# A Geowiki for Participatory Mobility

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**Abstract**

In this paper we present MoNa-map, a collaborative mapping system for monitoring temporary mobility barriers. This type of temporary data is known to exhibit a high change rate and, as a consequence, some existing barriers will not be mapped (false negatives) while some barrier which ceased to exist will still appear on the map (false positives). Our approach addresses the problem of balancing the two types of errors with a state-based data model that supports data aging and provides mechanisms to actively inform users about mobility barriers needing validation. The approach is evaluated in a simulation study which compares MoNa-map to simpler models.

*Keywords:* Volunteered Geographic Information, Temporary Data, GeoWiki, Mobility

# 1 Introduction

Collaborative mapping approaches are known to be successful at creating nation-wide base maps of impressive data quality [4]. However, their success in the area of thematic mapping, that is, the description of geospatial features specific to a particular application problem depends very much on whether the mapping workflow adequately meets the problem requirements [10].

The present article describes a technical assistance system that provides support for a special kind of thematic mapping: the mapping of non-permanent mobility barriers like roadblocks or icy sidewalks. These temporary barriers expire: any construction work eventually comes to an end and the snow cover even of a harsh winter melts away in spring. Any map of temporary objects becomes outdated after some time, presents wrong information and is not longer useful. Continouus updates are unavoidable.

We present a state-based model for mapping temporary objects. It addresses the data aging problem with a combination of automatic expiration and a mechanism to increase user attention on information which needs to be updated.

The paper is structured as follows: A review of related work discusses collaborative mapping approaches from the field of volunteered geographic information as well as monitoring approaches based on geographic wiki (section 2). In section 3 we present our solution for monitoring temporary barriers that uses a state-based mode. Finally, we evaluate our approach with a simulation study (section 4) and discuss the results obtained (section 5).

# 2 Volunteered Geographic Information

Especially two research fields are of interest to the collaborative monitoring of temporary mobility barriers: (1) mapping approaches based on volunteered geographic information, (2) geographic wiki approaches which deal with changing data.

For participative geospatial data, Goodchild [3] introduced the term volunteered geographic information (VGI). It describes any kind of georeferenced information provided by users. Examples range from communities collecting georeferenced photos (e. g. Panoramio[1] to the collaborative mapping of the geographical environment (e. g. OpenStreetMap[2] [5]). For a classification of different VGI concepts see Resch [12].

VGI does not follow the classical approach of data acquisition by trained experts from reliable resources, the crowdsourcing approach means that anyone can participate. Flanagin and Metzger [1] discuss the questions of data quality and reliability of VGI. Various studies from Haklay [4] and others on OpenStreetMap data quality show that it is comparable to traditional geographical datasets as maintained by public and commecial providers. Neis et al concludes in [8] the OSM dataset for Germany can be considered "complete" in comparison to a commercial dataset.

An increasing number of projects use OSM data to create specific services, e. g. for handicapped people. Wheelmap.org[3] is a collaborative map of wheelchair-accessible places. And rollstuhlrouting.de[4] [7] provides a wheelchair routing service using road surface and kerbstone height information from OpenStreetMap.

Several proposal have been made for geographic wiki. Roche et al [14] discuss the wikification of geographical information and define a WikiGIS as a system that applies wiki management and integration strategies to geospatial objects. Priedhorsky et al [11] define a geowiki as a VGI-based platform with the following features:

**Graphical web interface:** a web-map with navigation operations.
**On-line map editability:** if data is editable it can be edited in the browser.
**WYSIWYG editing:** complete set of editing operators

[1] `http://www.panoramio.com`
[2] `http://www.openstreetmap.org`
[3] `http://wheelmap.org/`
[4] `http://www.rollstuhlrouting.de`

Figure 1: MoNa-map

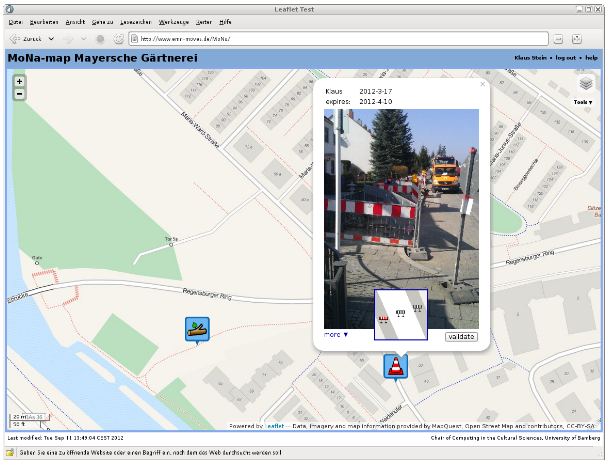
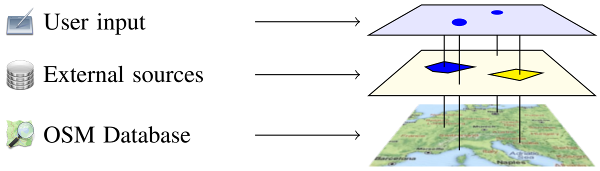



Figure 2: MoNa-map layers




**Robust linking:** objects are explicitely inked and not only co-located.

**Comprehensive data monitoring:** revision history and change monitoring.

So a geowiki allows users to collaborate on spatial data using a web browser in a robust and traceable way.

OpenStreetMap is focussed on collecting static data. Roads and buildings may change at some point in the future but with low rate. The platform FixMyStreet[5] [6] is used to map features users *want* to change: potholes, broken lightning, broken paving slabs and so on. This service from UK local governments allows to report these problems by mapping them, to track the resolution activities of the local administration and to discuss them with other users. A similar service for US cities is provided by SeeClickFix[6]. ParkScan[7], a project from the San Francisco Parks Alliance, asks people to report observations to the system which are automatically sent to the City's work order system. The pilot project GeoCiudadano in Quito, Ecuador tests the GeoCitizen-framework [13] which aims to provide a platform for participatory spatial planning at local level. For a literature review on public participation GIS see Ganapati [2]. Waze[8] takes Goodchild's "Citizens as sensors" [3] literally. It uses the mobile phones of car drivers as sensors to detect traffic jam in real time. Users do not need to interact actively and the collected data is very short-term.

Panciera et al [9] analyse contribution motives of users. To enhance contribution they suggest to emphasize how the user, other users or the system itself benefit from these contributions, to appeal to shared values of the community and to highlight potential problems and invite users to fix them.

All of the systems we discussed are able to map temporary data. However, they do not use the knowledge that some of the mapped objects are known to change in the near future and need to be revisited. A process to invite users in a non-disruptive way to check these temporary objects after some time is missing, the problem of dealing with temporary geospatial objects remains unsolved.

## 3 The Mobile Neighbourhood Map

A Geowiki based assistance system for temporary barriers handles objects and attributes which change so fast that they are not mapped as part of the regular mapping process e. g. for OpenStreetmap. Arguably, the most straightforward approach to collaborative mapping of temporary data consists in providing a static map as background layer and allow users to put markers on this map with information about obstacles. Such a simple system, however, would not address the following questions:

**Aging and error balancing:** the mapped data is temporary by definition and therefore will have to be removed in (near) future. Any map of temporary objects has to deal with two types of errors. *False positive errors* occur whenever a barrier is shown on the map but has ceased to exist in the environment. On the other hand *false negative errors* occur when a barrier which still exists is removed from the map. Monitoring approaches need to balance the two types of errors.

**Attention:** the collaborative collection of spatial data shows two main mechanisms:

> **Preferential attachment:** areas which are visited by a lot of people are mapped fast and corrected frequently. If a lot of people visit a place the chance of detecting and correcting errors is rather high.
>
> **White spots on the map:** areas where no one has mapped until now invite dedicated mappers to map them, they directly tell that there is a satisfying challenge.

While the high coverage of crowded areas also works for temporary objects there is no equivalent to white spots on the map.
Additionally, while the sudden appearance of some obstacle (a construction site, a fallen tree, etc.) gains attention its removal is only noticed by people who did see it before.

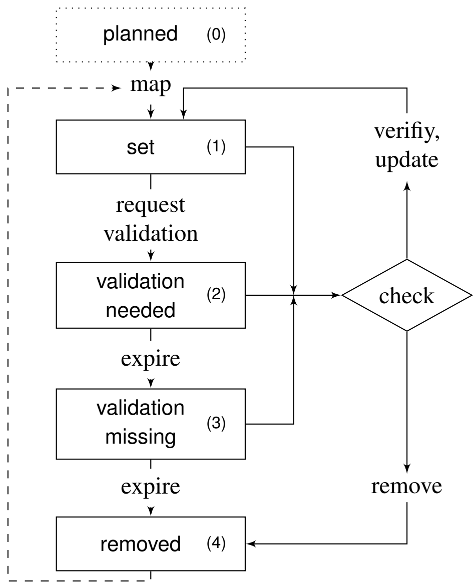
**Background knowledge and ancillary information:** using background knowledge about different types of barriers and information from other sources (e. g. about the local infrastructure) can improve data quality.

**Dependencies:** a set of obstacles may be caused by a common reason or be otherwise connected and should be treated accordingly.

MoNa-map (figure 1) is a geowiki for collaborative mapping of temporary data. This section describes the state-based data model which addresses these requirements.

[5] `http://www.fixmystreet.com`
[6] `http://www.seeclickfix.com`
[7] `http://www.parkscan.org`
[8] `http://www.waze.com`

Figure 3: states of a temporary object




## 3.1 MoNa-map structure

For mapping temporary mobility barriers we adopt a map structure that consists of three layers: a base map, a thematic layer with local information and a temporary data layer for the user input during the collaborative mapping process (figure 2).

MoNa-map uses OpenStreetMap as base layer. The thematic layer augments the base layer with additional data provided by third-party sources like planned roadblocks. The temporary data layer describes the temporary mobility barriers and therefore holds all user edits. Users map temporary barriers by creating a temporary data item depicting obstacles like a snow heap or a construction site or attributing existing objects, e. g. this road is icy.

Each temporary data item consists of the barrier class (“construction site”, “closed area”, “mud”, etc.), positional data, creation/modification and expire dates, creating/modifying users and other metadata. Items are displayed on the map as icons representing their class.

There are essentially two options for addressing the issue of barriers represented on the map but no longer present in the evironment. The simplest solution consists in delegating the task to the intelligence of the crowd. This assumes that any barrier which ceases to exist will eventually be removed from the map by some caring member of the user community. However, this assumption is hardly realistic. In practice, users of such a static system will be confronted with a high number of false positive errors. We therefore explored a second option which involves an automatic aging mechanism for barriers. Such a mechanism is suited to reduce an intolerable number of false positives at the price of introducing some false negative errors. In other words, any aging mechanism runs the risk of automatically removing barriers which are still present in the environment. The challenge of designing an appropriate mechanism consists in finding a mode of operation that balances both type of errors in an appropriate way. In the following we describe such a mechanism.

Figure 4: Icon states of an item


Although in data aging, the exact expiring date of the mapped object is unknown, it can be estimated by the system based on a number of factors: creation time, barrier class, additional user knowledge and background knowledge. Removing items after this estimated expire time from the map reduces the the problem of outdated information.

If the assumed expire date is too close items providing valuable information disappear, if it is set too far outdated items stay too long. So items need to be checked by users after some time and either be removed or validated. Our state-based approach to data aging combines automatic aging with user interaction.

## 3.2 Item States

Figure 3 presents the lifecycle of an item. When an item is mapped it starts in state (1) and the system assigns default expire dates which may be adjusted by the user who maps the barrier. When the first date is reached a validation request is sent to selected users and the item state changes to validation needed (2). When the next date is reached the item expires and goes into the state validation missing (3) and is shown on the map as unverified. When the final expire date is reached the item is in state removed (4). It is deleted from the map and marked as removed in the database. Any user interactions in steps (1) to (3) reset the aging counter. The user either decides to explicitly remove the item (state 4) or validates or updates it bringing it back to state 1 with new expire dates. State (0) is used when background information is available to indicate planned barriers.

The different states correspond to the different information needs of passive (receiving) and active (mapping) usage. A passive user does *information pull*: he or she wants to get an overview about barriers in the area at a certain point in time. In this view items in states 1 and 2 are shown as valid on the map and items in state 3 are shown as potentially outdated. This can be used to plan a route or use a barrier-aware routing service.

Any user may subscribe to an item to be informed when validation is needed. By default the creator of an item and any user who did verify or modify it in the past get subscribed. The system actively (*information push*) sends a message to all subscribers at transition from state (1) to state (2). If the user is currently logged in the message is immediately shown. Otherwise it is presented on next login. The user can additionally subscribe to be informed through external channels like email, rss or twitter.

Active messaging adresses a selected group of users (subscribers) to draw attention to certain spots (items in state (2)). Items in state (3) “unvalidated” by their appearance (figure 4) invite all mappers to verify them. One could join state (2)

Figure 5: Attributes of Mußstraße (Bamberg) in the OSM database. Kerbstone heights still have to be mapped for this street.

| Attribute name | value |
|---|---|
| name | Mußstraße |
| highway | residential |
| surface | asphalt |
| lit | yes |
| maxspeed | 30 |
| source:maxspeed | sign |
| footway | both |
| footway:both:surface | concrete_plates |
| parking:lane:both | parallel |
| parking:lane:both:parallel | lay_by |
| parking:condition:right | free |
| parking:condition:left | residents |
| parking:condition:left:residents | L |

and (3), i. e. send validation requests and directly mark items as unverified, but this would lead to items switching between state (1) and (3) back and forth, irritating inexperienced passive users.

Messaging users *before* an item expires relieves them from actively remembering when to revalidate a barrier. This is particularly important for casual users. Users actively looking for tasks can subscribe to all items in a certain area and therefore get informed about all validation requests in their surroundings. Additionally they can select all items in states 2 and 3 to be highlighted on the map to get an overview.

While all dates in general are accessible by the users only the creation or last modification date and the assumed expire date (end of state 2) are presented by default to avoid confusion.

## 3.3 Background knowledge

The life span of an obstacle depends on various factors. Branches lying on the road from the last storm will be removed within days, the duration of a construction site can span a wide range from days to several months or even years, icy roads and snow piles depends on weather, exposition to sunlight and whether, how often there is a snow clearing service for the road and so on. Therefore the obstacle class can only give a very rough hint about the duration.

OpenStreetMap provides detailed information like road surface, footway existence and surface and so on as shown in figure 5. The sidewalks are not modelled as objects on their own but as attributes to the street. Using OSM as a database and not only as an underlying bitmap map gives access to all attributes even if they are not rendered on the map.

On the next layer the local authorities or housing associations have useful background information, and with the upcoming open data movement they may be provided in machine readable form. The information which roads (sidewalks, trails) are cleared from snow or salted helps, same for areas which are only maintained in summer and so on. Background knowledge does not neccessarily come from some external source but can be directly entered in the system. For example, the information that a trail is not exposed to sunlight in winter because it is in the shadow of a house is local knowledge which can be very helpful to determine expire dates.

Construction works normally are planned in advance, and local authorities may provide this kind of information as open data. This gives a scheduled start and end time for these items whichs allows to actively draw attention of users to potential items. At the scheduled date a new item is created for the obstacle in state planned (0). Users monitoring a corresponding area are automatically subscribed to the item and get a message.

## 3.4 Connections between Items

Barriers are often not independent from each other. A street festival may affect several streets, some are totally blocked, others only for cars, not for pedestrians and so on, and after the festival all of them will get removed. When road works block a sidewalk and some tubes run across the street both obstacles are connected and the tubes will not stay when the road works are finished.

Mapping dependent barriers as one large extended item does not allow a detailed description of each barrier. therefore they are mapped as different items connected with explicit dependency relations. If an item $A$ is connected to another item $B$ and a user modifies or removes $B$ this has implications for $A$. First, when editing $B$ the user is informed in an unintrusive way that $A$ is connected and can actively decide what to do. If $A$ is left untouched the type of the connection determines the next step.

The link between $A$ and $B$ can either be unidirectional $A \rightarrow B$ ($A$ depends on $B$), $A \leftarrow B$ ($B$ depends on $A$) or bidirectional $A \leftrightarrow B$. The pipe in the example above depends on the building lot. So when the building lot item gets removed the pipe item automatically switches state regardless of its expire dates. When the pipe gets removed the building lot item is unaffected. The roadblocks set up for the festival on the other hand are alle connected bidirectionally as they get removed when the festival is over.

The data model supports to distinguish *weak* and *strong* dependencies where a strong dependency forces a direct transition to state (3) while a weak dependency moves the item to state (2) and adjusts the expire dates accordingly. By default only strong dependencies are available for the user to keep the user interface less complex.

# 4 Simulation

In order to assess the effects of our approach to data aging on community mapping, we run a simulation which compared four scenarios.

- The *no-support* scenario simulates a static system without aging support. Items are set or removed manually by users.
- The *simple-aging* scenario additionally removes mapped items after an expire time. User interaction (validation) during the expire time shifts the expire time accordingly. No "unvalidated" (gray) items (state 3) exist.
- The *smart-aging* scenario simulates the stateful system described in this paper.

- In the *validation-propagation* (connected) scenario additionally groups of $n = 5$ items are connected. Validations and changes on connected items are propagated, i. e. if one item is validated or removed by an user a connected items which is in an incomatible state (one item in state (1) or (2), the other item in state (4)) is switched to state (3) (unvalidated).
  The effects of increased user interaction by indicating connected items to the user is not modeled in the simulation.

The simulations do not use any background knowledge, which means that the probability of a barrier to get mapped is the same in all scenarios. Therefore, the simulation starts with five barriers which are already mapped and have a lifespan from one to ten weeks.

In the stateful model items actively draw user attention in two ways: sending messages at the transition from state (1) to state (2) and displaying the item as "unvalidated" (gray) in state (3). This is modeled by an increased probability of user interaction during these states. We assume a low basic probability for user interaction to simulate a situation with a small number of active users. Figure 6d gives the values used in the simulation. In the *simple-aging* scenario items expire after $14+3+7 = 24$ days as this is the time items are fully removed in the stateful model.

The stateless *no-support* model gives a large number of false positives, i. e. removed barriers which are still mapped (figure 6a). Even after 100 days, 30 days after the last barrier was removed there are still more than 30 % of the icons on the map. The *simple-aging* model shows the same increase of false positives until its first expire time is reached after 24 days. After that all aging models stay below 10 % false positives and go back to 0 % 10 days after the last barrier is removed.

Reducing the type I error increases type II (figure 6b): items are removed from the map while barriers still exist.[9] After 24 days 50 % of the items in the *simple-aging* simulation expire while the corresponding barrier still exists as the probability of a user verification before is low. In the stateful models only $\approx 35\,\%$ wronly expire at this date. The higher probability of user interaction shows positive effects. The following decrease of false negatives in all scenarios is mainly caused by the fact that all barriers are removed one after another. After ten weeks all barriers are removed, false negatives are not longer possible. The connected items perform better as the effect of user interaction on one item is propagated among them.

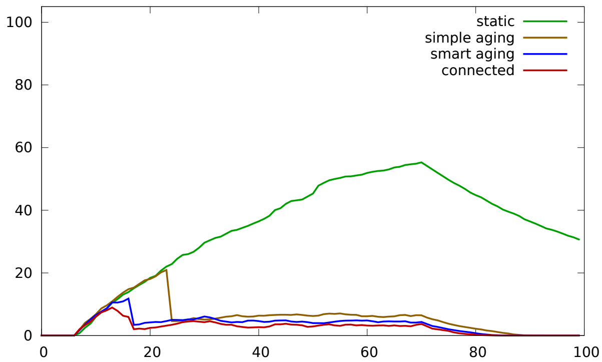
Figure 6c shows the aggregated values including the unvalidated (gray) items. The *no-support* model by design has no false negatives but during the 100 days 33.8 % of all items are false positive (have no corresponding barrier). The *simple-aging* model has only 5.5 % false positives but 10.8 % false negatives. The stateful models have a lower number of false positives and false negatives but instead present unvalidated items in 7.2 % (*smart-aging*) or 10.8 % (*validation-propagation*) of the time.

It is not possible to avoid both types of errors at the same time. If an existing barrier is not (longer) on the map users notice them when on their route and have to take detours. If on the other hand items on the map indicate barriers which are not longer there users who rely on this information will choose suboptimal routes. The second problem with false positives is visual clutter. A map full of wrong items is not reliable and therefore will not be used at all, contrary to a map which shows only some of the barriers but with high reliability. The unvalidated (gray) items can help passive users. In a concrete situa-

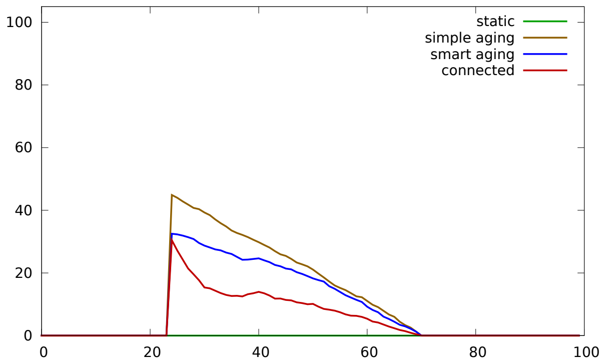
[9] there are no false negatives for the stateless model as we start with the mapped item. As the mapping probability for creating an item is the same in all models the additional error would also be the same.

Figure 6: Barrier-item coverage over time. Results of 1000 runs on $n = 5$ items. Barrier lifetime from 7 to 70 days (uniform distribution).

(a) false positives: the barrier no longer exists but is still shown on the map




(b) false negatives: the barrier still exists but the corresponding item has been removed on the map




(c) item to barrier distribution

| barrier | yes | | | no | | |
|---|---|---|---|---|---|---|
| item | ■ | ▒ | □ | ■ | ▒ | □ |
| static | 38.5 % | 0.0 % | 0.0 % | 33.8 % | 0.0 % | 27.8 % |
| simple aging | 28.3 % | 0.0 % | 10.8 % | 5.5 % | 0.0 % | 55.4 % |
| smart aging | 25.9 % | 4.9 % | 8.6 % | 3.5 % | 2.5 % | 54.6 % |
| connected | 26.1 % | 7.4 % | 5.0 % | 2.5 % | 3.4 % | 55.6 % |

(d) expire dates and mapping probability per day for the different states

| state | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $t_{\text{expire}}$ | 14 | 3 | 7 | |
| $p$ | 2 % | 8 % | 4 % | 2 % |

tion the user gets the information about a potential barrier and can decide whether to take the risk. This is only feasible if the number of gray barriers stays small.

In the *no-support* model items stay on the map for a long time, the decay is much too slow, the map gets outdated very fast and would therefore get cluttered with items over time if new barriers are mapped. The *simple-aging* model improves this on the cost of false negatives, and the stateful models are able to further improve the situation. One factor is the introduction of unvalidated items ($\approx 10\,\%$), the other the higher probability of user interaction.

Whether it is better to have unmapped, falsely mapped or unverified (gray) barriers depends on the user structure and individual needs as well as the environment. Both errors can be balanced by adjusting expire times.

# 5 Conclusion and Outlook

Temporary map data becomes outdated and any system designed to handle such maps has to deal with this problem to avoid cluttering.

We showed how the state-based MoNa-map approach reduces the number of wrongly mapped as well as missing barriers and allows for error balancing between false positives, false negatives and items in the "unknown" state by adjusting expire times. This "unknown" state addresses also the attention problem. Active users – casual as well as dedicated – are supported by active messaging and visualization. The results of the simulation indicate that the state-based model (*smart-aging*) and the concept of connected items provide a suitable solution.

This paper is focussed on the presentation of the model. Aspects like using background knowledge to highlight planned barriers and adjust expire dates, linking the items to OSM objects on the base map, system support for link setting between items, personalization and a description of the MoNa-map interface will be presented in future work.

For mobile use we plan to provide a special smartphone client to support location based mapping. A location-aware tool can actively ask the user whether he or she sees an expected barrier.

# Acknowledgements

We thank our project partners, notably at the Institute of Psychogeronology in Erlangen, and the members of the senior citizen councils of Bamberg, Erlangen, and Nürnberg. This work is funded by BMBF grant 16SV5700K (Technology and Innovation), Cooperation project "Europäische Metropolregion Nürnberg macht mobil durch technische und soziale Innovationen für die Menschen in der Region" (EMN-MOVES).

Maps are based on OpenStreetMap using Leaflet. The OSM logo is cc by sa Ken Vermette.

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