

Towards Real-Time Summarization of Scheduled Events from Twitter Streams *

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ABSTRACT

This paper explores the real-time summarization of scheduled events such as soccer games from torrential flows of Twitter streams. We propose and evaluate an approach that substantially shrinks the stream of tweets in real-time, and consists of two steps: (i) sub-event detection, which determines if something new has occurred, and (ii) tweet selection, which picks a representative tweet to describe each sub-event. We compare the summaries generated in three languages for all the soccer games in *Copa America 2011* to reference live reports offered by Yahoo! Sports journalists. We show that simple text analysis methods which do not involve external knowledge lead to summaries that cover 84% of the sub-events on average, and 100% of key types of sub-events (such as goals in soccer). Our approach should be straightforwardly applicable to other kinds of scheduled events such as other sports, award ceremonies, keynote talks, TV shows, etc.

Categories and Subject Descriptors

H.3.3 [Information Storage and Retrieval]: Information Search and Retrieval; H.1.2 [Models and Principles]: User/Machine Systems—*Human information processing*

General Terms

Experimentation

Keywords

twitter, real-time, events, summarization

*The present paper gives more technical and experimental details about the work published as a poster at HT'2012 [8].

1. INTRODUCTION

Twitter¹ has gained widespread popularity as a microblogging site where users share short messages (*tweets*). Twitter users not only tweet about their personal issues or nearby events, but also about news and events of interest to some community [5]. Twitter has become a powerful tool to stay tuned to current affairs. It is known that, in particular, Twitter users exhaustively share messages about (all kinds of) events they are following live, occasionally giving rise to related trending topics [9].

The community of users live *tweeting* about a given event generates rich contents describing sub-events that occur during an event (e.g., goals, red cards or penalties in a soccer game). All those users share valuable information providing live coverage of events [1]. However, this overwhelming amount of information makes difficult for the user: (i) to follow the full stream while finding out about new sub-events, and (ii) to retrieve from Twitter the main, summarized information about which are the key things happening at the event. In the context of exploring the potential of Twitter as a means to follow an event, we address the (yet largely unexplored) task of summarizing Twitter contents by providing the user with a summed up stream that describes the key sub-events. We propose a two-step process for the real-time summarization of events—sub-event detection and tweet selection—, and analyze and evaluate different approaches for each of these two steps. We find that Twitter provides an outstanding means for detailed tracking of events, and present an approach that accurately summarizes streams to help the user find out what is happening throughout an event. We perform experiments on scheduled events, where the start time is known. By comparing different summarization approaches, we find that learning from the information seen before throughout the event is really helpful both to determine if a sub-event occurred, and to select a tweet that represents it.

To the best of our knowledge, our work is the first to provide an approach to generate real-time summaries of events from Twitter streams without making use of external knowledge.

¹<http://twitter.com/>

Thus, our approach might be straightforwardly applied to other kinds of scheduled events without requiring additional knowledge.

2. DATASET

We study the case of tweets sent during the games of a soccer competition. Sports events are a good choice to explore for summarization purposes, because they are usually reported live by journalists, providing a reference to compare with. We set out to explore the *Copa America 2011* championship, which took place from July 1st to 24th, 2011, in Argentina, where 26 soccer games were played. Choosing an international competition with a wide reach enables to gather and summarize tweets in different languages. The official start times for the games were announced in advance by the organization.

During the period of the *Copa America*, we gathered all the tweets that contained any of `#ca2011`, `#copaamerica`, and `#copaamerica2011`, which were set to be the official Twitter hashtags for the competition. For the 24 days of collection, we retrieved 1,425,858 unique tweets sent by 290,716 different users. These tweets are written in 30 different languages, where 76.2% are in Spanish, 7.8% in Portuguese, and 6.2% in English. The tweeting activity of the games considerably varies, from 11k tweets for the least-active game, to 74k for the most-active one, with an average of 32k tweets per game.

In order to define a reference for evaluation, we collected the live reports for all the games given by Yahoo! Sports². These reports include the annotations of the most relevant sub-events throughout a game. 7 types of annotations are included: goals (54 were found for the 26 games), penalties (2), red cards (12), disallowed goals (10), game starts (26), ends (26), and stops and resumptions (63). On average, each game comprises 7.42 annotations. Each of these annotations includes the minute when it happened. We manually annotated the beginning of each game in the Twitter streams, so that we could infer the timestamp of each annotation from those minutes. The annotations do not provide specific times with seconds, and the actual timestamp may vary slightly. We have considered these differences for the evaluation process.

3. REAL-TIME EVENT SUMMARIZATION

We define real-time event summarization as the task that provides new information about an event every time a relevant sub-event occurs. To tackle the summarization task, we define a two-step process that enables to report information about new sub-events in different languages. The first step is to identify at all times whether or not a specific sub-event occurred in the last few seconds. The output will be a boolean value determining if something relevant occurred; if so, the second step is to choose a representative tweet that describes the sub-event in the language preferred by the user. The aggregation of these two processes will in turn provide a set of tweets as a summary of the game (see Figure 1).

3.1 First Step: Sub-Event Detection

² <http://uk.eurosport.yahoo.com/football/copa-america/fixtures-results/>

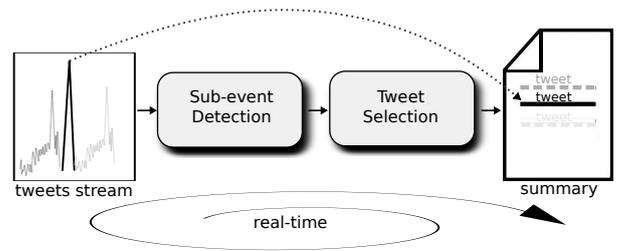


Figure 1: Two-step process for real-time event summarization.

The first part of the event summarization system corresponds to the sub-event detection. Note that, being a real-time sub-event detection, the system has to determine at all times whether or not a relevant sub-event has occurred, clueless of how the stream will continue to evolve. Before the beginning of an event, the system is provided with the time that it starts, as scheduled in advance, so the system knows when to start looking for new sub-events. With the goal of developing a real-time sub-event detection method, we rely on the fact that relevant sub-events trigger a massive tweeting activity of the community. We assume that the more important a sub-event is, the more users will tweet about it almost immediately. This is reflected as peaks in the histogram of tweeting rates (see Figure 2 for an example of a game in our dataset). In the process of detecting sub-events, we aim to compare 2 different ideas: (i) considering only sudden increase with respect to the recent tweeting activity, and (ii) considering also all the previous activity seen during a game, so that the system learns from the evolution of the audience. We compare the following two methods that rely on these 2 ideas:

1. **Increase:** this approach was introduced by Zhao et al. [7]. It considers that an important sub-event will be reflected as a sudden increase in the tweeting rate. For time periods defined at 10, 20, 30 and 60 seconds, this method checks if the tweeting rate increases by at least 1.7 from the previous time frame for any of those periods. If the increase actually occurred, it is considered that a sub-event occurred. A potential drawback of this method is that not only outstanding tweeting rates would be reported as sub-events, but also low rates that are preceded by even lower rates.
2. **Outliers:** we introduce an outlier-based approach that relies on whether the tweeting rate for a given time frame stands out from the regular tweeting rate seen so far during the event (not only from the previous time frame). We set the time period at 60 seconds for this approach. 15 minutes before the game starts, the system begins to learn from the tweeting rates, to find out what is the approximate audience of the event. When the start time approaches, the system begins with the sub-event detection process. The system considers that a sub-event occurred when the tweeting rate represents an outlier as compared to the activity seen before. Specifically, if the tweeting rate is above 90% of all the previously seen tweeting rates, the cur-

rent time frame will be reported as a sub-event. This threshold has been set a priori and without optimization. The outlier-based method incrementally learns while the game advances, comparing the current tweeting rate to all the rates seen previously. Different from the increase-based approach, our method presents the advantages that it considers the specific audience of an event, and that consecutive sub-events can also be detected if the tweeting rate remains constant without increase. Accordingly, this method will not consider that a sub-event occurred for low tweeting rates preceded by even lower rates, as opposed to the increase-based approach.

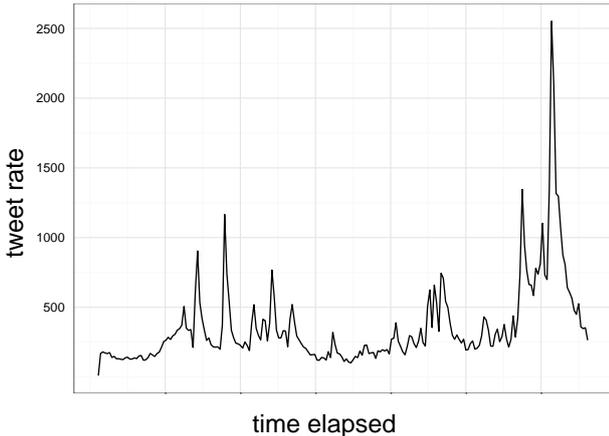


Figure 2: Sample histogram of tweeting rates for a soccer game (Argentina vs Uruguay), where several peaks can be seen.

Since the annotations on the reference are limited to minutes, we round down the outputs of the systems to match the reference. Also, the timestamps annotated for the reference are not entirely precise, and therefore we accept as a correct guess an automatic sub-event detection that differs by at most one minute from the reference.

This evaluation method enables us to compare the two systems to infer which of them performs best. Table 1 shows the precision (P), recall (R) and F-measure (F1) of the automatically detected sub-events with respect to the reference, as well as the average number of sub-events detected per game (#). Our outliers approach clearly outperforms the baseline, improving both precision (75.8% improvement) and recall (3.7%) for an overall 40% gain in F1. At the same time, the compression rate for the outliers approach almost doubles that of the baseline (56.4%). From the average of 32k tweets sent per game, the summarization to 25.6 tweets represents a drastic reduction to only 0.079% of the total. Keeping the number of sub-events small while effectiveness improves is important for a summarization system in order to provide a concise and accurate summary. The outperformance of the outlier-based approach shows the importance of taking into account the audience of a specific game, as well as the helpfulness of learning from previous activity throughout a game.

	P	R	F1	#
Increase	0.29	0.81	0.41	45.4
Outliers	0.51	0.84	0.63	25.6

Table 1: Evaluation of sub-event detection approaches.

3.2 Second Step: Tweet Selection

The second and final part of the summarization system is the tweet selection. This second step is only activated when the first step reports that a new sub-event occurred. Once the system has determined that a sub-event occurred, the tweet selector is provided with the tweets corresponding to the minute of the sub-event. From those tweets, the system has to choose one as a representative tweet that describes what occurred. This tweet must provide the main information about the sub-event, so the user understands what occurred and can follow the event. Here we compare two tweet selection methods, one relying only on information contained within the minute of the sub-event, and another considering the knowledge acquired during the game. We test them on the output of the outlier-based sub-event detection approach described above, as the approach with best performance for the first step.

To select a representative tweet, we get a ranking of all the tweets. To do so, we score each tweet with the sum of the values of the terms that it contains. The more representative are the terms contained in a tweet, the more representative will be the tweet itself. To define the values of the terms, we compare two methods: (i) considering only the tweets within the sub-event (to give highest values to terms that are used frequently within the sub-event), and (ii) taking into account also the tweets sent before throughout the game, so that the system can make a difference from what has been the common vocabulary during the event (to give highest values to terms that are especially used within the minute and not so frequently earlier during the event). We use the following well-known approaches to implement these two ideas:

1. **TF:** each term is given the value of its frequency as the number of occurrences within the minute, regardless of its prior use.
2. **KLD:** we use the Kullback-Leibler divergence [4] (see Equation 1) to measure how frequent is a term t within the sub-event (H), but also considering how frequent it has been during the game until the previous minute (G). Thus, KLD will give a higher weight to terms frequent within the minute that were less frequent during the game. This may allow to get rid of the common vocabulary all along the game, and rather provide higher rates to specific terms within the sub-event.

$$D_{\text{KL}}(H||G) = H(t) \log \frac{H(t)}{G(t)} \quad (1)$$

With these two approaches, the sum of values for terms contained in each tweet results in a weight for each tweet. With

weights given to all tweets, we create a ranking of tweets sent during the sub-event, where the tweet with highest weight ranks first. We create these rankings for each of the languages we are working on. The tweet that maximizes this score for a given language is returned as the candidate tweet to show in the summary in that language. The two term weighting methods were applied to create summaries in three different languages: Spanish, English, and Portuguese. We test them on the output of the outlier-based sub-event detection approach described above, as the approach with best performance for the first step. Thus, we got six summaries for each game, i.e., TF and KLD-based summaries for the three languages. These six summaries were manually evaluated by comparing them to the reference. Table 2 shows some tweets included in the KLD-based summary in English.

In the manual evaluation process, each tweet in a system summary is classified as correct if it can be associated to a sub-event in the reference and is descriptive enough (note that there might be more than one correct tweet associated to the same sub-event). Alternatively, tweets are classified as novel (they contain relevant information for the summary which is not in the reference) or noisy. From these annotations, we computed the following values for analysis and evaluation: (i) recall, given by the ratio of sub-events in the reference which are covered by a correct tweet in the summary; and (ii) precision, given by the ratio of correct + novel tweets from a whole summary (note that redundancy is not penalized by any of these measures).

		es	en	pt
Goals (54)	TF	0.98	0.98	0.98
	KLD	1.00	1.00	1.00
Penalties (2)	TF	1.00	0.50	1.00
	KLD	1.00	0.50	1.00
Red cards (12)	TF	0.75	0.75	0.83
	KLD	0.92	0.92	1.00
Disallowed goals (10)	TF	0.40	0.50	0.40
	KLD	0.40	0.50	0.30
Game starts (26)	TF	0.73	0.74	0.79
	KLD	0.84	0.79	0.83
Game ends (26)	TF	1.00	1.00	1.00
	KLD	1.00	1.00	1.00
Game stops & resumptions (63)	TF	0.62	0.60	0.57
	KLD	0.68	0.60	0.59
Overall	TF	0.79	0.74	0.78
	KLD	0.84	0.77	0.82

Table 3: Recall of reported sub-events for summaries in Spanish (es), English (en), and Portuguese (pt).

Table 3 shows recall values as the coverage of the two approaches over each type of sub-event, as well as the macro-averaged overall values. These results corroborate that simple state-of-the-art approaches like TF and KLD score outstanding recall values. Nevertheless, KLD shows to be slightly superior than TF for recall. Regarding the averages of all kinds of sub-events, recall values are near or above 80% for all the languages. It can also be seen that some sub-

events are much easier to detect than others. It is important that summaries do not miss the fundamental sub-events. For instance, all the summaries successfully reported all the goals and all the game ends, which are probably the most emotional moments, when users extremely coincide sharing. However, other sub-events like game stops and resumptions, or disallowed goals, were sometimes missed by the summaries, with recall values near 50%. This shows that some of these sub-events may not be that shocking sometimes, depending on the game, so fewer users share about them, and therefore are harder to find by the summarization system. For instance, one could expect that users would not express high emotion when a boring game with no goals stops for half time. Likewise, this shows that those sub-events are less relevant for the community. In fact, from these summaries, users would perfectly know when a goal is scored, when it finished, and what is the final result.

	es	en	pt
TF	0.79	0.74	0.79
KLD	0.84	0.79	0.83

Table 4: Precision of summaries in Spanish (es), English (en), and Portuguese (pt).

Table 4 shows precision values as the ratio of useful tweets for the three summaries generated in Spanish, English and Portuguese. The results show that a simple TF approach is relatively good for the selection of a representative tweet, with precision values above 70% for all three languages. As for recall values, KLD does better than TF, with precision values near or above 80%. This shows that taking advantage of the differences between the current sub-event and tweets shared before considerably helps in the tweet selection. Note also that English summaries reach 0.79 precision even if the tweet stream is, in that case, an order of magnitude smaller than their Spanish counterpart, suggesting that the method works well at very different tweeting rates.

4. RELATED WORK

Automatic summarization of events from tweets is still in its infancy as a research field. Some have tackled the task in an offline mode, after the events were finished. For instance, Hannon et al. [3] present an approach for the automatic generation of video highlights for soccer games after they finished. They set a fixed number of sub-events that want to be included in the highlights, and select that many video fragments with the highest tweeting activity. Others, such as Petrović et al. [6], have shown the potential of Twitter for the detection and discovery of events from tweets. While some have studied events after they happened, there is very little research dealing with the real-time study of events to provide near-immediate information. Zhao et al. [7] detect sub-events occurred during NFL games, using an approach based on the increase of the tweeting activity. We set this approach as the baseline in our sub-event detection process. Afterward, they apply a specific lexicon provided as input to identify the type of sub-event. Different from this, our approach aims to be independent of the event, providing a summarized stream instead of categorizing sub-events. Chakrabarti and Punera [2] were the first to present an approach –which is based on Hidden Markov Models–

Sub-event	Selected Tweet	Narrator's Comment
Game start	RT @user: Uruguay-Argentina. The Río de la Plata classic. The 4th vs the 5th in the last WC. History doesn't matter. Argentina must win. #ca2011	The referee gets the game under way
Goal	Gol! Gol! Gol! de Perez Uruguay 1 vs Argentina 0 Such a quick strike and Uruguay is already on top. #copaamerica	GOAL!! Forlan's free kick is hit deep into the box and is flicked on by Caceres. Romero gets a hand on it but can only push it into the path of Perez who calmly strokes the ball into the net.
Goal	Goooooooooooooooooal Argentina ! Amazing pass from Messi, Great positioning & finish from Higuain !! Arg 1 - 1 Uru #CopaAmerica	GOAL!! Fantastic response from Argentina. Messi picks the ball up on the right wing and cuts in past Caceres. The Barca man clips a ball over the top of the defence towards Higuain who heads into the bottom corner.
Red card	Red card for Diego Pérez, his second yellow card, Uruguay is down to 10, I don't know if I would have given it. #CopaAmerica2011	You could see it coming. How stupid. Another needless free kick conceded by Perez and this time he is given his marching order. He purposely blocks off Gago. Uruguay have really got it all to do now.
Red card	#ca2011 Yellow for Mascherano! Double yellow! Adios! 10 vs 10! Mascherano surrenders his captain armband!	It's ten against ten. Macherano comes across and fouls Suarez. He's given his second yellow and his subsequent red.
Game stop (full time)	Batista didn't look too happy at the game going to penalties as the TV cut to hit at FT, didn't appear confident #CA2011	The second half is brought to an end. We will have extra time.
Game end	Uruguay beats Argentina! 1-1 (5-4 penalty shoot out)! Uruguay now takes on Peru in Semis. #copaamerica	ARGENTINA 4-5 - URUGUAY WIN. Caceres buries the final penalty into the top right-hand corner.

Table 2: Example of some tweets selected by the (outliers+KLD) summarization system, compared with the respective comments narrated on Yahoo! Sports.

for constructing real-time summaries of events from tweets. However, their approach requires prior knowledge of similar events, and so it is not easily applicable to previously unseen types of events.

5. CONCLUSIONS

We have presented a two-step summarization approach that, without making use of external knowledge, identifies relevant sub-events in soccer games and selects a representative tweet for each of them. Using simple text analysis methods such as KLD, our system generates real-time summaries with precision and recall values above 80% when compared to manually built reports. The fact that users tweet at the same time, with overlapping vocabulary, helps not only detecting that a sub-event occurs, but also selecting a representative tweet to describe it. Our study also shows that considering all previous information seen during the event is really helpful to this end, yielding superior results than taking into account just the most recent activity. The activity for the soccer games studied in this work varies from 11k to 74k tweets sent, showing that regardless of the audience tweeting about an event, our method effectively reports the key sub-events occurred during a game. Finally, all of the most relevant types of sub-events, such as goals and game ends, are reported almost perfectly.

Note that our method does not rely on any external knowledge about soccer events (except for the schedule time to begin), so it can be straightforwardly applied to other kinds of events. As future work, we intend to evaluate the performance of the method on other kinds of scheduled events such as award ceremonies, keynote talks, other types of sport events, product presentations, TV shows, etc.

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