

# Designing systems for mobile collaboration

Niels Seidel

niels.seidel@fernuni-hagen.de

Chair for Cooperative Systems at FernUniversität in Hagen  
Hagen, Germany

## ABSTRACT

Due to the widespread use of mobile communication devices, the mobility in everyday life including mobile working habits, a variety of collaborative software applications accompany us every day. In this paper, we aim to capture and describe the essence of the design solutions implemented in these applications in the terms of design patterns. To achieve this goal, we examined relevant services and applications in literature that enable people to collaborate on the go. Furthermore, the geographic characteristics of place, space, and mobility are discussed with regard to location-based collaboration including references to the theory of relativity. As result 11 design patterns for mobile collaboration have been elaborated. The design patterns describe, in addition to basic technologies, generic map services and privacy preserving solutions. In particular the patterns GEO FENCING, LOCALE ME, GEO TRACING, and SUBSTITUTE POSITION are presented in detail. These patterns are intended to guide computer science teachers and software developers on how to design mobile collaboration systems that mediate collaboration in physical space through interactions in virtual space.

## CCS CONCEPTS

- **Human-centered computing** → *Social media*.

## KEYWORDS

Mobile Collaboration, Mobile Interaction, CSCW, Design Patterns

### ACM Reference Format:

Niels Seidel. 2021. Designing systems for mobile collaboration. In *European Conference on Pattern Languages of Programs (EuroPLoP'21)*, July 7–11, 2021, Graz, Austria. ACM, New York, NY, USA, 15 pages. <https://doi.org/10.1145/3489449.3489999>

## 1 INTRODUCTION

In most collaborative systems, collaboration is assumed to take place in the virtual space. Collaboration partners who

are distant from each other interact either only with each other or additionally with virtual artifacts. The possibility of interacting with each other despite spatial separation is initially an advantage over forms of togetherness in real life. In this situations we are using various devices on-the-move and do not care about location. But location becomes important if we like to meet someone in reality or if we want to stay in contact with people who are not at a fixed location. Systems supporting collaboration in physical mobile settings therefore help us to overcome barriers like unobvious terrain, challenging wayfinding, or complex traffic situations. These system aim at bringing people together in order to start or continue their collaboration. Since locality and changes in the locality play an important role for this endeavor, we refer to the term mobile collaboration [15, 37–39]. Mobility and its link to locality have often been dismissed in the considerations on how to design systems supporting collaboration. Most of the research in the field of computer-supported collaborative work (CSCW) and social computing focused on virtual spaces that have few, if any, points of reference to the real world. Apart from that several sharing platform require links to the real world. For instance, home-stay or ride-sharing services inherently need to initiate real encounters. In this paper, we therefore focus on the cross-relations between real and virtual spaces in the design of collaborative systems.

The sociologist Manuel Castells expanded the concept of space to *spaces of flow* as “material arrangements [that] allow for simultaneity of social practices without territorial contiguity” [11]. Social practices happening in a synchronous or asynchronous manner do not imply a spatial contiguity [10]. Even if spaces of flows or virtual worlds seem to be detached from real spaces, there are numerous points of reference and relations between both concepts. For example, in the physical world we find links in the form of QR codes that refer to a virtual space. Conversely, we use online mapping and positioning services to explore physical places and spaces. Many of these bridges between real spaces and spaces of flow help us to move seamlessly from virtual collaboration to real collaboration or vice versa. For this to happen, elements referring to both spatial concepts need to be arranged and designed accordingly.

The goal of this paper is to fill the gap in the literature on computer-mediated interaction with patterns that consider aspects of mobile collaboration. Due to the widespread use of mobile communication devices, the mobility in everyday life and the widespread mobile working methods, a variety of collaborative software applications have been established in practice. In this paper, we aim to capture and describe the essence of the design solutions implemented in these

---

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from [permissions@acm.org](mailto:permissions@acm.org).

*EuroPLoP'21*, July 7–11, 2021, Graz, Austria

© 2021 Copyright held by the owner/author(s). Publication rights licensed to ACM.

ACM ISBN 978-1-4503-8997-6/21/07...\$15.00

<https://doi.org/10.1145/3489449.3489999>

applications in the terms of design patterns. To achieve this goal, we consider the theoretical background, the state of the art in research as well as relevant services and applications that enable people to collaborate on the go.

In computer science, design patterns play an important role in teaching and learning, e.g., in software engineering (e.g., [30, 36]) or also in human computer interaction (e.g., [8, 12, 31]). Therefore, the target audience of this paper are teachers who, in the spirit of Griffiths and Pemberton [20] want to practically apply design patterns in the design process with students. Some of the design patterns presented here have already been used in courses and discussed with students. The patterns thus constitute a specially structured form of learning resource. Since the design of mobile collaboration systems requires certain expertise in the field of software development, people with these skills are therefore also part of the target audience.

Furthermore, Designers and developers of location-based collaborative applications can be considered as target audience and will benefit from the systematic approach presented here.

The rest of the article is divided into eight sections. First, we shed a light on the spatial spaces, places, and mobility in terms of computer-mediated interactions. Next, we look at the state of the art in mobile collaborative systems and related design patterns in section 3. Section 4 provides an overview of the Design Patterns presented in this article including some notes on the origin and application of patterns in teaching courses. Sections 5–7 deal with one layer each of the patterns: base technology, mapping, and privacy. The article ends with a summary and an outlook.

## 2 SPATIAL SPACES, PLACES, AND MOBILITY

Mobile collaboration refers to movement in space and the relocation of the place where cooperative work processes are carried out. Before we look more closely at the design pattern making this possible, we would like to analyze related terms like space, place, and mobility by contrasting their physical and virtual meaning.

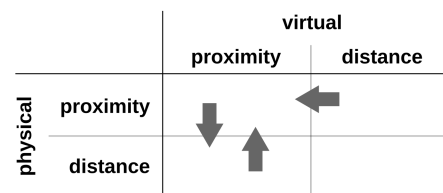
### 2.1 Space

First, let us consider the concept of “space”. In linguistic usage the term has several meanings. On the one hand we associate with it more or less limited areas or volumes, which can be described by coordinates. On the other hand we understand by it a delimited structure or constellation of subjects, objects and processes. The subjects, objects and processes are located in space, they have their place – enough place – and stand in relative position to each other. Spatial arrangements of elements can be described by their proximity or distance, whereby elements close to each other are positively or negatively related to each other. This correlation is also called *spatial autocorrelation*. Waldo Tobler formulated the first law of geography:

*Everything is related to everything else, but near things are more related than distant things.* [50]

This law was empirically proven and formulated already earlier in other disciplines in a similar way (see “Gesetz der Nähe”, Gestaltpsychologie [53]). But in relation to space it has no absolute validity, since the diversity of geographical spaces is marked by contrasts and borders, e.g. between land and sea, mountain and valley, forest and field as well as political divisions like state borders [28]. In this sense distance is related with the effort to overcome this distance. The way of *physical distance* is not the same as the way of *digital distance* or *virtual distance*. In virtual space and hyperspace distances exist, but cannot be quantified exactly. Even the distance between two pixels is not necessarily the same for all users due to differences in screen resolution, display size and the pointer devices used (cf. *Fitts’ Law* [17]). Trying to express proximity to a group member by the number of clicks is just as unhelpful as trying to specify the number of pages the REMOTE CURSOR (cf. [42]) is located away in a SHARED EDITOR. Consequently, motion in terms of distance change, speed and acceleration in virtual space cannot be represented conclusively.

In the context of mobile collaboration, physical and virtual distance are two independent dimensions. The matrix in Fig. 1 compares the virtual and physical proximity and distance of two collaboration partners. Collaborative work in virtual space is possible when both people are in the same virtual space, i.e. have agreed to use the same collaboration tool. This tool can help to overcome the physical distance or to continue working together despite it. Note, the design of tools of this type is the subject of this article. If no agreement has yet been reached on the application to be used, the virtual distance can only be overcome in physical proximity. If there is both a physical and a virtual distance, no collaboration can take place immediately.



**Figure 1: Relation between virtual and physical proximity and distance of two collaboration partners. The arrows indicate transitions to achieve or maintain a collaboration.**

### 2.2 Place

In contrast to space, a place has a social significance (e.g. city center), a cultural role (e.g. town hall) or a function (e.g. traffic lights). In this respect, places are more clearly defined than spaces and grow out of people’s individual and collective experience. While a space always represents a potential for something, the place is already semantically occupied. In the virtual we also know specific places which have a specific address (URL) and purpose (e.g. market place, news site, multiplayer game). The way in which meaningful information

can be located in geographical spaces will be discussed in the following sections.

### 2.3 Mobility in space and time

A further aspect, which is not considered in the first law of geography, is the movement or mobility of objects which are in the immediate vicinity at a certain point in time, but which can be far apart shortly afterwards. This applies, for example, to a person standing on a platform whose collaboration partner is currently rushing past in a train. The location of the interaction partners is an important context variable in mobile collaboration. In the space-time matrix of Grudin [21] it is differentiated between people who are at the same location and those who are at different predictable and unpredictable locations. Although we are primarily concerned with the mobility of the individuals involved, in view of autonomous agents and companions their own movements must also be considered detached from the users. The matrix that I am introducing in Tab. 1 expands this view and shows a comparison of the interaction of stationary and mobile actors in the form of users and devices. Let us consider the following three examples:

#### **stationary device / mobile, predictable user**

*USB dead drop:* The art project initiated by Aram Bartholl consists of a USB stick mounted in a wall, which serves as an anonymous *peer-to-peer file sharing* network. People passing by can connect directly to their mobile devices or via cable and copy or store files.

#### **externally controlled, mobile device / mobile user**

*botiful:* As a telepresence robot, *botiful* presents itself as a small three-wheeled vehicle on which a mobile phone is parked during a video conference in order to let the small robot be controlled by another conversation partner. In addition to the driving movements, the vehicle can also play gestures such as nodding or shaking its head.

#### **mobile, user-defined device / mobile, unpredictable user**

*Wifi in a train:* As a passenger of a train, I am mobile without being able to directly influence the train's journey. However, with a mobile device on board, you can move relatively freely in the train and collaborate ad hoc. You can also access the WWW via WIFI access points in order to collaborate with people inside or outside the train.

The examples make clear that mobility is always relative to the reference system. An observer usually chooses the reference system according to his or her own position. If he or she chooses the earth as reference system, the movement of the planet around its own axis as well as in the solar system and universe is ignored. Things are considered immobile if they stand firmly on the ground and do not move in relation to the ground (e.g. houses, mountains). But if you look at a seated person in a moving train, he or she is mobile because the train does not stand still and immobile because he or she sits on a seat and does not move in the train. This seemingly paradoxical state illustrates the possibility of simultaneous

mobility in several reference systems. In virtual space or hyperspace, the respective platforms (e.g. websites, apps, social networks) are regarded as reference systems. Users can be in multiple reference systems at the same time and jump back and forth between them. Simultaneous mobility in several virtual reference systems is nothing unusual.

The relativity of space and time can also be experienced in distributed systems (cf. [34]). In a perfect system, it is assumed that events taking place simultaneously are also perceived as simultaneous by all observers (e.g. collaboration partners) because the signals are transmitted at the speed of light. Time losses due to transmission at the speed of light are not perceptible to humans within the planet Earth. In practice, however, there are delays in transmission, for example due to computation times at the sender or receiver or due to a reduced transmission rate, a high transmission distance or routing via several intermediate nodes on the internet. More generally, following Matherat and Jaekel [34], it can be said that no physical system exists that can deliver time over all virtual space simultaneously. Two events that one user sees simultaneously may appear to another user in a different temporal sequence. Changes in temporal sequences also result in changes in causality. From the relativity of time it follows that even a geo-position of moving agents matching in virtual space depends on the perspective of the observer. Thus, in mobile collaboration there is no space dependent on the observer. The space is dependent on the observer and the observer's imaginary motion due to a delay in data transmission. This delay leads to an apparent motion of the observers involved in the collaboration, known as special relativity.

For collaboration in spatial space, it is initially crucial for participants to locate themselves and others. Benyon and Wilmes [5] refers them as spatial problems because of a distance between people, places, things and the movement or co-ordination of people or things from place to place. However, the awareness of location is not a simple undertaking. In the physical world, we need the support of all sensory organs to perceive people in our immediate and distant surroundings. Some tools like binoculars help us to increase the sensory performance. Sometimes we recognize persons only indirectly by sounds or do not know exactly which person is in the environment.

Considering collaborative systems the awareness locality refers to the workspace awareness as proposed by Gutwin and Greenberg [22, 23]. If the workspace is not limited to a specific virtual environment (e.g. a platform, social network) the surrounding area in the real world needs to be considered for awareness support as well. Thus, location awareness in this context goes beyond online availability. Awareness of other people's location allows implication about physical reachability for on demand communication and collaboration. Location awareness therefore, directly supports coordination activities and possibly reduces coordination effort. Although location is readily available given various technologies, some

**Table 1: Examples of interaction between stationary and mobile users and devices.**

		Device		
		stationary	mobile, predictable, user-controlled	mobile, not predictable, externally controlled
User	stationary	Desktop computer	Dron	telepresence robot
	mobile, self predictable	kiosk-system, tabletops, <i>dead drop</i>	smartphone, table	telepresence robot (e.g. <i>botiful</i> )
	mobile, not predictable	—	using Wifi, 5G, etc. in a vehicle	—

challenges arise for awareness information in terms of its relevance, capture, translation, transmission, and presentation [19].

Based on this explanation of place, space, and mobility in relation to group awareness, we now look at related research that has either considered specific systems to support mobile collaboration or related design patterns.

### 3 RELATED WORKS

This section summarizes related work that includes aspects of mobile collaboration in the design of software applications on different levels. We begin with rooms and buildings as the smallest geographic level, where small groups in particular can collaborate using extensive technical support. Beyond that, the location-based community platforms discussed in the second subsection enable communication and collaboration at a local and regional level. Collaboration in public spaces among different stakeholders is the subject of the third subsection. In even more expansive areas, map applications become essential to enable location-based collaboration. Therefore, the fourth subsection is about map-based collaboration systems. In the last subsection, existing design patterns that have been developed for related fields such as Human-Computer Interaction are discussed.

#### 3.1 Collaboration near-by

The notion of smart spaces describes the integration of digital artefacts into physical spaces (e.g. [13, 26]). [4] therefore also refers to these as “blended spaces”. Since physical spaces often refer to offices, meeting rooms, or homes, near-by collaboration is the aim. Android supports near-by connection to display notifications or send messages<sup>1</sup>. Madden et al. [33] have used so-called “blended interactions” for near-by interaction Jetter et al. [26]. These interactions include gestures and responses for two devices at a time. The authors distinguish simultaneously executed gestures like *bump*, *shake* or *touch* as well as gestures executed unilaterally like *swipe*, *throw* or *approach*.

<sup>1</sup>See <https://developers.google.com/nearby/> (last accessed 2021-09-30)

The non-profit company Dynamicland<sup>2</sup> aims to advance interaction without screens and devices, in which collaboration and interaction with computers is done using physical materials such as paper, clay, tokens, and toys. Following the vision of ubiquitous computing, the technology disappears in favor of everyday materials used for controlling and even programming the hidden devices. For the users it seems that “Space is the computer”.

However, in near-by collaboration, mobility is limited to a small space and therefore geographic specifics and mobility is not taken into account.

#### 3.2 Location-based communities

Location-based services are online social networks dedicated for a delimited area like a city, a quarter or a small region. The regional distinction can be defined by a subcommunity of a larger social network like a location-based group within Facebook. In contrast, so called hyper local networks assign users by the given address, their current location, or their geographic preference to an existing location-based community. FriendZone by Swisscom Mobile as one of the early examples for location-based communities provided instant messaging among friends including support for location awareness, anonymous instant messaging between users matched because of similar user profiles, and text chat [9]. Today we find a large variety of location based communities within different platforms. Remarkable in this regard are anonymous hyperlocal social network like YikYak and Jodel [7]. The focus on a very small local area requires solutions to hide its identity or locality. However, for most of the location-based community platforms a map-based navigation is not necessary in order to coordinate mobile collaboration since the collaborators know the places very well.

#### 3.3 Collaboration in public space

Collaboration in public space extends to large areas such as cities, villages or regions. The following research has a strong experimental and partly artistic character (e.g. [16, 24, 25, 27]). Fischer and Hornecker [16] examined systems to be implemented in public space that enable playful exchange and collaboration among people. In detail the

<sup>2</sup>See <https://dynamicland.org/> (last accessed 2021-09-30),

authors distinguish involved people actively meet, actively engage, observe, and just pass-by. Heinemann and Mitchell [24] conducted four interventions in public space for offering collaboration, requesting collaboration, allowing for collaboration, and making collaboration contextually relevant. The tangible interaction framework by [25] included collaborative activities in public space. The framework includes the tangible manipulation, spatial interaction, embodied facilitation, and expressive representation. A “clavir” (piano), for instance, was built as a walkable keyboard played sound when light sensors were triggered above the keys. One or more people stepped and danced across the keys in order to create music.

Kasahara et al. [27] developed a tablet application to situate three dimensional drawings, texts, and photos on a augmented reality spatial canvas. These user location-based expressions can be shared with any other person who uses the same software at the same location.

The detection of potholes on public roads [35] and earth quakes [29] are examples for participatory, but passive sensing and joint data and knowledge collection in public space. Examples for active participation are Civic issue tracker and also Open Streetmap. A comprehensive classification of geotagging was conducted by [55].

In summary, it can be stated that collaborative work in public spaces has hardly been supported by technical systems so far. Collaboration is mostly limited to defined locations (e.g. [16, 24, 25]), where specific technical devices are installed. A location-independent collaboration as in [35] ended in geotagging or is focused on rare events like earthquakes [29]. Coordination in geographic space is enabled by only a few works (e.g. [27]). Support for workspace awareness in the sense of [22, 23], which extends the workspace to the whole public space, is missing.

### 3.4 Map-based collaboration

Map-based collaboration has many areas of application: decision-making (e.g. [54]), situated learning (e.g. [56]), maintenance of public space (e.g. [43, 51, 55]), traffic monitoring (e.g. [44]) and communication (e.g. [45]). Geotagging has become a common practice for map-based collaboration (e.g. [43, 45, 51]), especially through geotagged photos and messages. Snyder et al. [45], for instance, visualized real-time tweets on a map which were semantical classified using a pre-trained Word2Vec model. The “Argumentation Map” by Sidlar and Rinner [43] links arguments and concerns with spatial places on a city map. The more recent work of Simon Weckert emphasized possible manipulation of online map services such as Google Maps, like hiding borders or renaming areas for dedicated audiences. In a art performance, he generated a traffic jam message on Google maps on a multi-lane road by pulling 99 cell phones along the road on a handcart [44].

Current map-based applications support mobility in geographic space primarily by annotating tags that contain

mainly location-specific information, but rarely support communication and mobile collaboration. The maps are mainly used as an entry point for further interactions.

### 3.5 Design pattern for mobile collaboration

The *mobility patterns* presented by Roth [40] addressed early technical solution regarding mobile services, security, data, and user interface, without considering group collaboration and locality. Similarly, Neymem, Ochoa & Pino proposed messaging design patterns [38] and coordination patterns [37] for mobile collaboration. The design patterns for distributed knowledge spaces by Essmann and Hampel [15] leave out collaboration taking place outside of technical well-equipped spaces. [41] focused on mobile gaming patterns with regard to the taxonomy of learning outcomes by Benjamin Bloom [6]. The authors refer to six patterns that more or less describe general categories such as augmented reality, collaborative actions, and physical navigation. Schümmer and Lukosch [42] do not consider mobile collaboration in their work about “Patterns for computer-mediated interaction”, but they offer a number of connecting points for the patterns presented here in the paper, e.g. the pattern VIRTUAL ME. In the more general interaction design patterns by Tidwell [49] or Crumlish and Malone [14] also include solutions for interactions in physical space, but do not address the aspect of mobile collaboration. In summary, the design for applications that support mobile collaboration has not yet been described in terms of design patterns or similar guidelines.

## 4 OVERVIEW OF THE DESIGN PATTERNS

The patterns presented in the following three sections will be formatted in the alexandrian style. One to three asterisks behind the pattern name indicate the dissemination of the solution. The first part of the pattern is a short description of the context, followed by three diamonds (◆◆◆). In the second part, the problem (in bold), the background, and the forces are described, followed by three diamonds (◆◆◆). The third part offers the solution (in bold), consequences of the pattern application including a discussion of possible advantages and liabilities. In the second last part of the pattern known application examples that are partly illustrated by screen shots are presented. The final part consist of a list of related patterns in underlying pattern language as well as patterns of the previously referenced languages such as Crumlish and Malone [14], Schümmer and Lukosch [42], Tidwell [49].

The forces as well as the advantages and disadvantages of applying a pattern were considered in terms of seven dimensions. These dimensions are derived from the context of space and time as well as the specifics of collaboration in these settings. In a broader sense, the dimensions describe properties and qualities of the overall design space. As guidance for lateral thinking on every of the seven direction the reader shall be encouraged to consider multiple perspectives. In the following list, the seven criteria are explained in more detail:

**Navigation** Finding locations or the people who are there is a central challenge of mobile collaboration. Wayfinding is therefore one of the coordinating activities described in the 3K model by Teufel et al. [48].

**History** Every geo-position taken by a person is the consequence of past movements in space. In terms of group awareness, the history of past spatial movements can help to trace past collaborative processes and sometimes also explain the intention of actions.

**Topicality** The movement of the people involved in the collaboration and the objects involved requires the information to be up-to-date. If the timeliness cannot be guaranteed, the geo-information will be inaccurate and the group awareness will be impaired.

**Reliability** Mobility imposes restrictions on the connectivity of the devices used to support mobile collaboration via software. Interruptions in connections, delays in communication and temporarily reduced data transfer rates must be taken into account in mobile collaboration settings.

**Communication** Collaborative systems cannot function without communication support. In mobile collaboration, communication plays an important role because

the people involved can usually only communicate with each other by help of a computer and its communication facility.

**Reciprocity** Collaboration in mobile settings is based on reciprocity. It is therefore important to consider possible counter-reactions of the collaboration partners.

**Consent** The transfer of personal data, such as the current whereabouts, must take place by mutual agreement.

This list may still have some blind spots regarding the hardware used, the limited runtime of battery-powered devices, and the scalability in general. However, for sake of readability and in order to avoid hardware-specific assertion these further dimensions have been neglected.

The 10 design patterns identified so far are arranged in three layers (see Tab. 2). The top layer comprises basic technological approaches and architectures for mobile collaboration. The second layer contains solutions on how to visualize geographic information on maps. The bottom layer addresses the need for privacy. In this paper the four highlighted design patterns in Tab. 2 will be presented on the following pages.

**Table 2: Overview of the design patterns organized in three layers. The patterns represented in that article are shaded in blue.**

<b>Base Technology Layer</b>	
GEO-LOCATION	Indicate the longitude, latitude, and altitude of the user and the persons, objects and events relevant to him/her.
SPATIAL ORIENTATION	Show in which direction someone is moving or facing.
GEO FENCING	Informing users if entering or exiting a specified geographical area.
<b>Mapping Layer</b>	
LOCALE ME	Visualize the relative position and orientation of the user and the persons, objects and events relevant to him/her on a map.
GEO TRACING	Visualize the last traveled path of the collaboration partner to the current position on a map.
NEIGHBORHOOD	Display on a map the persons, objects and events located in the surrounding area of the user's place of residence and relevant to him/her.
GEO TAGGING	Enrichment of a map with geo-referenced information about people or objects located at a specific place.
<b>Privacy Layer</b>	
SUBSTITUTE POSITION	Allow users the ability to move their current geographic location, which is visible to others, to any other location.
GENERALIZED POSITION	Provide roughly scaled positioning information about a person or object instead of the exact position.
WHITE SPOTS	Define areas where location-based services are not available for group processes.
LOCANYM	A locanym is a geolocated version of a pseudonym tied to a particular and verified geographical area.

## 5 BASE TECHNOLOGY LAYER

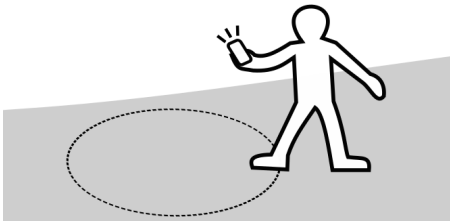
There are many ways to determine the spatial position of a person or artifact. In some cases it is necessary to determine the geographical coordinates (longitude, latitude, altitude), in other cases a relative position in relation to a reference position is sufficient. In the case of Corona Warn App, which was developed by Deutsche Telekom and SAP, for example, it was sufficient to determine the distance to other users of the app. Furthermore, the accuracy of the position information required for the collaboration partners can vary in the range of a few centimeters to several kilometers. Depending on the device and its connectivity, very different base technologies are available for implementation, e.g. GPS, A-GPS, Bluetooth, NFC, audio beacons [2], aerial photography, satellite images, radar, lidar, echo sounder, but also indirect recording methods like tachograph or license plate recognition can be used. In the design pattern GEO LOCATION the problem of localization is discussed in more detail.

After the position of cooperating persons has been determined, further awareness information can help to improve the collaboration. For example, it is important to know in which direction a person is moving or has turned in order to identify his or her intention. The pattern SPATIAL ORIENTATION is elaborated as a solution in this respect.

In a mobile setting it can also be important to be informed as soon as a certain target is reached or a certain person is approached. The pattern GEO FENCING describes general application domains and technical solutions.

### 5.1 Geofencing

**Informing users if entering or exiting a specified geographical area**



Certain information is only relevant to users when they are in a particular location.



**When entering or leaving a certain geographic area users are not aware of information or services that become relevant and available there.**

- Navigation: Navigation to the unknown vs. navigation to the known.
- Consent: Who wants to know what is there?
- History: Knowledge about services available at a certain location can date back.
- Topicality: Relevant information must reach users in a timely manner, not just when they have almost left the site.

- Reliability: If the information has a geographical reference, it should only be available at that location.
- Communication: The capacity to process information is limited, which is why location-based information should not be offered regardless of location.
- Reciprocity: If I get to know the location does the location get to know me as well?



**Virtually mark a geographic location of interest by longitude, latitude and a radius to provide location specific information and services. Trigger events as soon one enters or leaves this location.**

A geofence provides a way to determine, whether a user or agent is near a certain location. The location is defined by the longitude and latitude, while the proximity is set by a radius. The smaller the radius, the greater the proximity to the location. By this means circular geographic areas can be designated as point or region of interest. When a user enters this area, an event is triggered immediately or with a defined delay. When leaving the area another event can be triggered. For Android and iOS developers the geofencing runs in background without stressing the battery too much. Web-based solutions require the user to have the web-app open and usually do not optimize battery intensive positioning tasks.

The existence of a geofence can be linked to a point in time and a duration. After expiration the location-based event will not be available anymore. Multiple geofences may overlap or coexist. By overlapping circles, more complex shapes can be defined as geofence by using logical operators. The total number of concurrent geofences is usually limited.

According to the Android guidelines, geofences combine “the awareness of the user’s current location with awareness of the user’s proximity to locations that may be of interest”. Although geofences have been used for various location based services, including advertisement and tourism, the technology offers further applications for mobile collaboration. Compared to the design patterns for computer mediated interaction by Schümmer and Lukosch [42] geofences provide the foundation for additional geographic awareness support, e.g. having a USER LIST of people or agents who are in the same place; determining who is away (AWAY MESSAGE); PERIODIC REPORT of attendees at physical events; location-based ACTIVITY INDICATOR

**Benefits.**

- Navigation: Entering the radial area of a geofence indicates that the dedicated location has been reached. Thus, geofences enable a kind of trial and error navigation by notifying the user until the destination is reached.
- Consent: Geofencing only works with the user’s consent to capture the geo location in the background.
- History: No matter from which direction and with which speed the fence is crossed, the event is triggered. Everything that happened before entering the geofence is irrelevant for triggering the event.

- **Topicality:** Geofences can be defined and removed dynamically.
- **Reliability:** The reliability depends on the used method for determining the GEO LOCATION.
- **Communication:** The triggered event should inform the user about the reached or left location and the corresponding event.
- **Reciprocity:** –

#### Liabilities.

- **Navigation:** Fences are not navigatable in the way that the user can get an overview of existing fences.
- **Consent:** Consenting to the collection of location data in an app (e.g. ACCESS\_BACKGROUND\_LOCATION on Android) implies also consenting to location-based services using geofences. Consequently, users can also enter a geofence without realizing it, allowing the app operator to record presence in a specific area.
- **History:** When crossing the geofence, the event is still triggered even if you have already entered the area shortly before. Further more, it is unclear whether the service provider collects personal information about the people that have had been at a location.
- **Topicality:** In the current geofence implementations gradual awareness support is not considered. As soon as you have entered the fence the awareness support disappears.
- **Reliability:** User's proximity to a location of interest does not consider barriers (e.g. buildings, rivers) and altitudes (e.g. floors of a building) since the sensitive area is defined as a perfect circle around the location.
- **Communication:** The events can be triggered without the user noticing or consenting to it. With regard to current data privacy legislation like the European GDPR, geofences may violate the OPT-IN principle.
- **Reciprocity:** Geofences are not visible to the user. Even the events can be triggered in the background when entering or leaving a predefined area. This lack of transparency in the design of the current geofencing APIs should be approached in environments dedicated for mobile collaboration.

**Known uses.** Geofencing solutions are used in very different areas and on different platforms, e.g.

- *Geolocation Sensor:* The work of the former W3C working group *Geofencing API*<sup>3</sup> was partly covered in the *W3C Geolocation Sensor draft*<sup>4</sup>.
- *Android geofencing:* Per App up to 100 geofences can be created for Android devices<sup>5</sup>.

<sup>3</sup>See <https://w3c.github.io/geofencing-api/> (last accessed 2021-09-30).

<sup>4</sup>See <https://w3c.github.io/geolocation-sensor/> (last accesses 2021-09-30).

<sup>5</sup>See <https://developer.android.com/training/location/geofencing> (last accessed 2021-09-30).

- *iOS region monitoring:* The *region monitoring* in iOS alerts when the user enters or exits a geographical region<sup>6</sup>.

#### Related Patterns.

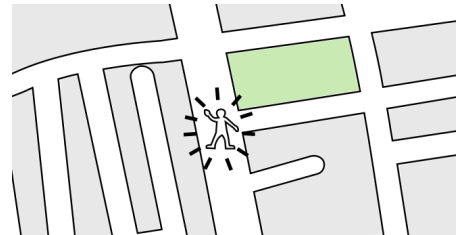
GEO POSITION

## 6 MAPPING LAYER

In the introduction to this article we got to know the “place” with its cultural role, function and social significance. A very special place in this respect is for most people their own home. As the center of life, the home is not limited to an apartment or a house, but also includes the surrounding streets, paths, green spaces, buildings, public facilities and other forms of infrastructure and landscape. Since people often move around in this environment, they have a good knowledge of these places. In the course of time they have gained experience with the characteristics of the area and the people living there. The intrinsic interest to learn news related to the place and its surroundings is often based on a sense of connection. In linguistic usage one then takes possession of these places and calls oneself “my community”, “my village”, “my town”, “my hood”, “my community”, “my quarter” or “my street”. A separate form of the LOCAL ME pattern is therefore the NEIGHBORHOOD. If well known place are projected on a map we must be aware that the information on the map underrepresents reality. Simon Weckert [44] points out that maps in particular are not neutral and often convey political, economic and social values.

### 6.1 Local Me

**A user wants to see where she/he is in relation to other people and places.**



A user is located at a geographical position in a certain environment (GEO-LOCATION) and facing a certain direction.



**A user doesn't know where he/she is on the map and where the others are.**

- **Navigation:** The route to a destination can only be determined if the starting point is known.
- **Consent:** If you expect help with positioning, you must be willing to provide location data.
- **History:** If you can remind yourself of past way points, this can help you locate yourself on a map. Without such or other clues (e.g. street names, landmarks) it is almost impossible to find yourself on a map. Clues can also be used to infer the position of other users.
- **Topicality:** Places are sometimes not clearly identifiable.

<sup>6</sup>See [https://developer.apple.com/documentation/corelocation/monitoring\\_the\\_user\\_s\\_proximity\\_to\\_geographic\\_regions](https://developer.apple.com/documentation/corelocation/monitoring_the_user_s_proximity_to_geographic_regions) (last accessed 2021-09-30).

- **Reliability:** If one is lost, it is the result of an interruption in orientation in space.
- **Communication:** Describing one's whereabouts to someone is all the more difficult the less one knows about the surroundings and can name landmarks.
- **Reciprocity:** If two people do not know where each other is, they cannot find each other.



**Visualize the relative position and orientation of the user in the center of the map and show nearby persons, objects and events relevant to him/her.**

In this way, you can not only get an overview of what is happening around you, but you can also join ad-hoc people or find necessary aids. The relative representation makes it possible to estimate the effort required to cover the distance. The prerequisite for this, however, are characteristics of the map in terms of its presentation, scale, subject matter, topicality and section, which should provide information about paths, barriers or other location-related features.

Beside the single local me, the data of multiple users can be represented and aggregated on a map. For instance, heavily crowded streets are emphasized on the map in order to navigate to less frequented routes.

In case of online social networks users are asked to enter location information as part of their user profile or VIRTUAL ME. The geographic nature of these inputs can be also used to provide a more static representation of the LOCAL ME. This static location could be seen as a SUBSTITUTE POSITION

#### Benefits.

- **Navigation:** The map indicates available ways, destinations, and relevant artifacts to go. A changing position of a *Local Me* indicate the route one is taking.
- **Consent:** The user is free to disclose his location data. Even without a release, the map service should be usable.
- **History:** Its about here and now so that past traces on the map accumulate at the resulting position. On a broader time scale past, present, and predicted future location of individuals and accumulations of individuals are also displayable by number or other visual representations.
- **Topicality:** The location of oneself appears to be in the center of everything, since all remaining elements appears around the center.
- **Reliability:** In case of a short interruption of the positioning, the LOCAL ME remains at the last detected position on the map.
- **Communication:** Since all involved users know the position of each other they can focus on their collaborative activities and do not need to coordinate their positions and environment.
- **Reciprocity:** The assumption is that all those I can see can also see me. No one can hide completely (SUBSTITUTE POSITION) in virtual space.

#### Liabilities.

- **Navigation:** Way-finding to moving targets must consider the route traveled (GEO TRACES).
- **Consent:** When starting an App the first time or visiting a web page the first time the user needs to confirm the usage of location data. This consent is valid for all later sessions or until it is explicitly withdrawn. In order to immerse into location privacy one can SUBSTITUTE POSITION or provide a GENERALIZED POSITION
- **History:** The LOCAL ME represents the user here and now. There is no history, there are no GEO TRACES by default.
- **Topicality:** Location is modeled as point, but a human requires more space than a point.
- **Reliability:** The accuracy of location information requires reception of at least three signal sources whose position is known. Sources of interference, interruptions, or varying signal will move the Local Me to a location that does not match the user's position. In the worst case one is represented at all and thus, does virtually not exist for the collaboration partners.
- **Communication:** Since the Local Me represents the real position other may not find one on the virtual map or in the real world.
- **Reciprocity:** Everyone can see me on the virtual map, but they have to find me first.

#### Known uses.

- The course of the location-based games like *Pokémon Go*, *Pac-Manhattan*, and *Minecraft Earth* changes with regard to the players position in geographic space.
- *Foursquare* as a location-based recommendation systems uses the LOCAL ME to ask users to rate, critique, sometime blame restaurants and other public places.
- Bicycle-sharing systems, particular floating services represent the available vehicles on a map.
- As an alternative to an automatically detected GEO-LOCATION Wang et al. [52] examined the design of location fields in user profiles. They conducted controlled experiments in order to investigated design options like length, prompts, verification, and visibility.

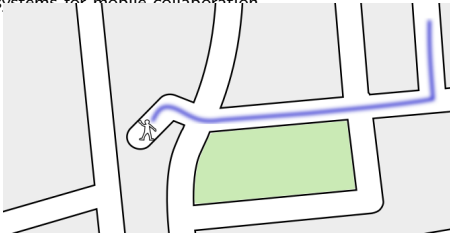
#### Related Patterns.

Schümmer and Lukosch [42] presented the VIRTUAL ME as a representation of the self in virtual communities. The VIRTUAL ME is commonly known as user profil and sometimes part of a social media channel. The GEO-LOCATION provides the geo information necessary to extend the VIRTUAL ME to a LOCAL ME

Since the LOCAL ME requires the positioning information the design patterns SUBSTITUTE POSITION, GENERALIZED POSITION, and WHITE SPOTS provide solutions to keep privacy as needed.

## 6.2 Geo Traces

**Visualize the last traveled path of the cooperation partner to the current position on a map.**



Intended cooperation among a group of people that know each other.



**You do not know where your cooperation partners are right now and which route they have taken.**

- Navigation: If you don't know the path your cooperation partner has traveled so far, you can't estimate future whereabouts.
- Consent: In terms of privacy the disclosure of information about continuous paths traveled is more sensitive than roughly resolved way points.
- History: Personal track recordings are not available for others.
- Reliability: From a physical point of view, you are always in one place. If in the course of time the transmission of this location position is interrupted, missing information needs to be interpolated.
- Communication: Asking again and again for the location or the way is tedious and disruptive. The coordination activities prevent those involved from focusing on the actual collaboration.
- Reciprocity: The location of the searched is more important for the searcher than the position of the searcher is for the searched.



**Therefore, visualize the last traveled path of the involved cooperation partner, vehicle, or device to its current position on a map.**

#### Benefits.

- Navigation: Based on the GEO TRACES, the current and potential next position of the cooperation partner can be used for path finding.
- Consent: The trace function is usually granted only temporarily for short periods of time and for a limited group of people.
- History: GEO TRACES represent the history of past locations. This context information is a valuable source for fostering group awareness in spatial space.
- Topicality: GEO TRACES indicate the current position and the direction from which this position was reached.
- Reliability: Interruptions of a sequence of way points can be interpolated. Recognize possible stops that have been passed and routes that have been chosen.
- Communication: The map traces can be more precise, accurate, and up to date than verbal descriptions.
- Reciprocity: All collaboration partners should be aware that their personal traces are available to the other.

#### Liabilities.

- Navigation: The movements of a person from point A to B do not replace proper routing if you are not at either point yourself. Furthermore, the chosen route of the cooperation partner does not have to be the best or shortest route between A and B.
- Consent: A person cannot be tracked without their consent. It must be possible to stop or suspend tracking at any time (SUBSTITUTE POSITION, GENERALIZED POSITION). It is recommended to limit the duration of the tracking.
- History: After the tracking has been terminated the data traces need to be cleared on the map.
- Topicality: Predicting fast moving vehicles is difficult [3]. The visualization of altitude changes, e.g. in a multistory house, require special attention to inform precisely about the position.
- Reliability: In areas with poor network coverage or inaccurate geo positioning, interpolated locations and routes can greatly limit the usefulness Geo Traces.
- Communication: In some cases exact traces contain more information than necessary to find someone.
- Reciprocity: The demand for mutual provision of the GEO TRACES can lead to display problems on the map if a larger number of persons participate.

**Known uses.** Examples of this pattern can be found on Google Maps, especially the *real-time location-sharing*, or various other map services where GPS data of routes can be stored. In addition to routes and current position data, other information can be linked to locations.

- Traffic flows in the public transport of cities include all available means of transport from trains, subways, buses and ferries to cabs. On so-called real-time maps or live maps, geo traces result in connection with the timetable data. These means of transport are tools that can support the cooperation of several people in public space. The means of transport themselves can also serve as a (moving) place of meeting and work. See examples like the Transit Visualization Client<sup>7</sup> or the *Echtzeitzeitankunft* of the City of Ulm, Germany<sup>8</sup>.
- The real time location sharing feature provided by Google maps enables users to share their position and movement for limited time with one or multiple people. Similar services are offered by other companies like WeChat,
- The movements of air planes can be tracked using map services like *Planefinder*<sup>9</sup>.
- The smartphone application *MoveMeant* collects location traces from small communities. The aggregated community data of venues visited by at least two persons becomes available for community members by a map. [46, 47]

<sup>7</sup>See <https://tracker.geops.ch/> (last accessed 2021-09-30).

<sup>8</sup>See <https://echtzeit.swu.de/> (last accessed 2021-09-30).

<sup>9</sup>See <https://planefinder.net/> (last accessed 2021-09-30).

- Similar to *MoveMeant* the application called *Movement* collects location data traces from a defined community and identifies matches of persons who visited the same venues and locations [32].

### Related Patterns.

GEO POSITION, ORIENTATION

## 7 PRIVACY LAYER

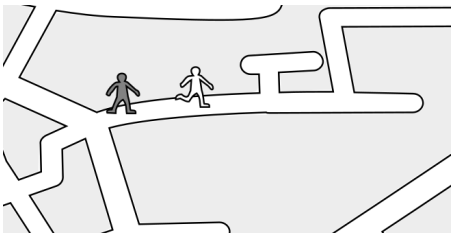
Complete privacy in mobile collaboration scenarios is only possible when all location services are turned off. Consequently full privacy is not compatible with the use of location-based services [1]. However, in view of data retention, it is not possible to deactivate positioning services in relation to service providers. Even the strategy of temporary use is of limited help. In this context, it is worth recalling Paul Watzlawick's statement that one cannot not communicate. This is also true for mobile communication, because a switched off device or the activated flight-mode always gives information about the inactivity of the user and allows for example conclusions about sleep or work rhythms<sup>10</sup>

The extent to which location data is used in a collaborative system should be determined by the user. However, the preconditions for self-determined use of the data is a question of the design of the collaborative application. The patterns in the privacy layer can therefore be regarded a filters between the base technology providing access to geo data and the application layer that provides the data to a group of users. These filters enable the obfuscation, transition, and fade out location information of persons.

There exist different approaches to achieve a privacy-preserving design for location-aware collaborative systems: First, the positioning at certain places can simply be prevented by physical shielding in order to define **WHITE SPOTS**. If the location data has already been determined, it can at least be replaced (**SUBSTITUTE POSITION**) or blurred (**GENERALIZED POSITION**) within the application in use. Additionally, the link between the user and the location could be resolved by a **LOCANYM** [18], which is a pseudonym generated from the location data.

### 7.1 Substitute Position

**Allow the user to substitute its geolocation by an arbitrary location**



<sup>10</sup>Robert Heaton demonstrated how the 'last-seen' attribute can be read from the chat of WhatsApp (<https://web.whatsapp.com/>). See <https://robertheaton.com/2017/10/09/tracking-friends-and-strangers-using-whatsapp/>.

Location information of the cooperation partners is required for a certain period of time, while otherwise it remains hidden.



**Users are reluctant to permanently share their current location with their collaboration partners.**

- **Navigation:** There are many roads to Rome, but as long as you get to your destination, the path you have chosen should not matter.
- **Consent:** Many application require a one-time consent to use location data. This consent cannot be suspended or paused.
- **History:** By accumulating the movement history, detailed user profiles can be created that provide a great many insights into personal life.
- **Topicality:** The longitude and latitude may give the position of a person only very inaccurately, if the height is not indicated, for example, in multi-story buildings.
- **Reliability:** Disconnections make users appear at positions where they last connected to the internet. In some application, disconnections are also counted as abstinence.
- **Communication:** Unless automatic positioning were possible, location changes would have to be communicated continuously to its cooperation partners.
- **Reciprocity:** Collaboration partners may also be uncomfortable with learning a specific location of a fellow collaborator.



**Allow users to move their current geographic location, which is visible to others, to any other location.**

Specifying a default or fictitious location is a way of concealing one's own location. Alternatively, one can go completely underground and disappear from the map or give only an approximate location (**GENERALIZE POSITION**). By replacing the location information, however, even more extensive movements remain hidden. By replacing a location, it may appear unchanged for a longer time. However, **SUBSTITUTE POSITION** should not be understood as an undercover mode. In many systems the default location is used as a substitute whenever there is no other geo information available.

**Benefits.**

- **Navigation:** In case of fast changing positions a static representation on a map suggests a salient user experience.
- **Consent:** The substitution of a position enables to switch into a private mode even if a consent for positioning was given before.
- **History:** The history of positioning data will have gaps that could make them useless for the creation meaningful user profile, targeted advertisements, or location based services.
- **Topicality:** By replacing a position with a fictitious whereabouts, unique and non-critical locations can be specified.

- **Reliability:** Promoting a fixed substituted position is robust against any positioning problems.
- **Communication:** Only intended and thus relevant location changes will be communicated to the collaboration partners.
- **Reciprocity:** A substituted position could be replaced by the real coordinates if all other collaboration partner would do the same.

**Liabilities.** In the case of a permanent relocation of the virtual location, however, cooperation partners could become suspicious because the person is not at the specified location or stays in one place for an astonishingly long time.

- **Navigation:** It is easier to fake a fixed location than to simulate movement along a fictitious route.
- **Consent:** Substitute position is an opt-out approach. In terms of an opt-in, it would have to be assumed that a person's location is not known to other users. If the person desires, the location can be obfuscated or replaced by a fictitious location. The disclosure of the actual location would be the second stage of an opt-in.
- **History:** Over time, an unchanging position appears suspicious if it does not change minimally in the course of time.
- **Topicality:** A persistent stay in a fixed location makes others suspect that this behavior is unnatural. Possible causes could be inadequate internet connectivity, transmission or software errors, but also a physical separation between the human and his tracking device.
- **Reliability:** The protective mechanism described above will be revealed if the user pretends to be in a place where position data cannot be determined at all. This applies, for example, to areas where no internet services are available due to the lack of a mobile network.
- **Communication:** With the change from the true position information to the faked information, one unconsciously communicates a transition from a private to a group public mode. These mode changes also result in personal data traces.
- **Reciprocity:** The desire to hide can be linked to the need to keep the desire itself as a secret. The ideal of reciprocity cannot be fulfilled.

#### Known uses.

- Before it was technically possible to determine a user's position, location information was presented as part of the user's VIRTUAL ME in terms of origin, residence or address. This type of inaccurate position information is still the rule in online collaboration, while current position data is an exception.
- To fake a location in the context of mobile communication, it is sufficient to leave the corresponding tracking device (e.g. smartphone) at a certain location while being somewhere else.
- Some ride sharing services allow tracking the location of a rider just before the agreed departure time. The rest of the time, the location of the driver is secret.

- The passport feature provided by the dating app *tinder* allows users to add multiple additional locations. At a time a user has to decide for one of the defined locations. After changing a location the contacts of the previously selected location see the user profile up to 24 hours.
- On smartphones running Android so called fake GPS apps are available in order to change the geo position for all remaining apps. Since many apps cannot be used without access to location data, this type of app gives users an effective way to hide their whereabouts from app providers.

#### Related Patterns.

GENERALIZED POSITION, WHITE SPOTS

## 8 CONCLUSION AND OUTLOOK

Due to the widespread use of mobile communication devices, the mobility in everyday life including mobile working habits, a variety of collaborative software applications accompany us every day. In this paper, I have captured and described the essence of the design solutions implemented in these applications in the terms of design patterns. To achieve this goal, I have examined relevant services and applications in literature that enable people to collaborate on the go. Furthermore, the geographic characteristics of place, space, and mobility have been discussed with regard to location-based collaboration in the field of CSCW. In particular, the reference to relativity and quantum mechanics and its implications for CSCW have been discussed for the first time. Another contribution to the body of CSCW theory is the extension of the Grudins' space-time matrix by considering the interaction of stationary and (predictable) mobile actors as users and devices.

As a contribution to practice in teaching and learning as well as software engineering 11 design patterns for mobile collaboration have been elaborated. The design patterns cover base technologies, generic map services and privacy preserving solutions. In particular the patterns GEO FENCING, LOCALE ME, GEO TRACING, and SUBSTITUTE POSITION have been presented in detail.

These patterns are intended to guide computer science teachers and software developers on how to design mobile collaboration systems that mediate collaboration in physical space through interactions in virtual space.

## ACKNOWLEDGEMENTS

I want to thank my shepherd Elissaveta Gourova for reviewing the paper and giving precious and helpful feedback on the content and style. Also the feedback of all members of the writers' workshop at the *EuroPLoP 2021* online conference was highly appreciated and therefore I want to thank all of them.

## REFERENCES

- [1] Rüdiger Grimm Andreas Dhein. 2017. Standortlokalisierung in modernen Smartphones. *Informatik Spektrum* 40, 3 (2017), 245–254. <https://doi.org/10.1007/s00287-016-0964-7>
- [2] D Arp, E Quiring, C Wressnegger, and K Rieck. 2017. Privacy Threats through Ultrasonic Side Channels on Mobile Devices. In *2017 IEEE European Symposium on Security and Privacy (EuroS P)*. 35–47. <https://doi.org/10.1109/EuroSP.2017.33>

- [3] Roni Bar-David and Mark Last. 2016. Context-Aware Location Prediction. In *Big Data Analytics in the Social and Ubiquitous Context*, Martin Atzmueller, Alvin Chin, Frederik Janssen, Immanuel Schweizer, and Christoph Trattner (Eds.). Springer International Publishing, Cham, 165–185.
- [4] David Benyon and Oli Mival. 2015. Blended Spaces for Collaboration. *Computer Supported Cooperative Work (CSCW)* 24, 2 (2015), 223–249. <https://doi.org/10.1007/s10606-015-9223-8>
- [5] David Benyon and Bettina Wilmes. 2004. The Application of Urban Design Principles to Navigation of Information Spaces BT - People and Computers XVII — Designing for Society, Eamonn O'Neill, Philippe Palanque, and Peter Johnson (Eds.). Springer London, London, 105–125.
- [6] B. S. Bloom, M. D. Engelhart, E. J. Furst, W. H. Hill, and D. R. Krathwohl. 1956. *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain*. David McKay Company, New York.
- [7] Alexander Böhm, Benjamin Taubmann, and Hans P Reiser. 2016. Geographic Localization of an Anonymous Social Network Message Data Set. In *2016 11th International Conference on Availability, Reliability and Security (ARES)*. 844–850. <https://doi.org/10.1109/ARES.2016.47>
- [8] Jan Borchers. 2002. Teaching HCI Patterns: Experience from Two University Courses. In *CHI 2002 International Conference on Human Factors and Computing Systems*. ACM.
- [9] Assaf Burak and Taly Sharon. 2003. *Analyzing Usage of Location Based Services*. Association for Computing Machinery, New York, NY, USA, 970–971. <https://doi.org/10.1145/765891.766100>
- [10] Manuel Castells. 1997. An introduction to the information age. *City* 2, 7 (1997), 6–16. <https://doi.org/10.1080/13604819708900050>
- [11] Manuel Castells. 1999. Grassrooting the space of flows. *Urban Geography* 20, 4 (1999), 294–302. <https://doi.org/10.2747/0272-3638.20.4.294>
- [12] Alexander Chatzigeorgiou, Nikolaos Tsantalis, and Ignatios Deligiannis. 2008. An empirical study on students' ability to comprehend design patterns. *Computers & Education* 51, 3 (2008), 1007–1016. <https://doi.org/10.1016/j.compedu.2007.10.003>
- [13] Chao Chen, Sumi Helal, Scott de Deugd, Andy Smith, and Carl K Chang. 2012. Toward a Collaboration Model for Smart Spaces. In *Proceedings of the Third International Workshop on Software Engineering for Sensor Network Applications (SESENA '12)*. IEEE Press, 37–42.
- [14] Christian Crumlish and Erin Malone. 2009. *Designing social interfaces: Principles, patterns, and practices for improving the user experience*. O'Reilly, Sebastopol, CA, USA.
- [15] Bernd Essmann and Thorsten Hampel. 2005. A Design Pattern for Mobile-distributed Knowledge Spaces. In *Proceedings of the 2005 Symposia on Metainformatics (MIS '05)*. ACM, New York, NY, USA. <https://doi.org/10.1145/1234324.1234327>
- [16] Patrick Tobias Fischer and Eva Hornecker. 2017. *Creating Shared Encounters Through Fixed and Movable Interfaces*. Springer Singapore, Singapore, 163–185. [https://doi.org/10.1007/978-981-10-1962-3\\_8](https://doi.org/10.1007/978-981-10-1962-3_8)
- [17] Paul M. Fitts. 1954. The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology* 47, 6 (1954), 381–391. <https://doi.org/10.1037/h0055392>
- [18] Sebastien Gambs, Marc-Olivier Killijian, Matthieu Roy, and Moussa Traore. 2012. Locanym: Towards Privacy-Preserving Location-Based Services. In *Proceedings of the 1st European Workshop on Approaches to MObiquitous Resilience (ARMOR '12)*. Association for Computing Machinery, New York, NY, USA. <https://doi.org/10.1145/2222436.2222437>
- [19] Saul Greenberg and Carl Gutwin. 2016. Implications of We-Awareness to the Design of Distributed Groupware Tools. *Computer-Supported Cooperative Work* 25, 4-5 (2016), 279–293.
- [20] Richard N. Griffiths and Lyn Pemberton. 1998. Teaching Usability Design Through Pattern Language. <http://www.it.bton.ac.uk/staff/lp22/CHIpaper.html>
- [21] Jonathan Grudin. 1994. Computer-Supported Cooperative Work: History and Focus. *IEEE Computer* 27, 5 (1994), 19–26.
- [22] Carl Gutwin and Saul Greenberg. 1996. Workspace Awareness for Groupware. In *Conference Companion on Human Factors in Computing Systems (CHI '96)*. ACM, New York, NY, USA, 208–209. <https://doi.org/10.1145/257089.257284>
- [23] Carl Gutwin and Saul Greenberg. 2002. A Descriptive Framework of Workspace Awareness for Real-Time Groupware. *Comput. Supported Coop. Work* 11, 3 (2002), 411–446. <https://doi.org/10.1023/A:1021271517844>
- [24] Trine Heinemann and Robb Mitchell. 2014. Breaching Barriers to Collaboration in Public Spaces. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction (TEI '14)*. Association for Computing Machinery, New York, NY, USA, 213–220. <https://doi.org/10.1145/2540930.2540951>
- [25] Eva Hornecker and Jacob Buur. 2006. Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06)*. Association for Computing Machinery, New York, NY, USA, 437–446. <https://doi.org/10.1145/1124772.1124838>
- [26] Hans-Christian Jetter, Harald Reiterer, and Florian Geyer. 2014. Blended Interaction: Understanding Natural Human—Computer Interaction in Post-WIMP Interactive Spaces. *Personal Ubiquitous Comput.* 18, 5 (2014), 1139–1158. <https://doi.org/10.1007/s00779-013-0725-4>
- [27] Shunichi Kasahara, Valentin Heun, Austin S Lee, and Hiroshi Ishii. 2012. Second Surface: Multi-User Spatial Collaboration System Based on Augmented Reality. In *SIGGRAPH Asia 2012 Emerging Technologies (SA '12)*. Association for Computing Machinery, New York, NY, USA, 1–4. <https://doi.org/10.1145/2407707.2407727>
- [28] Daniel A Keim, Jörn Kohlhammer, Geoffrey Ellis, and Florian Mansmann. 2010. *Mastering The Information Age - Solving Problems with Visual Analytics*. Eurographics.
- [29] Qingkai Kong, Richard M Allen, Louis Schreier, and Young-Woo Kwon. 2016. MyShake: A smartphone seismic network for earthquake early warning and beyond. *Science Advances* 2, 2 (2016). <https://doi.org/10.1126/sciadv.1501055>
- [30] Christian Köppe. 2012. A Pattern Language for Teaching Design Patterns (Part 1). In *Proceedings of the 16th European Conference on Pattern Languages of Programs (EuroPLoP '11)*. ACM, New York, NY, USA, 2:1–2:21. <https://doi.org/10.1145/2396716.2396718>
- [31] Kostas Koukoulos, Babak Khazaei, Andy Dearden, and Mehmet Ozcan. 2009. Teaching Usability Principles with Patterns and Guidelines. In *Creativity and HCI: From Experience to Design in Education*, Paula Kotze, William Wong, Joaquim Jorge, Alan Dix, and Paula Alexandra Silva (Eds.). IFIP - International Federation for Information Processing, Vol. 289. Springer US, 159–174. [https://doi.org/10.1007/978-0-387-89022-7\\_11](https://doi.org/10.1007/978-0-387-89022-7_11)
- [32] Xiao Ma, Ross McLachlan, Donghun Lee, Mor Naaman, and Emily Sun. 2016. Movement: A Secure Community Awareness Application and Display. In *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion (CSCW '16 Companion)*. Association for Computing Machinery, New York, NY, USA, 106–109. <https://doi.org/10.1145/2818052.2874337>
- [33] Dominick Madden, Horst Schneider, and Kirstin Kohler. 2018. Multiscreen Patterns - Interactions Across the Borders of Devices. *i-com* 17, 1 (2018), 91–95.
- [34] Philippe Matherat and Marc-Thierry Jaekel. 2011. Relativistic Causality and Clockless Circuits. *J. Emerg. Technol. Comput. Syst.* 7, 4 (2011). <https://doi.org/10.1145/2043643.2043650>
- [35] A Mednis, G Strazdins, R Zviedris, G Kanonirs, and L Selavo. 2011. Real time pothole detection using Android smartphones with accelerometers. In *2011 International Conference on Distributed Computing in Sensor Systems and Workshops (DCOSS)*. 1–6. <https://doi.org/10.1109/DCOSS.2011.5982206>
- [36] Orna Muller, Bruria Haberman, and David Ginat. 2007. Pattern-Oriented Instruction and its Influence on Problem Decomposition and Solution Construction. In *Proceedings of the 12th annual SIGCSE conference on Innovation and technology in computer science education*. ACM, Dundee, 151–155. <https://doi.org/10.1145/1268784.1268830>
- [37] Andrés Neyem, Sergio F Ochoa, and José A Pino. 2008. Coordination Patterns to Support Mobile Collaboration BT - Groupware: Design, Implementation, and Use, Robert O Briggs, Pedro Antunes, Gert-Jan de Vreede, and Aaron S Read (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 248–265.
- [38] Andrés Neyem, Sergio F Ochoa, and José A Pino. 2009. Communication Patterns to Support Mobile Collaboration BT - Groupware: Design, Implementation, and Use, Luís Carriço, Nelson Balóian, and Benjamim Fonseca (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 270–277.

- [39] Andrés Neyem, Sergio F Ochoa, and José A Pino. 2011. A Patterns System to Coordinate Mobile Collaborative Applications. *Group Decision and Negotiation* 20, 5 (2011), 563–592. <https://doi.org/10.1007/s10726-011-9258-2>
- [40] Jörg Roth. 2002. Patterns of Mobile Interaction. *Personal and Ubiquitous Computing* 6, 4 (2002), 282–289. <https://doi.org/10.1007/s007790200029>
- [41] Birgit Schmitz, Roland Klemke, and Marcus Specht. 2012. Mobile Gaming Patterns and Their Impact on Learning Outcomes: A Literature Review. In *21st Century Learning for 21st Century Skills*, Andrew Ravenscroft, Stefanie Lindstaedt, Carlos Delgado Kloos, and Davinia Hernández-Leo (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 419–424.
- [42] Till Schümmer and Stephan Lukosch. 2007. *Patterns for computer-mediated interaction*. Wiley, Hoboken, NJ.
- [43] Christopher L Sidlar and Claus Rinner. 2009. Utility assessment of a map-based online geo-collaboration tool. *Journal of Environmental Management* 90, 6 (2009), 2020–2026. <https://doi.org/10.1016/j.jenvman.2007.08.030>
- [44] Simon and Weckert. 2020. The map is not the territory, but another version of reality. *Datenschleuder* 103 (2020), 0x26–0x2c.
- [45] Luke S Snyder, Morteza Karimzadeh, Ray Chen, and David S Ebert. 2019. City-Level Geolocation of Tweets for Real-Time Visual Analytics. In *Proceedings of the 3rd ACM SIGSPATIAL International Workshop on AI for Geographic Knowledge Discovery (GeoAI 2019)*, Association for Computing Machinery, New York, NY, USA, 85–88. <https://doi.org/10.1145/3356471.3365243>
- [46] Emily Sun. 2017. Leveraging Location Sharing to Increase Social Capital in Local Communities. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW '17 Companion)*, Association for Computing Machinery, New York, NY, USA, 97–100. <https://doi.org/10.1145/3022198.3024946>
- [47] Emily Sun, Ross McLachlan, and Mor Naaman. 2017. Move-Meant: Anonymously Building Community Through Shared Location Histories. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*, Association for Computing Machinery, New York, NY, USA, 4284–4289. <https://doi.org/10.1145/3025453.3025653>
- [48] Stephanie Teufel, Christian Sauter, Thomas Mühlherr, and Kurt Bauknecht. 1995. *Computerunterstützung für die Gruppenarbeit*. Addison-Wesley, Sebastopol.
- [49] Jenifer Tidwell. 2011. *Designing Interfaces – Patterns for Effective Interaction Design* (2 ed.). O'Reilly Media, Sebastopol. 576 pages.
- [50] W R Tobler. 1970. A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic Geography* 46 (sep 1970), 234–240. <https://doi.org/10.2307/143141>
- [51] Fernando Torre, S Andrew Sheppard, Reid Priedhorsky, and Loren Terveen. 2010. Bumpy, Caution with Merging: An Exploration of Tagging in a Geowiki. In *Proceedings of the 16th ACM International Conference on Supporting Group Work (GROUP '10)*, Association for Computing Machinery, New York, NY, USA, 155–164. <https://doi.org/10.1145/1880071.1880097>
- [52] Ting-Yu Wang, F Maxwell Harper, and Brent Hecht. 2014. Designing Better Location Fields in User Profiles. In *Proceedings of the 18th International Conference on Supporting Group Work (GROUP '14)*, Association for Computing Machinery, New York, NY, USA, 73–80. <https://doi.org/10.1145/2660398.2660424>
- [53] Max Wertheimer. 1964. *Produktives Denken*. Verlag Waldemar Kramer, Frankfurt/Main. 260 pages.
- [54] Anna Wu, Xiaolong Zhang, Gregorio Convertino, and John M Carroll. 2009. CIVIL: Support Geo-Collaboration with Information Visualization. In *Proceedings of the ACM 2009 International Conference on Supporting Group Work (GROUP '09)*, Association for Computing Machinery, New York, NY, USA, 273–276. <https://doi.org/10.1145/1531674.1531714>
- [55] Shanqi Zhang. 2019. Public participation in the Geoweb era: Defining a typology for geo-participation in local governments. *Cities* 85 (2019), 38–50. <https://doi.org/10.1016/j.cities.2018.12.004>
- [56] Gustavo Zurita and Nelson Baloian. 2012. Context, Patterns and Geo-collaboration to Support Situated Learning BT - Ubiquitous Computing and Ambient Intelligence, José Bravo, Diego López-de Ipiña, and Francisco Moya (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 503–511.

Received February 2019