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Analyzing Social Behavior of Software Developers Across Different Communication Channels

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Abstract

Software developers use different project repositories (i.e., mailing list, bug tracking repositories, discussion forums etc.) to interact with each other or to solve software related problems. The growing interest in the usage of social media channels (i.e., Twitter, Facebook, LinkedIn) have also attracted the open source software community and software developers to adopt an identity in order to disseminate project-related information to a wider audience. Much research has been carried out to analyze the social behavior of software developers in different project repositories but so far no one has tried to study the social communication patterns of developers in other social media channels. We in this paper presents a new dimension to the social aspects of software developers and study if the social communication patterns of software developers is different on project repositories and social media channels (i.e., Twitter).

1 Introduction & Motivation

In software engineering, many tools with underlying repositories have been introduced to support the collaboration and coordination in distributed software development. Research has shown that these project repositories contain rich amount of information about software projects. By mining the information contained in these project repositories, practitioners can depend less on their experience and more on the historical data [14]. Examples of project repositories are [15]: source control repositories, bug tracking repositories, mailing list archives etc. Software developers\(^1\) use these repositories to interact with each other or to solve software-related problems. Much research has been carried out to analyze the social network structure and behavior of software developers by extracting rich information from these project repositories [22, 13, 24].

\(^2\)https://twitter.com/SolrLucene
\(^3\)https://www.facebook.com/mysql
\(^4\)https://twitter.com/olamy/status/23103128734285824
\(^5\)https://twitter.com/olamy/status/305334578103582720

The growing interest in the usage of online social media channels (e.g., Facebook, Twitter, LinkedIn etc.) have also attracted the open source software community. Open source projects are often found to adopt an identity on these social media channels (e.g., Apache Solr/Lucene\(^2\) on Twitter, MySQL\(^3\) on Facebook) in order to disseminate project-related information (release announcements, major bug fixes etc.) or gather feedback/questions posted by the users. Software developers contributing to open source projects also exists on social media channels. Quite often, they discuss, debate or share experiences with others relevant to a software project using hashtags (e.g., #apache, #maven, #hadoop etc.). Hence, the discussions covering open source projects are not limited to dedicated forums or mailing lists, there also exists huge amount of information on the social media channels. However, on the social media channels, less technical details relevant to the project’s architecture, code or bugs are discussed. Much of the information available is regarding the experiences\(^4\) or announcements\(^5\) particular to a software project but such valuable information can not be ignored.

It is worth mentioning that the information related to open source projects are distributed on the Web in heterogeneous data islands i.e., social media channels and project repositories. Hence, there is a need to bridge the connection between project repositories and social media channels as shown in Figure 1. By enabling this connection, we will have an integrated view on the software project which can be exploited to support certain use case scenarios:

- End-users response on a particular release of a software project.
- The popularity of a software project by applying sentiment analysis [17] on social messages (i.e., tweets,

\(^1\)In this paper, we use the term “software developers” or “developers” to represent those who have commit rights on the source control repository of a project.
• Keeping track of software developer’s social activity related to a software project.
• Analysis of the social behavior of software developers in different communication channels (i.e., social media channels, project repositories).

![Figure 1: Linking Social Media Channels and Project Repositories.](image1)

The social behavior of users have been studied in depth in the past on different communication channels separately. However, to the best of our knowledge, no research work has been done so far on the comparison and analysis of the social behavior of software developers in different communication channels. There is no research work available which analyzes the behavior of software developers communication with each other on the mailing list/bug repositories and their communication on social media channels (e.g., Twitter). This motivates us to study the social communication patterns of software developers in different communication channels.

Among different social media channels available to date, we chose Twitter as a social media channel for this study. Our initial investigation reveals that software developers contributing to open source projects also use and communicate with each other on the social media channels (Twitter in particular). For example, Figure 2 shows the developers social network structure (derived from the communication happened on the mailing list) of an Apache project. Among them, few developers are also found on Twitter. We derived the social network structure based on their tweets (e.g., mentioning other developers in tweets) which is shown in Figure 3. We removed the labels from nodes (cf. Figure 2 and Figure 3) in order to keep the privacy of developers.

![Figure 2: Social Relation on Mailing List](image2)

![Figure 3: Social Relation on Twitter](image3)

The social network structures of software developers (cf. Figure 2 and Figure 3) contributing to the same software project provides us the basis to investigate the social behavior of software developers in different communication channels. We will investigate if software developers use Twitter as another medium of communication in contrast to the traditional medium of communication (mailing list, bug tracking repositories, forums etc.). This will laid down the foundations to study the social behavior of software developers with each other in different communication channels. In the current scope of this paper, we will not take into account what software developers are discussing on Twitter but instead we will focus on the communication happened between developers on Twitter in a given period of time and compare it with their communication happened on project repositories for the same period of time.

The contribution of this work is manifolds: we have identified social media channels as a platform which is used by the open source community and software developers to disseminate project-related information to a wider audience. Further we highlighted the need to integrate project repositories and the social media channels (interlinking project-related tweets/posts/hashtags, developer ID(s), project ID(s) etc.) in order to get an integrated view on the software project. We have introduced a new dimension to analyze the social aspects of software developers by taking into account non-traditional communication channels (i.e., Twitter, stackoverflow, LinkedIn, Facebook etc.) which are also used by software developers. We have conducted an initial experiment to investigate the correlation between software developers communication with each other on Twitter and in project repositories by analyzing their communication data over time.

2 Methodology

In this section, we describe our methodology to extract information from different data sources and the usage of a common model and standard format to represent extracted
information in order to support better query and integration. Further, we describe our approach to compute communication network data which later is used to understand how software developers communicated with each other in different communication channels over the period of time.

2.1 Transforming Data Sources into RDF

With “Linked Data Driven Software Development” (LD2SD) [20], we have introduced a Linked Data-based methodology to relate and integrate data across software repositories explicitly and unambiguously. We propose to use Semantic Web technologies to represent data from different software repositories. As such, we propose to use RDF [21] (Resource Description Framework) as the core, target data model. Once modeled in RDF, the data can be easily integrated, indexed and queried using the SPARQL query\(^7\) standard and associated tools. Finally, the integrated data can be published on the Web using Linked Data principles\(^8\) allowing third parties to discover and subsequently crawl the knowledge, and also allowing to interlink with background or other related information available remotely on the Web. We refer the readers to [16] for details on how these standards would be used. Instead here we focus on transforming data from project repositories and Twitter to RDF. We used our custom written script to convert mailing lists and bug tracking repositories data to RDF. An excerpt of an exemplary RDF representation of an email is shown in Listing 1. Due to space limitations, we do not show the RDF representation of a bug report but refer the readers to [19] for further details on the RDFication process.

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix ls: <http://purl.org/dc/elements/1.1/> .
@prefix sioc: <http://rdfs.org/sioc/types#> .
@prefix sioct: <http://purl.org/sioc/types#> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix email: <http://srvgal85.deri.ie/linkedfloss/mail2rdf/> .
@prefix twitter: <http://srvgal85.deri.ie/linkedfloss/twitter/> .

#堕http://www.w3.org/TR/rdf-sparql-query/ #http://www.w3.org/DesignIssues/LinkedData.html

email:body "There’s been little to no feedback on beta-2 so ..." .
dc:subject "Re: guice & memory usage was:" .
soc:mentions <http://srvgal85.deri.ie/linkedfloss/twitter/aheritier> ;
ls:status_count "6050" ;
dcterms:creator <http://srvgal85.deri.ie/linkedfloss/twitter/brettporter> ;
dcterms:language "en" ;
sioc:mentions <http://srvgal85.deri.ie/linkedfloss/twitter/aheritier> ;
...  
```

Listing 1: An Exemplary Email RDFication.

In order to compute the social communication of a software developer with other fellow software developers on Twitter, we first manually checked if software developers exists on Twitter and using the Twitter account frequently. We found few software developers who does exist on the Twitter platform but tweeted very little (=10-20 tweets only). We skipped such software developers in the data crawling and transformation process due to less data available for them. Twitter offers an Application Programming Interface (API)\(^9\) which makes it easy to crawl and collect data from Twitter. We crawled developers Twitter profiles and their tweets using Twitter API and later transformed it to RDF using our custom written scripts. An excerpt of an exemplary RDF representation of a developer’s Twitter profile is shown in Listing 2.

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix ls: <http://purl.org/dc/elements/1.1/> .
@prefix sioc: <http://rdfs.org/sioc/types#> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix email: <http://srvgal85.deri.ie/linkedfloss/mail2rdf/> .

ls:status_count "6050" ;
dcterms:creator <http://srvgal85.deri.ie/linkedfloss/twitter/brettporter> ;
dcterms:language "en" ;
sioc:mentions <http://srvgal85.deri.ie/linkedfloss/twitter/aheritier> ;
... 
```

Listing 2: An Exemplary Twitter Profile in RDF.

Developers often tweets about project-related information using hashtags (e.g., #maven, #lucene) or communicate with other fellow developers by explicitly mentioning his/her name in a tweet. An excerpt of an exemplary RDF representation of a tweet is shown in Listing 3. After transforming the data sources to RDF, we loaded the RDF data sets into our public SPARQL endpoint\(^10\).

```
@prefix sioctypes: <http://rdfs.org/sioc/types#> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix ls: <http://purl.org/dc/elements/1.1/> .
@prefix sioc: <http://rdfs.org/sioc/types#> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix email: <http://srvgal85.deri.ie/linkedfloss/mail2rdf/> .

ls:status_count "6050" ;
dcterms:creator <http://srvgal85.deri.ie/linkedfloss/twitter/brettporter> ;
dcterms:language "en" ;
sioc:mentions <http://srvgal85.deri.ie/linkedfloss/twitter/aheritier> ;
... 
```

Listing 3: An Exemplary Tweet RDFication.

In this paper, we are not focusing on interlinking developer’s information and project related tweets from Twitter to the various software artifacts (i.e., bug, email, commit ID, source-code, developer ID etc.) contained in project repositories. Hence, we do not present any approach on creating owl:sameAs links between relevant entities across different data sources. Different approaches [23, 11, 18, 19] could potentially be utilized in order to achieve the interlinking between Twitter data sets and software artifacts but it is not in the current scope of this paper.

2.2 Social Relation Computation Approach

The social network structure based on the mailing list archives was constructed by using the reply structure of the
Developers (SVN) 24 7 51 18 11 51
Developers (Twitter) 35 47 37 16 82 10 11 28 36 9 40

the poster of email 4C5D409A.9060901 (cf. line#12). Hence, we can easily query
the poster of email 4C5D409A.9060901 (cf. line#12) in
order to create a social link between both software developers. In the case of bug tracking repository, link was de-
scribed on the comment posted by a software developer
on a particular bug and the immediate previous commenter
on the same bug. The social network structure based on
the Twitter data was constructed by exploiting the common
practice of using well defined markup in a tweet: @ fol-
lowed by a user identifier address the user. This approach
defines a link as the interaction between the software de-
veloper who posted the tweet and the software developer men-
tioned in the tweet. For example, Listing 3 indicates that the
tweet mentions a software developer which is also reflected
through sioc:mentions property (cf. line#11). Hence,
we can create a social link between both software develop-
ers (aheiritter and brettpporter). Social relations
between developers on the Twitter was extracted by query-
ing the Twitter data sets using sioc:mentions predicate
property. Social relation between any 2 software develop-
ers were computed only if both software developers com-
municated directly to each other on the project repositories
and the Twitter platform. Periods without any communica-
tion are common as software developers may still contribute
to the same project even if they haven’t communicated for
many days. To tackle this issue, communication between
software developers were captured on monthly basis where
each month value represent the number of times both soft-
ware developers communicated directly to each other. Col-
lecting communication data on monthly basis provides good
amount of data for every pair of software developers in or-
der to analyze their social communication patterns over the
period of time. The initial time-stamp for calculating the so-
cial relation between any 2 software developers were com-
puted by comparing the earliest dates where communication
happened between both software developers on the project
repositories and Twitter. The later date was then used as
the starting time-stamp to compute the social relation be-
tween both software developers. For example, let say ear-
liest communication happened between 2 developers on the
project repositories was 2008-05-25 and on the Twitter
was 2010-03-15. Thus, we will consider 2010-03-15
as the starting time-stamp and compute monthly social in-
teraction between both software developers on the project
repository and Twitter over the period of time.

3 Evaluation

Before we discuss the results of our evaluation, we de-
scribe the projects selected for evaluation. We gathered
data from project repositories of 10 Apache projects (c.f Ta-
ble 1). The reason of choosing Apache projects is that the
repositories are on the Web and available to download (i.e.
mailing list archives, bugs, commit logs etc.). We selected
data from the beginning of each Apache project to date.
The primary source of communication among developers
in Apache projects is through mailing lists. Most Apache
projects have at least 3 different mailing lists: user, dev
and commits but some projects have more than 3 mailing
lists (e.g. announcements, notifications etc.). For our study, we downloaded only the dev mailing list
archives of each Apache project under consideration. The
reason is, software developers communicate often with each
other on the dev mailing list rather than on any other mail-
ing list. From the source-control repository data sets of
each Apache project, we extracted a list of software de-
velopers who made commits to the project. Later, we manually
checked if these software developers also exist on Twitter
and using the Twitter account frequently. Table 1 shows for
each Apache project the number of software developers who
have made commits to the source-control repository and the
developers found on Twitter.

<table>
<thead>
<tr>
<th>Apache Projects</th>
<th>Developers (SVN)</th>
<th>Developers (Twitter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apache Camel [1]</td>
<td>36</td>
<td>24</td>
</tr>
<tr>
<td>Apache Felix [3]</td>
<td>47</td>
<td>17</td>
</tr>
<tr>
<td>Apache Hadoop [4]</td>
<td>97</td>
<td>35</td>
</tr>
<tr>
<td>Apache Logging [5]</td>
<td>37</td>
<td>7</td>
</tr>
<tr>
<td>Apache Lucene [6]</td>
<td>51</td>
<td>18</td>
</tr>
<tr>
<td>Apache Maven [7]</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Apache Mete [8]</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>Apache MyFaces [9]</td>
<td>82</td>
<td>16</td>
</tr>
<tr>
<td>Apache OFBiz [10]</td>
<td>25</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 1: Developers Contributed to Apache Projects and found on Twitter.

The results in Table 1 shows good evidence of the ex-
istence of software developers on Twitter. Although, not
t all software developers contributing to the Apache projects
found on Twitter. Based on the methodology described in
previous section, we found 107 distinct pair of software de-
velopers who communicated with each other on the project
repositories and Twitter. In the specific case of Apache Of-
Biz project, we didn’t find even a single pair of software
developers who communicated with each other on project
repositories and Twitter. For each pair of software de-
veloper, we computed how many times both software devel-
opers communicated directly with each other on the project
repositories and Twitter, on monthly basis. For an exam-
ple, we show the communication happened between a pair
of software developers over the period of time in Figure 4.
The figure shows that communication pattern among both
software developers is different throughout the time period
under consideration. For example, in 2009-08-12 both
developers communicated directly with each other 7 times
on the project repositories in contrast to 6 times commu-
communication on Twitter for the same month. Further, we see few months where both developers didn’t communicate at all (e.g., 2011-09-12) and in certain months they appear to communicate on only one communication channel (e.g., 2011-03-12).

![Figure 4: Social Communication Between 2 Software Developers on Different Communication Channels.](image)

Given the social dynamics of software developers in different communication channels (cf. Figure 4), we evaluated if there is a correlation between both developers’ communication pattern on project repositories and Twitter by measuring Pearson’s correlation. The Pearson correlation test based on the communication data between both developers yielded a correlation value, $r=0.447$. The $r$ value indicates that the social communication between both developers on different communication channels is significant and show a positive correlation of developers communicating on different communication channels.

In order to find if the communication among software developers is directly proportional on different communication channels, we aggregated the monthly communications occurred on the project repositories and Twitter for every pair of software developers. We plotted the resulting graph in Figure 5. The graph shows that for majority of software developers, the communication on project repositories and Twitter is not directly proportional.

The highest correlation value we found is a developer pair with the value (193,105) where 193 indicates the communication counts on project repositories and 105 on Twitter. The Pearson correlation was calculated for that particular pair based on their monthly communication data which resulted in $r=0.522$. Similarly, the lowest correlation value found is a developer pair with value (107,1) which resulted in $r=-0.040$. We calculated the Pearson’s correlation for all developer pairs and computed the mean and median value which is shown in Table 2.

![Figure 5: Scatterplot of Twitter vs. Project Repositories Communication Between Software Developers](image)

<table>
<thead>
<tr>
<th>Developer pairs</th>
<th>Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>107</td>
<td>0.191</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Table 2: Mean and Median of Correlation Values

Based on the results in Figure 5 and Table 2, we found that the correlation between developers’ communication on Twitter and project repositories is not strong. One potential reason could be the 140 characters limitation on Twitter which keeps software developers to communicate more through traditional communication channels (i.e., mailing list, IRC channels, forums etc.). Other reason might be the usage of Twitter to communicate non-work related activities. However, it is quite interesting to observe how developers communicate with other fellow developers in different communication channels. In our experiment, we found many developers who communicated less on Twitter but their communication on project repositories were strong.

As a next step for future work, we will also take into account the social communication graph of a developer with fellow developers as well as non-developers. Based on that, we will be able to understand if developers communication pattern on Twitter is low in general or if they have less communication only with fellow developers.

4 Conclusion & Future Work

In this paper, we have motivated and introduced a new dimension to the analysis of social dynamics of software developers by taking into account social media channels. The usage of social media channels is becoming popular among open source software community and software developers to disseminate project-related information to a wider audience. This motivated us to investigate if the communication behavior of software developers is same across different communication channels or different from each other. Our initial results based on the data of 10 different Apache projects shows that there is very low correlation between software developer communications across different communication channels. Further, our results shows that the social communication between software developers on Twitter is comparatively low than the traditional communication
channels (i.e., mailing lists, bug tracking repositories etc.).

The work proposed in this paper laid down the idea of taking into account all possible social media channels which developers could possibly use to communicate with each other. Based on that, researchers will be able to measure and compare the hierarchy and centralization of software developers in different communication channels in contrast to previous studies where researchers had been using only mailing lists, bug tracking repositories or discussion forums [24, 12]. Furthermore, integrating social messages/posts to project-related artifacts will open up new research challenges allowing to analyze the impact of end-user's response on the success/failure of an open source project.

In the near future, we will take into account stackoverflow communication network data and further analyze the behavior of software developers communication patterns across a variety of communication channels.

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References