduce the size of the dataset. While tweets were being converted, URL were removed — since most of them were minified in order to fit in less than 140 characters, without translating the minified URL, not a lot of information can be gathered. Also, all tweets that were not identified as being in English were also removed. The tweet shown in JSON format in Figure 4.1 is converted to CSV in Figure 5.1.

Add table with dataset characteristics

5.1.2 SOM training

Refer dataset info on Describe naive approach to SOM training in R Describe amount of weird words

5.1.3 Reducing SOM vector size

5.1.3.A Identify Tweets language

Identifying tweets that were not in the English language was done through the usage of Ruby library called `whatlanguage`¹, which tries to identify one language through Bloom Filters. Inside the tweet there is a field which identifies the user language, we found that `x` is not accurate. Removing tweets that weren't in the English language reduced the amount of different words in `x` and therefore will reduce the dimensional size of the SOM.

5.1.3.B Text Manipulation for VSM reduction

all the text techniques used show amount of words reduction with the introduction of a new technique and the amount of time that it takes to be applied

¹<https://github.com/peterc/whatlanguage>

Work done on the INESC twitter dataset with SOMs. SOM implementations used, what where their strong points and weaknesses

5.1.3.C Clustering with Word Selection

Results of SOMs using selected words based on occurrence after applying SVM reduction
Results where pretty bad

5.1.4 Clustering with NLP selected words

results of som using arktweet NLP types of tags selected show tweets that had no representation review clusters and results

5.1.5 Conclusions

5.2 Twitter Crawler

This problem could be solved in any of the following ways:

- **First approach:** For each tweet, fetch the user information including the users he is connected to.
- **Second approach:** Create our own crawler, where the social connections, tweets and users are saved.

When designing the twitter crawler, we took into consideration that it had to be extremely resilient in order to be able to be left alone, crawling the twitter, until told to stop. Also if anything happened to the machine where the crawler was running it would be necessary to return to some previous crawling state, with minimum data loss. Algorithm **I NEED TO WRITE THIS ALGORITHM** shows the crawler algorithm, which works in the following way:

- **Step 1:** Choose some seed users to start crawling or deserialize a serialized version of the crawler if available.
- **Step 2:** For each seed user get all of his followers, and add them to an array if they haven't yet been crawled.
- **Step 3:** Repeat step one with random users taken from the array on step 2, until API limit is reached.
- **Step 4:** When API limit is reached, print the state of the crawled network, serialize the current state, and wait 15 minutes until it is possible to resume crawling.

5. Evaluation Metrics

5.2.1 Crawler Performance

show number of tweets per second, number user per second, and users reached per second.
compare the with the theoretical maximum compare size of the serialized social network with the
amount of tweets and users it is getting compare time taken to deserialize with amount of tweets
crawled compare time to serialize with amount of tweets crawled

5.3 SOM Framework

The SOM framework was developed in the Ruby programming language ² due to the desired characteristic of allowing great levels of introspection and being an almost pure object oriented programming language. Due to this characteristics making modifications to core parts of the algorithm is fairly easy.

The SOM Framework was developed in a test driven fashion, having 100% of its public methods tested and documented for expected behavior. These characteristics, associated with the fact that was published under an open source license, makes it available for other researchers to implement their own SOM variants.

By default, the base SOM algorithm is implemented as described by the Algorithm 1 in Section 2.2.

5.3.1 Clustering Color Vectors

Out of the box, the SOM Framework implements a squared output space, where all residing neurons are manipulated as arrays. It is possible at any given moment of the training to export the output space to JSON, CSV or to visualize its current U-Matrix. Also during training a progress bar is displayed in order to know how much time will be needed for the training to end.

Due to the features described above, it is possible to train a SOM to identify random colors — RGB vectors — while printing the results. In order to do this we will start by:

- Initializing a SOM object with an output space size of 15 by 15 neurons, which will yield a total of 255 neurons — and directly maps to the maximum number of clusters — and 700 epochs.
- Create 1500 input patterns with size 3 and random values between 0 and 255.
- Tell the SOM to print its state at the end of each epoch.

The machine used for training had the hardware specifications outlined in table 5.2

²<https://www.ruby-lang.org/en/>

Table 5.1: Test machine one specs

Operative System	OSX 10.9.5
Memory	8 GB, 1067MHz DDR3
Processor	2,4GHz Intel Core 2 Duo
Hard Drive	128GB SSD

A summary of the training is specified in Table ??

Table 5.2: SOM training resumed

Number of Neurons	225
Output Space Size	15x15
Number of Input Patterns	1500
VSM size of Input Patterns and Neurons	3
Number of Epochs	600
Training Duration	14 hours
Type of Train	print each epoch training
Initial learning rate	0.6
Initial Radius	8

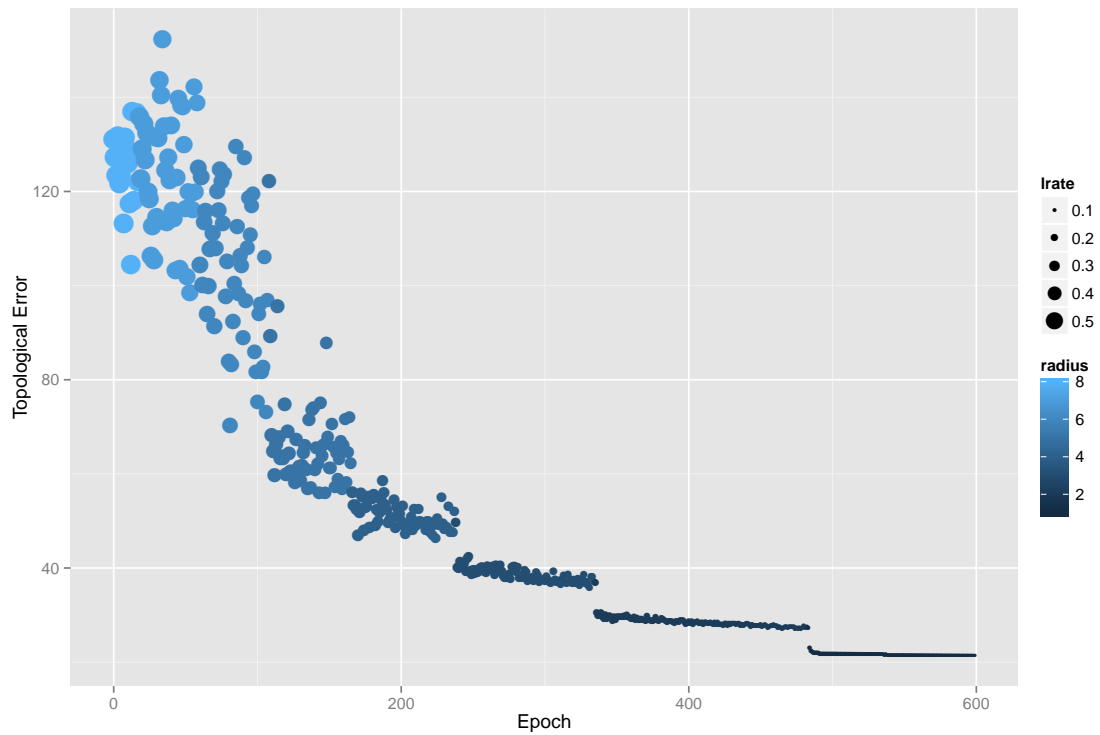


Figure 5.2: Changes in topological error throughout the SOM training, lrate stands for learning rate, and radius for radius applied to the winning neuron

5. Evaluation Metrics

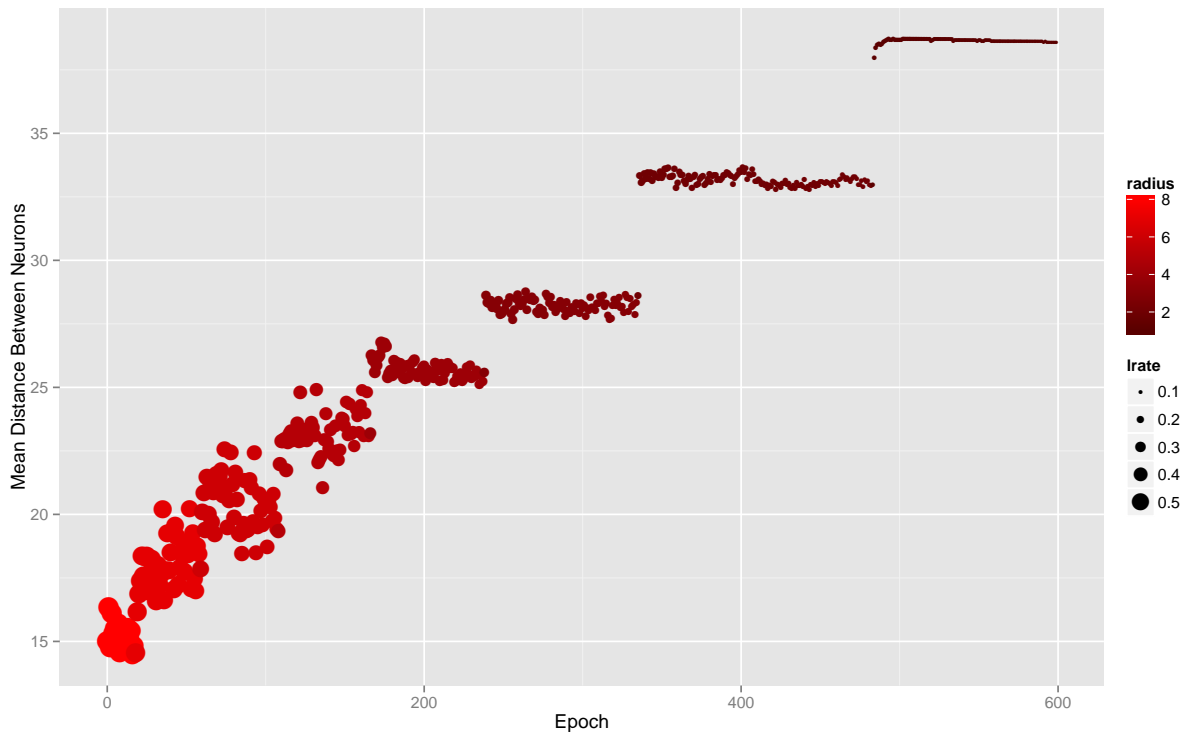


Figure 5.3: Changes in the average distance between neurons, throughout the SOM training

5.3.2 Benchmarking

5.4 Homophilic SOM

5.5 Conclusions

Only these methods are not enough to cluster tweets

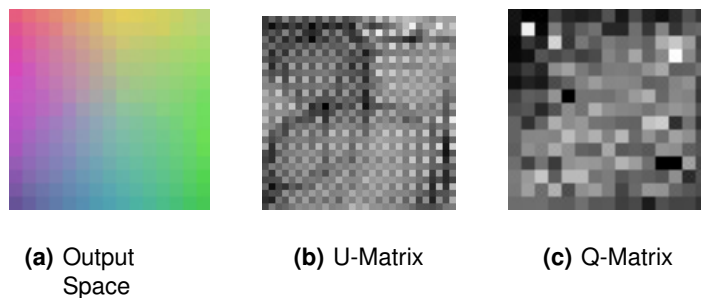


Figure 5.4: SOM state after first epoch of training. Its learning rate is at 0.598, and radius at 8.

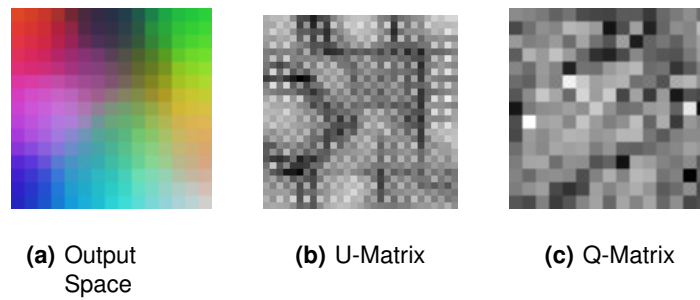


Figure 5.5: SOM state after second epoch of training. Its learning rate is at 0.22, and radius at 3.

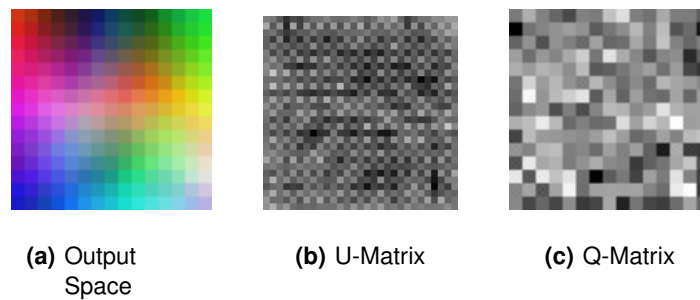


Figure 5.6: SOM state after third epoch of training. Its learning rate is at 0.081, and radius at 1.

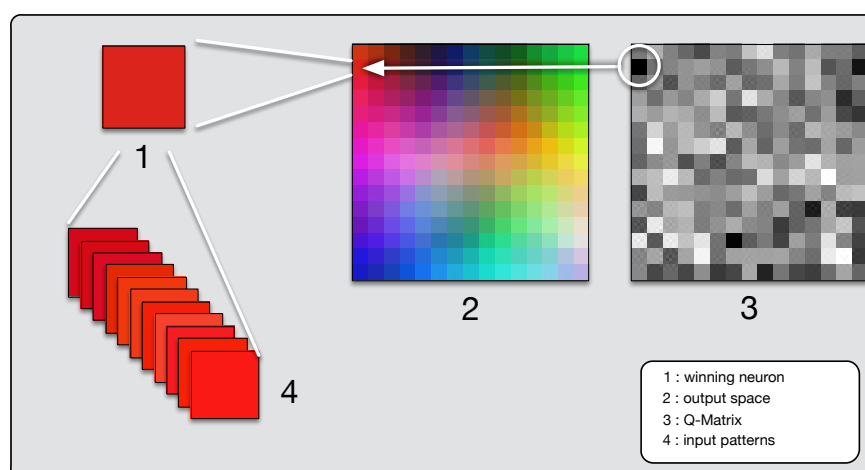


Figure 5.7: Input patterns associated with the neuron with maximum topological error -31 . Even though the neuron has the biggest topological error of all neurons, it still has a good representation of the input patterns. The colors in this image are not figurative, and represent the entities at the end of training

6

Conclusions and Future Work

6. Conclusions and Future Work

Draw your conclusions here and sell your work. Transmit to the jury how hard it was to develop the presented work.

A future work section is usually here.

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Appendix A

B

Appendix A
