The design of road conditions mapping system by utilizing openstreetmap spatial data

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Abstract. Land transportation still becomes a vital role in human and material mobility to date. In developing countries, like Indonesia, the development of land transportation infrastructure is growing very fast, but the level of road damage is also still quite high. Therefore, road users need information on road conditions that will be passed. This research proposes the use of openstreetmap data to develop spatial data of road conditions dynamically and inexpensively, because it is open access and free editable. The focus is to design spatial data of road conditions and to present a visualization of road condition maps based on Openstreetmap. The raw data will be exported to the Spatial Database Management Systems (SDBMS) and then redesigned the data so that the system can add the status of road condition on each road segments. The result is a system design that can store spatial data and present a visualization of the road condition map. With this system, anyone can update the condition data of a road and can access the road condition map through the web and mobile applications.

1. Introduction

Currently, land transportation facilities have a very vital role in social and economic aspects, namely as a distribution channel between one region with another on an island. Therefore, Information on road conditions is needed by the community as road users and the government as the owner and maintainer of the road, considering the percentage of damaged roads in developing countries is still quite high. Information on road conditions is needed when road users will use the road, so they can make a good preparation and plan on the journey, such as choosing an effective path and preparing the vehicle according to the terrain to be traversed. In addition, this information is also very useful to reduce the risks in travel such as accidents, vehicle damage, and congestion.

To map road conditions, spatial data of all existing roads is required. With reference to this data, we can mark the condition of each road segment. The spatial data types (POINT, LINE REGION, etc.) provide us the fundamental abstraction for modeling the structure of geometric entities in space as well as their relationships [1]. Currently, there are quite some spatial data providers, especially road map data, ranging from data collected by local governments to data compiled by global providers, such as Google Maps, Openstreetmap, and ESRI. They can be used in navigation, in research, in the development of location-based applications [2]. In this study, we propose the use of spatial data from Openstreetmap with the following considerations:

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a. Openstreetmap is a collaborative project to create a free editable map of the world. It is also free to be accessible to anyone and anywhere as long as we are connected to the internet.
b. Openstreetmap spatial data can also be freely downloaded by anyone who needs and can be processed for specific needs.
c. Currently, the spatial data of roads network that was covered by Openstreetmap is very complete, up to date, and accurate, especially for Indonesia.

The core product of Openstreetmap is a spatial database, which contains geographic data and information from all over the world [3]. With the availability of spatial data, we can utilize it without the need to do data collection of roads independently. Next, we can add information related to road conditions based on the road data. Because the data can be accessed from anywhere and by anyone, then the input of information related to the condition of the road can be done by the public, so the road condition data will continue to grow quickly, continuously, and dynamically.

2. Methodology

A spatial database is related to objects in space, including points, lines and polygons typical databases grasp various numeric and character types of data, additional functionality needs to be added for databases to process spatial data types [4]. Spatial data represents multi-dimensional data with points, surfaces, and lines, as a list of numbers using a particular coordinate system [5]. To build a system capable of processing spatial data, we need a Spatial Database Management Systems (SDBMS). There are now quite some database software systems that provide the ability to process spatial data, such as Oracle, Postgresql, Mysql, and ESRI [4]. In this study, we chose Postgresql because it is open source, supports multiple spatial functions, and is quite mature when compared to another open-source DBMS. Static road map data from openstreetmap will be exported to SDBMS for processing and further manipulated by system requirements. Furthermore, the data can be presented via web and mobile applications. The architectural model of the mapping system to be constructed is presented in Figure 1.

![Figure 1. Systems Architecture](image)

2.1. Exporting from Data Source

OpenStreetMap is a web-based project for creating free and open worldwide maps. Openstreet maps are built entirely by volunteers [3] by conducting surveys using GPS, digitizing satellite images, collecting geographic data, and releasing them for public use. It is freely available to all users online around the world [6]. The base map and supporting data can be downloaded for free and open, for further use, processing, and redistribution. This research will use Openstreetmap road spatial data for Indonesia, especially Java region, as a data source. Openstreetmap data can be easily converted into other widely used spatial data formats, such as KLM (Google Earth) and SHP (ArcGIS) [7].

Furthermore, Openstreetmap source data is exported to PostgreSQL which already has PostGIS extension so that it can perform operations for spatial data. Postgresql with this PostGIS extension can next be classified as a Spatial Database Management Systems (SDBMS), a DBMS that can process
spatial data. Then the data already stored on this SDBMS can be further processed for the needs of road condition mapping.

2.2. Spatial Data Processing and Presentation
Spatial data from OSM are stored in SDBMS with multiline-string geometry data type. The multiline-string data type is a geometry data type in the form of a collection containing the only line-string. While line-string is a collection of dots that form a set of straight lines that are connected. This data type usually was used to map items such as roads, rivers, trails, and circuit paths. This road geometry data needs to be processed before it can be marked the type of damage. The length of a line varies from tens of meters to thousands of meters, thus requiring the splitting of road data into segments with a maximum length of 5 meters. Each of these road segments will each be marked according to their condition. The steps to present roads condition data is showed in Figure 2.

![Figure 2. Spatial Data Processing Steps](image)

Therefore, marking the damage of a road segment can be performed on at least 1 data road segment with a maximum length of 5 meters. Each road segment can be marked by the reporter and stored in a separate status table. The data sets of road segments that have been marked according to their respective conditions are then displayed in a map form on the web browser and mobile device. To display spatial data in the form of maps in web browsers and mobile devices, we can use the Leaflet [8], Node.js [9], and Github libraries [10].

3. The Design
This section describes the type and level of road damage and is extended to database design that refers to the spatial data requirements of road conditions. Implementation of database design requires a segmentation process to break the road into small sections which can then be marked in accordance with the conditions.

3.1. Roads Condition
Technically, road damage indicates a condition in which the structural and functional roads are not able to provide optimal service to the traffic that crosses the road. Generally, road damage is largely due to user behavior, mismanagement and implementation, and inadequate road maintenance.

According to the ministry of public works, through the directorate general of Bina Marga [11], the type of road damage is divided into the following four major categories:

1. **Cracking** is a symptom of damage to the surface of the pavement so that it will cause water on the surface of the pavement to enter the underlying layer and this is one of the factors that will make it widespread.

2. **Distortion** is a change in the shape of the road that occurs due to the weakness of the base soil, less compaction on the base layer, resulting in additional compaction due to traffic load.

3. **Disintegration** is a type of road surface damage that leads to chemical and mechanical damage to the pavement layer. This damage can be in the form of hollow road conditions, the release of grain material of the road, and peeling of the surface layer.

4. **Bleeding/flushing** is a type of physical change of the road as it softens during high temperatures. The level of road damage will be divided into 3 standard levels, i.e. light, medium, and heavy. This refers to the severity of a type of road damage.
3.2. Database Design
The database design will contain the entity segment of the road as a whole and the segment data entity that is reported in its condition. Street segment entities will be populated with segmented process result data of all road segments taken from Openstreetmap. Each segment will represent a section of the path that can be assigned a status according to its condition. Each segment will contain information such as road id, length, geometry data, region, and road metadata. The relational diagram is shown in Figure 3.

| Field    | Data Type |
|----------|-----------|
| osm_id   | varchar(10) |
| code     | smallint  |
| name     | varchar(100) |
| oneway   | varchar(1) |
| maxspeed | smallint  |
| geom     | geometry  |

| Field    | Data Type |
|----------|-----------|
| osm_id   | varchar(10) |
| sid      | integer   |
| name     | varchar(100) |
| lgeom    | geometry  |
| centroid | geometry  |
| length   | double    |
| region   | integer   |

| Field    | Data Type |
|----------|-----------|
| osm_id   | varchar(10) |
| sid      | integer   |
| lgeom    | geometry  |
| centroid | geometry  |
| length   | double    |

| Field    | Data Type |
|----------|-----------|
| rd       | bigint    |
| user_rpt | varchar(50) |
| ts_rpt   | timestamp |
| type_id  | smallint  |
| level    | smallint  |
| info     | varchar(100) |
| photo    | varchar(1) |
| status   | varchar(1) |

Figure 3. Table relations

The pnm_roads table represents the data of all paths taken directly from Openstreetmaps. The spatial data path is stored in multiline-string format. Next all the path data is broken down into segments stored in the pnm_road_segments table, where the spatial data of the path segment is stored in line-string format. Next data segments reported by the system status will be stored in the pnm_damaged_roads table. Each user's road damage report will be stored in the pnm_dmg_reports table, including report_id, type of damage, level of damage, related information, image, and status (valid or otherwise). Each road damage report will include one or more road segments and will be stored in the pnm_dmg_segments table. Each stored segment will contain information from line-string geometry, centroid point geometry, and segment length.

3.3. Roads Segmentation
A data path on Openstreetmap is represented in the form of a line string, where the length of each segment varies from tens of meters to thousands of meters. To record the condition of the road, it takes a shorter segment so that the data collection of road conditions will be more detailed. Each path generated from Openstreetmap will be broken down into many segments where the maximum length of a road segment is 5 meters. To segment a path with a maximum length of 5 meters can use the following query:

```sql
SELECT a.osm_id,(a.ra).path[1] AS sid,a.name,st_segmentize((a.ra).geom,
   0.00004533::double precision) AS lgeom,
st_length((a.ra).geom::geography) AS length
FROM ( SELECT osm_id::bigint AS osm_id,name,st_dump(geom) AS ra
   FROM pnm_roads) a;
```

3.4. Marking of Road Conditions
A road segment may have a damaged status if a report from a user associated with the segment has been validated by the system administrator. Usually, a report will include many segments on a road line. Any incoming reports from users will not be immediately considered valid, so it takes the validation process from the administrator so that the report can be used by other users. The color of the damaged road segment is determined by the type and level of damage. The type of damage represents the type of color, and the level of damage represents the thickness of the color. In this case, there are 4 types of damage so there will be 4 colors that represent each type of damage, namely:
1. Cracking is presented in blue color, with 3 level of damage.
2. Distortion is presented in red color, with 3 levels of damage.
3. Disintegration is presented in green color, with 3 levels of damage.
4. Bleeding/flushing is presented in purple color, with 3 levels of damage.
4. Results of Spatial Presentation
Based on the data design described in the previous section, it is necessary to implement the database design on a PostgreSQL SDBMS with PostGIS extension. In this section will be presented about how the visualization of the segments that have been given status according to the type and level of damage.

4.1. Spatial Presentation
Spatial data already stored in SDBMS can then be accessed and presented via web apps and mobile devices. By using the web and mobile apps, the whole society can easily access this system, either to report or to view damaged road data and position visually. Therefore, with the entire community involved in reporting road damage, the system will be faster and more dynamic in terms of data development when compared to conducting independent road condition surveys.

4.1.1. Web Page Presentation
In developing web applications, we use the Node.js, an event-driven I/O server-side JavaScript environment that allows for JavaScript to operate on the server [12]. The leaflet is the leading open-source JavaScript library for mobile-friendly interactive maps [13]. An OpenStreetmap-based map will be displayed on a web page, as a basis for displaying damaged road data. Further damaged road segments will be added at the top layer, according to the geometry of the segments, including the coordinates, lengths, and locations of the region. The display on the web application is shown in Figure 4.

![Figure 4. Presentation in Web Application](image)

4.1.2. Mobile Device Presentation
In line with the platform that has been used in web application development, we use the react native libraries from Github to develop Android-based applications. Similar to web applications, applications on mobile devices also display Openstreetmap maps as map bases and then display damaged road segments according to those in the database. This web application will access a web service as an interface with the PostgreSQL database. The view to see the road conditions in the mobile application is shown in Figure 5.

4.2. Discussion
For now, there are still not many applications that utilize and process spatial data on Openstreetmap, whereas Openstreetmap has provided spatial data that is free to access and exploit such as roads, buildings, territorial boundaries, rivers, lakes, and so on. The majority of applications for data collection of road conditions are still dependent on self-survey methods to get spatial data of damaged roads, resulting in slow development and data dynamics. In addition, the information generated can only be accessed by the relevant parties who perform the survey so it can not be accessed by the public.

Prior to 2014, research and development of GIS software the majority used ArcView GIS software where data had to be input through independent surveys, which also conducted data collection and maintenance of roads [14] [15]. Then after that, developed software based on Google Maps but still
limited the coverage of its users [16]. Application and data design to map road damage will be used to develop a system that will receive road damage reports from the community and present them in visual form on an Openstreetmap-based map.

**Figure 5** Presentation in Mobile Application

### 5. Conclusion

The results of this spatial data design have been able to mark a road position in accordance with the conditions of the damage. Each road segment tag will store the road segment id, the type of damage, and the level of damage. Each type and level of damage will produce a specific color on a marked road segment so that it can be clearly visible to the user the difference between the damaged and the undamaged part of the road. Next, the results of this data and application design will be used to develop effective systems for reporting and mapping road conditions. The spatial data that has been collected will be used to develop an alternative path search system to avoid damaged roads. In addition, spatial data will also be used to perform mapping analysis of road improvements and cluster road damage areas.

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