Public Transport Stops State Detection and Propagation
Warsaw Use Case

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Keywords: Open Data, Public Transport, Text Mining, Events Detection, Geographic Information System.

Abstract: Publication of information on public transport in a form acceptable to third–party developers can improve a quality of services offered to the citizens. Usually, published data are limited to localisations of the stops and the schedules. However, a public transport model based on these data is incomplete without information about a current state of the stops. In this paper, we present a system that observes public sources of information on public transport such as Twitter feeds and official web pages hosted by the City of Warsaw. The incoming messages are parsed to extract information on events that concern public transport lines and stops. Extracted information allows us to detect a current state of the stops and to create linguistically independent and spatial oriented information in Geography Markup Language format that can be published using a web service. The system has been tested on real data from Warsaw district and the suburban zones.

1 INTRODUCTION

Public transport is an area that still needs improvement to satisfy its users. The public transport user's perception survey showed that the most important factors in public transport evaluation are on–time performance and reduction of waiting time (Nesheli et al., 2016). These criteria are strongly connected with stops and their current state.

Lack of information about the current state of the stops influence on public transport users' perception.When the user suddenly discovers that the stop is closed or the schedule on the stop is temporary changed his evaluation of the public system will decrease. Similarly, lack of knowledge about newly opened or reopened stops disturbs the user to take an advantage of public transport.

The City of Warsaw – as many other cities – publishes information about changes in public transport using various forms such as Rich Site Summary (RSS) or Tweeter. Figure 1 shows examples of published messages. However, the messages are published in Polish, without spatial localisation, and in the form that cannot be directly reused in third–party applications.

The last factor is critical because recent studies emphasise the role of Open Data also as an enabler of innovation (Lakomaa and Kallberg, 2013). Among other purposes in this area, Open Data can be used for application development (Lakomaa and Kallberg, 2013; Lindman et al., 2014). For example, 43 percent of surveyed Swedish start-up IT entrepreneurs find Open Data essential for their business plans (Lakomaa and Kallberg, 2013). Other survey showed, that most frequently designed and developed applications involve location based services (LBS) and dynamically changing urban data (Grabowski et al., 2015). Therefore, a proper politics in city data opening may increase services for the citizens. Moreover, information on stops' states are critical for public transport information systems and modelling (see Section 2).

In this paper, we presented a system that collects text data on public transport produced by the city hall. The data are collected from several sources including public city web pages and Twitter (Section 3). Next, the collected data are parsed to extract information about lines, stops, a type of the event, and a time span for the event (Section 4). The collected information is used to detect a current state of the public transport stops. Finally, the information is transferred into a localised form that contains a linguistically independent graphical presentation and can be reused through web services (Section 5). The system was tested on real data from City of Warsaw (Section 6).

Luckner, M., Kobojek, P. and Zawistowski, P.
Public Transport Stops State Detection and Propagation - Warsaw Use Case.
DOI: 10.5220/0006305102350241
In *Proceedings of the 6th International Conference on Smart Cities and Green ICT Systems (SMARTGREENS 2017)*, pages 235-241
ISBN: 978-989-758-241-7
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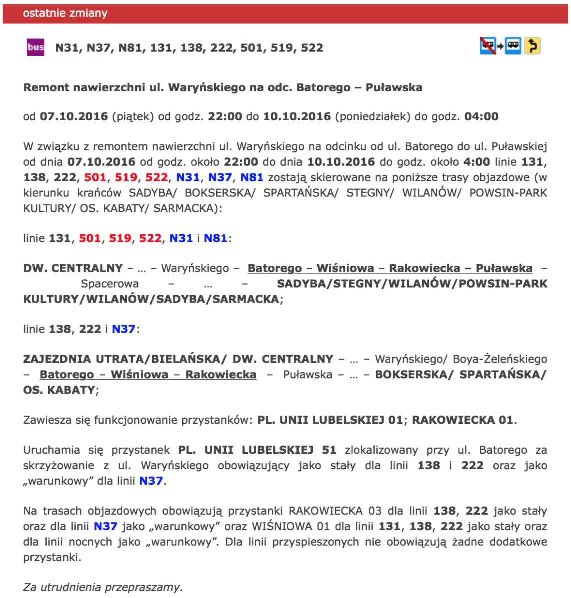

ostatnie zmiany

bus **N31, N37, N81, 131, 138, 222, 501, 519, 522**

Remont nawierzchni ul. Waryńskiego na odc. Batorego – Puławska

od **07.10.2016** (piątek) od godz. **22:00** do **10.10.2016** (poniedziałek) do godz. **04:00**

W związku z remontem nawierzchni ul. Waryńskiego na odcinku od ul. Batorego do ul. Puławskiej od dnia **07.10.2016** od godz. około **22:00** do dnia **10.10.2016** do godz. około **4:00** linie **131**, **138**, **222**, **501**, **519**, **522**, **N31**, **N37**, **N81** zostają skierowane na poniższe trasy objazdowe (w kierunku krańców SADYBA/ BOKSERSKA/ SPARTAŃSKA/ STEGNY/ WILANÓW/ POWSIN-PARK KULTURY/ OS. KABATY/ SARMACKA):

linie **131**, **501**, **519**, **522**, **N31** i **N81**:

DW. CENTRALNY – ... – Waryńskiego – **Batorego – Wiśniowa – Rakowiecka – Puławska** – Spacerowa – ... – **SADYBA/STEGNY/WILANÓW/POWSIN-PARK KULTURY/WILANÓW/SADYBA/SARMACKA**;

linie **138**, **222** i **N37**:

ZAJEZDNIA UTRATA/BIELAŃSKA/ DW. CENTRALNY – ... – Waryńskiego/ Boya-Żeleńskiego – **Batorego – Wiśniowa – Rakowiecka** – Puławska – ... – **BOKSERSKA/ SPARTAŃSKA/ OS. KABATY**;

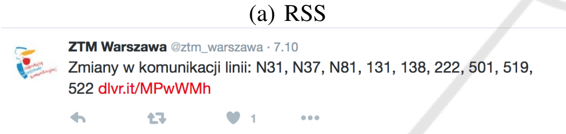
Zawiesza się funkcjonowanie przystanków: **PL. UNII LUBELSKIEJ 01**; **RAKOWIECKA 01**.

Uruchamia się przystanek **PL. UNII LUBELSKIEJ 51** zlokalizowany przy ul. Batorego za skrzyżowanie z ul. Waryńskiego obowiązujący jako stały dla linii **138** i **222** oraz jako „warunkowy" dla linii **N37**.

Na trasach objazdowych obowiązują przystanki RAKOWIECKA 03 dla linii **138, 222** jako stały oraz dla linii **N37** jako „warunkowy" oraz WIŚNIOWA 01 dla linii **131**, **138**, **222** jako stały oraz dla linii nocnych jako „warunkowy". Dla linii przyspieszonych nie obowiązują żadne dodatkowe przystanki.

Za utrudnienia przepraszamy.

(a) RSS



(b) Twitter

Figure 1: The examples of information about public transport events. The first example 1(a) is a well structured HTML broadcast as RSS. The second example 1(b) refers to the same event. The link in the tweet links to the same HTML.

2 RELATED WORK

Our system is a dynamic solution that informs about events that influence public transport but may not be noted in timetables.

Work (Tyrinopoulos, 2004) summarised types of models available in the public transport business. Only 11 percent of them were dynamics models that include real-time passenger information. That stress demand on dynamic systems.

Work (García et al., 2009) named three main subsystems of public transport information systems: timetable information subsystem, route information subsystem, and payment subsystem. In this categorisation a state of the stop is included in timetable information subsystem. An existence of a timetable suggests that the stop is working. Unfortunately, very often the schedules are not modified when stops are closed because of a sudden or temporary event.

Information on stops' states are also critical for any public transport model (Zheng et al., 2016; Rodrigues et al., 2016; Álvarez et al., 2010). The model should disable closed stops and enable reopened ones. Our system can conveys such information.

Work (Rathod and Khot, 2016) proposed an interesting alternative in a detection of events that influence the schedules. A multi-sensor system in a bus detects accidents and simultaneously sends information to public transport system.

3 COLLECTION OF TEXT DATA

In order to get some insights into the current state of transport stops first raw data needs to be collected and analysed. After preliminary analysis of the available data sources, four relevant text feeds have been chosen:

- RSS (http://www.ztm.waw.pl/rss.php) and Twitter (https://twitter.com/ztm_warszawa) feeds hosted by the Public Transport Authority in Warsaw, which contain important information about the municipal communication system,
- articles posted on http://warszawa19115.pl/glowna website which often indicates important events within the city which might influence also the transportation,
- information submitted by Warsaw citizens directly to 19115 which is the name of one of the official API services hosted by the city of Warsaw.

3.1 Overall Architecture

The task of getting external text data into our system consists of two parts:

1. retrieving data directly from the feed sources, parsing and identifying external weblinks – which is the responsibility a python component called `VaVelFeeds`,
2. fetching the external links along with all their dependencies (i.e. links present on the fetched HTML pages) – which is handled by a Spark Streaming job called `UriDownloader`.

The main reason behind having two components responsible for downloading web data is that the feed messages might link to external files of various types like for example images or video clips which may be large in size. Therefore a decision has been made to handle downloading and saving these links in a designated separate component which would be configured in an environment with efficient storage access. At the same time the readers communicating directly with the chosen data sources have only to fetch

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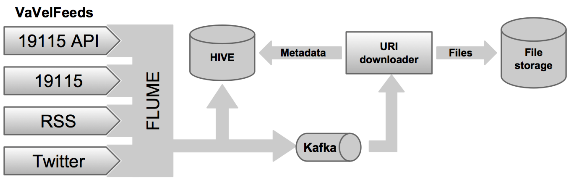

Figure 2: Schema of information collecting system. Custom components implemented for the project have gradient backround.

and process (relatively short) text documents, therefore these have a different performance characteristic and may benefit from a different deployment configuration.

The interaction between the mentioned components is depicted in Figure 2.

3.2 Fetching Text-feed Data

The `VaVelFeeds` python package (implemented specifically for the purposes of the described system) consists of a number of readers downloading text-feed data. These are also responsible for extracting necessary information like timestamps and main content and identifying external links which should also be downloaded. The messages fetched from all four sources are effectively converted into JSON objects and passed for further processing. Here Apache Flume is utilised to deliver these objects to both Kafka and HDFS sinks. A designated Kafka channel makes the feed messages available in near real-time for other components. To be precise, the latency is mostly influenced by polling frequencies of the individual text feed sources — these may be set very low to make the feed messages available as soon as possible, however certain restrictions regarding for example the usage of Twitter's API apply here.

The package strives to provide exactly-once processing semantics on a best-effort basis. Therefore, the history of recently consumed messages is stored on disk for each of the readers. This allows rejection of possibly duplicated messages early on in the processing pipeline. Such an approach is however not bulletproof – making the history size too small or deleting the contents of these files may result in processing duplicated messages. On the other hand shutting down the feed readers entirely for a too long period will result in loosing messages.

Scaling the system to handle more text-feed sources is straightforward, as it requires only creating an appropriate feed reader and plugging it in into Apache Flume. Here it is also possible to benefit from the already existing Flume sources which may be utilised in many cases.

3.3 Downloading Linked Content

A Spark streaming job called `UriDownloader` is responsible for downloading links extracted from text-feed messages. As depicted in Figure 2, this job consumes JSON messages from Kafka, processes them and saves the results to external storage. Each of the utilised technologies (and thus the entire system) is easily scalable.

Processing a single message proceeds as follows. First, the URIs from the message's links field are downloaded — if these contain HTML, further links are extracted from the content and also downloaded (this process is not continued for these '2nd level' links). Each downloaded link is stored in a seperate file with the file name generated as a hash of the file's content — this approach helps to avoid the problem of storing multiple copies of the same binary content.

Apart from the downloaded content, a record containing metadata is stored in Apache Hive. A sample record (in CSV) is given below:

```
2016-09-02T11:04:03.195+02:00,http://www.foo.com/foo.html,TEXT,abc/def/abcdef123,abcdef123
```

where the consecutive columns are: `download timestamp`,`URI`,`file type` (BINARY or TEXT), `file path`, `file content checksum`.

As the same URIs appear in multiple feed messages at various times, there is a need to handle potentially duplicated content. Storing each downloaded link as a separate file may lead to wasting storage space, therefore a hashing approach (described above) is used to prevent such problems. Although the content will not be stored multiple times using this solution, it still needs to be downloaded multiple times, which potentially wastes network bandwidth. A naive remedy would be to fetch the content of each URI only once, however this breaks in case of links that get updated – like news websites. Another solution is to utilise HTTP's ETags to detect whether the content has changed or not.

4 FEATURES EXTRACTION

The parsing module extracts meaningful and structured information about public transportation events from observed sources. Those events should regard particular lines and stops, usually lay in some span of time and be of some type. On the other hand, data from which this information is extracted forms a stream consisting of well-structured records. Each such record is in JSON format and contains information about its source (e.g. twitter or RSS) along with other data.

The module operates as follows. Each record – whether it is sourced from twitter or RSS – contains at least one website URL. Final results are extracted directly from these websites. If there is more than one hyperlink, results are gathered from each of those and then merged additively (i.e. if there's information about line A and line B in the first link, and line B and line C in the second link, then the final result will contain lines A, B and C).

The website is only parsed when it is of a certain structure. More specifically, only Public Transport Authority websites with specific information type are taken into the consideration. What is actually required by the website in order to be parsed by the module is an existence of an HTML element <td> with CSS class "linie". As it is implied by the data we have gathered, this element is only used when the news is about some public transportation event.

Once it is known that the processed page concerns such an event, four HTML elements are extracted for further computations. The first one is a header, which is always a first <h4> child element of the <div> with id "PageContent". We will refer to this element as "header". The second is a table cell which lists all the lines correlated with the news. It is the <td> element with class "linie", which is exactly the one used to determine whether the website is useful for further processing. We will refer to this element as "line header". The third one is a <p> element containing information about date range. This one is always a first direct sibling of the header element. We will refer to this element as "dates". The last one is text content. It consists of all <p> elements which are direct children of the <div> with id "PageContent". We will refer to this element as "content".

4.1 Parsing Schemes

Since all lines related to the news are listed in the line header element and separated by commas, extracting the lines is just splitting the text content of this element by the separator.

When it comes to dates, there are several possible scenarios. An event may or may not start at a specific date and may or may not stop at a specific date. What is more, both dates may or may not contain information about specific time. The module assumes, that if there is no time specified, it is set to 00:00 for starting date and 23:59 for ending date. One more possible scenario is when the event spans over one exact day. The pattern for a starting date looks as follows: "od dd.MM.yyyy (a day of the week) <od godz. HH:mm>" (text between <> is optional). This is parsed using the following regular expression (in Java language syntax):

```
od ([0-9]\{2\}\\.[0-9]\{2\}\\.[0-9]\
    {4\}) \\([A-Za-z]*\\)( od godz
    \\. ([0-9]{2}:[0-9]\{2\}))?
```

In this and in the following regular expression diacritical mark were removed for a presentation reason.

As it was previously stated, if there is no time specified, the "00:00" is assumed. However, if the event only concerns one, specific day, the pattern is: "dn. dd.MM.yyyy". The related regular expression:

```
dn. ([0-9]\{2\}\\.[0-9]\{2\}\\.[0-9]
    \{4\})
```

The end date is a similar case. The regular expression used for parsing:

```
do ([0-9]\{2\}\\.[0-9]\{2\}\\.[0-9]\
    {4\}) \\([A-Za-z]*\\)( do godz
    \\. ([0-9]\{2\}:[0-9]\{2\}))?
```

Stops information is extracted from the content text. Stops in the text are written in uppercase letters and usually consists of one or more words, separated by a dot, dash, or space and two digits. Example stops: RAKOWIECKA-SANKTUARIUM 06, KULSKIEGO 02, METRO POLE MOKOTOWSKIE 06. This is extracted using following regular expression:

```
([A-Z]++[ -.\]?)+ [0-9]\{2\}
```

Type is obtained from header element. It is whole text from this element without lines and stops. In order to remove the stops, it is required to remove the white spaces from stops name, as it is sometimes spelt differently in content text and in the header.

5 GRAPHICAL PRESENTATION

The transformation module converts the parsed events into Keyhole Markup Language format (KML). The KML is a descriptive language developed by Google Company, which complements Geography Markup Language (Open Geospatial Consortium, 2007) (standard defined by Open Geospatial Consortium) as a format for describing and storing geographical information including three-dimensional objects.

KML is connected a Web Map Service (WMS) z Web Feature Service (WFS). WMS (Open Geospatial Consortium, 2009b) produces a visual representation of spatial data, which is not the data itself. WFS (Open Geospatial Consortium, 2009a) enables the client to retrieve geospatial data through HTTP protocol (Chunithipaisan and Supavetch, 2009). It allows clients and servers to share data without having to convert data between proprietary formats (Ribeiro et al., 2004). The result is encoded in Geography Markup Language.

The format enables marking of spatial data with a time stamp or a time span. Therefore, the presentation of the events can be limited to requested period and published to interested receivers. Moreover, the created Geography Markup Language files can be easily published using a spatial data web service. The format can be successfully applied in various GIS tasks (Ying-Jun et al., 2009; Grzenda et al., 2011).

Before transformation of the events into KML structure data are cleaned by an elimination of duplicates that could be created during collection of data from various sources.

Next, all events are localised in time and space. For a spatial localisation the parsed stops' names are used. The geolocation is done using the Google Maps Geocoding API. In the results, stops' names are converted into geographic coordinates: latitude and longitude. To define a term of the event, the parsed dates are used to define a time stamp or a time span.

The localised events were described by a type. One and two words long prefixes are extracted from the parsed types of the events. The prefixes are compared with entries from a directory that exclusive maps a prefix into one of the following three groups:

restored stop the stop that was reopened after a modernisation,

closed stop the stop that was closed because of a modernisation or other event,

change on stop the stop with some changes on it. Mostly the events describe changes in the schedules and the routes.

Bus lines affected by stop's status are symbolised by a polyline that connects the localisations of the stops grouped by the event.

The final description of the events is stored using Keyhole Markup Language format:

```
<Placemark>
 <name>Pl. Unii Lubelskiej 01</name>
 <description><![CDATA[closed]]></
     description>
 <styleUrl>#icon-1899-DB4436</
     styleUrl>
 <Point>
  <coordinates>
      21.018658,52.212288,0.0</
      coordinates>
 </Point>
</Placemark>
```

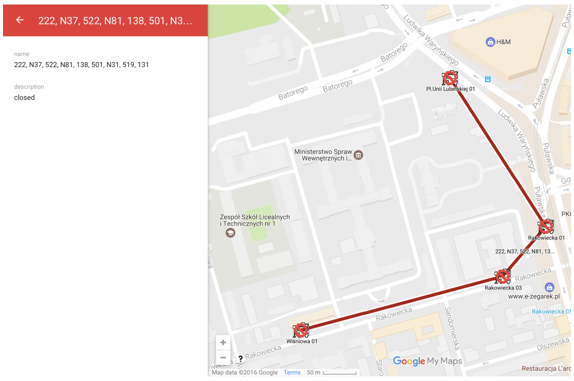

Figure 3: Detected event: closed stops with attached lines.

```
<Placemark>
 <name>222, N37, 522, N81, 138,
     501, N31, 519, 131</name>
 <description><![CDATA[closed]]></
     description>
 <styleUrl>#line-A52714-6</styleUrl
     >
 <LineString>
  <tessellate>1</tessellate>
  <coordinates>
      21.018658,52.212288,0.0
      21.0207,52.21035,0.0
      21.01978,52.2097,0.0
      21.01549,52.209,0.0</
      coordinates>
 </LineString>
</Placemark>
```

Figure 3 presents – in graphical form – the event presented in Figure 1.

The obtained event description is very limited in comparison to the original information. However, the created description is linguistically independent, localised, and can be propagated through a web service.

6 TESTS AND RESULTS

The designed system was tested on real data. RSS and Twitter feeds hosted by the Public Transport Authority in Warsaw were observed and collected over one month.

In observer period – from 10th of September 2016 to 10th of October 2016 – we have collected 827 messages from the observed sources. Among that number 733 did not contain information about public transport lines and stops. The rest of the messages – 94 cases – were successfully parsed and information on lines and stops were extracted. The extracted information was verified manually. No mistakes were detected.

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Tabela 1: Fragment of data on events connected with public transport produced by the city hall. For the presentation the descriptions were translated into English and the events were labelled with the states.

lines	stops	state	description	beginning	end
157, 116, N44	GEN.ZAJĄCZKA 01, GEN.ZAJĄCZKA 51	restored stop	restored primary localisation of the stop	2016-09-03 00:00	null
204, 527, N11	OS. DERBY 01, OS. DERBY VI 01, OS. DERBY III 01	closed stop	renovation of the surface of Skarbka z gór street	2016-10-01 00:00	2016-10-03 05:00
509, 186	NOWODWORY 55, NOWODWORY 02	change on stop	change of traffic organization on the terminal stop Nowodwory	2016-10-01 00:00	2016-10-02 23:59
...	...	...	...	...	...

The extracted information allowed us to remove duplicated entries. The duplication came into existence because of the various sources of raised information. After the filtration, 24 events were defined.

Table 1 shows partial information on 14 events assigned to stops. Each event contains information on lines and stops, a short description, the beginning time, and the end time. For a presentation reason, the descriptions were translated into English.

There are two types of observed events according to their localisation in the time. The first group includes temporary events. The beginning and the end of the event are known. The group consists of planned renovations, changes in schedules and localisations caused by various events in the city. For this group, the states are established temporarily.

The second group of the events has only one timestamp that describes the beginning of the event. This group – with a single exception – contains information on restored stops. The group also includes information on changes on the stop without a known end of the event.

The events were divided into three classes using events' descriptions. Each class is connected with a state of the stop. The distribution of the states is as follows: 4 messages about restored stops, 6 messages about closed stops, and 4 messages on changes on stops. Because a single event touches several stops the number of the stops with assigned states is as follows: 7 restored, 28 closed, and 10 with the changes in the schedules or locations.

The events were localised using geolocation of the stops. Figure 4 shows the positioned stops. The icons symbolise a type of the events: the restored stop, the closed stop, and changes on the stop. The results cover not only the Warsaw district but also the suburban zones.

Not all of the stops were localised on the map. The Google Maps Geocoding API does not cover temporary stops. All stops labelled with the numbers over fifty are temporary stops created mostly as a substitute stop for the closed one. The localised stops were distributed as follows: 4 restored stops, 22 closed

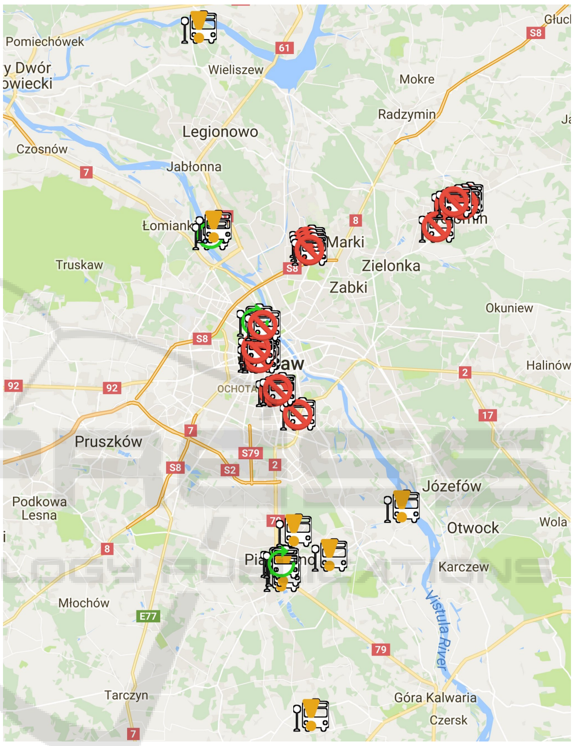

Figure 4: Localisation of detected events on the map

stops, and 8 stops with the changes in the schedules or locations. The number of the stops was reduced to 34 stops from 45 stops mentioned in events but each event is represented by at least a single localised stop.

7 CONCLUSIONS

We have presented the system that collects text data on public transport produced by the Warsaw city hall. The collected data are parsed to extract information about the status of stops used by public transport. Information about closed stops, reopened stops, and changes on stops is presented in graphical linguistically independent form using geolocation of the stops. Data are prepared using Geography Markup Language format that can be easily published using a web service. The output should be consumed by a notification system that allows us to analyse the users feedback. The notification system is in development.

ACKNOWLEDGEMENTS

This research has been supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 688380 *VaVeL: Variety, Veracity, VaLue: Handling the Multiplicity of Urban Sensors.*

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