

# CollaTrEx – Collaborative Context-Aware Mobile Training and Exploration

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**Abstract.** This paper introduces the CollaTrEx framework for collaborative context-aware mobile exploration and training. It is particularly designed for the in-situ collaboration within groups of learners performing together diverse educational activities to explore their environment in a fun and intuitive way.

Aside from employing both absolute and relative spatio-temporal context for determining the available activities, different buffering levels are an important conceptual feature supporting seamless collaboration in spite of temporary connection losses or when in remote areas.

CollaTrEx comprises a prototypical front-end implementation for tablet devices, as well as a web-based back-end solution for the creation and management of activities which can be easily extended to accommodate both future technologies and novel activity types.

**Keywords:** Collaborative learning · Context-awareness · Mobile learning · Location-based learning

## 1 Introduction

The proliferation of mobile devices equipped with a multitude of sensors as well as advanced recording and networking capabilities offers an enormous potential for educational applications. The advantages and opportunities of context-aware mobile learning are widely recognized [1], but modern smartphones, tablets or wearables with their GPS antennas, magnetometers and gyroscopes, not only allow for establishing precise spatio-temporal context. Their multi-touch screens, high-resolution cameras and microphones, together with the support of various long- and short-range network protocols, call for increased interactivity and collaboration. However, instead of harnessing these capabilities to full effect for a genuinely collaborative and interactive mobile learning experience, they are often left unexploited.

In this paper we introduce CollaTrEx, an integrated framework for collaborative context-aware mobile exploration and training with a focus on the in-situ

collaboration within groups of learners engaging in varied educational activities. Single-user mobile learning scenarios as subclasses of the corresponding, collaborative cases are inherently supported, as well.

To determine which activities are available and to provide a tailored experience both for leisure and academic settings, absolute and relative spatio-temporal context is employed. Furthermore, the framework supports different on- and offline modes and buffering strategies as, in particular in remote areas, the necessary infrastructure or proximity between groups of learners cannot always be assumed.

We will discuss the core conceptual design underlying the framework in the next section. Section 3 then introduces the general architecture of the CollaTrEx prototype system and details both the back end as well as the iOS-based tablet application. To further contextualize our approach, we will discuss related work in Sect. 4 before concluding with a summary and outlook on potential research directions and future developments.

## 2 Conceptual Design

The CollaTrEx framework integrates the two paradigms of situated learning [2, 3] and collaborative learning [4], thus combining context-aware, experiential and social factors. Its prime focus is on intra-group cooperative aspects, i.e., support for active in-situ collaboration within groups of learners exploring their environment. The diverse activities are designed to accommodate various age levels and content ranging from basic, e.g., for city guides or sightseeing, to academic, as for instance in the outdoor collaborative scenarios classified in [5].

In the following, we will outline the key conceptual elements of context, activity and the different buffering levels that form the basis of the suggested architecture and implementation.

### 2.1 Context

CollaTrEx relies on establishing absolute and relative spatio-temporal context to provide users with different activities. Before detailing these in Sect. 2.2, we first introduce the individual context types which are employed in varying combinations to determine which activities are available at a certain stage.

**Location.** The *absolute position* of users is the central factor in providing location-based information. Location data can be either a single point of interest (PoI), or a larger area of interest (AoI), optionally together with the orientation.

**Proximity.** While clearly related to location, the *relative position*, i.e., distance between two or more groups of users, can be a crucial contextual factor and necessary precondition for certain activity types involving inter-group cooperation.

**Time.** Aside from the spatial dimension, the temporal context plays an important role, i.e., certain activities are only available at certain points in time or during specific periods of time. Allowing for activities that are defined only for an *absolute time* frame during a day, week, month or year is particularly interesting for long-term exploration or finer-grained, choreographed experiences.

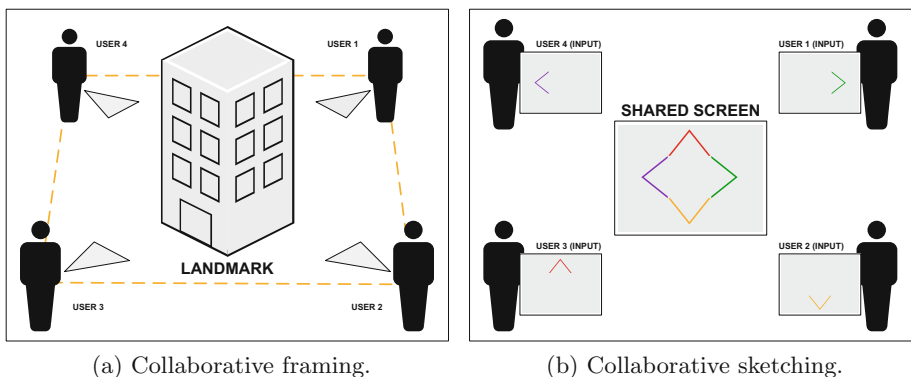
**History.** Similar to how location and proximity relate, time and history differ in that they reflect absolute and *relative time*, respectively. History comprises preceding events and previous achievements which might be necessary preconditions for coherent activity sequences.

As discussed in Sect. 1, modern mobile devices already provide all relevant features for establishing such spatio-temporal context with a high accuracy.

## 2.2 Activities

The central element in the CollaTrEx framework are the various activities which users can perform depending on their situational context. While the focus is on active group collaboration, single-user mobile learning scenarios are inherently supported, as well; they mostly constitute simpler subclasses of the corresponding collaborative activities.

The individual activity types can be easily combined, as for instance in the image capturing example introduced in Sect. 3.2, and the definition of activity sequences constituting of several subactivities is facilitated by the overall modular approach. It also allows for creating further activity types, in particular with regard to varying use cases and technological progress. The following list therefore is not comprehensive but intended to give an overview of the current activity types.



**Fig. 1.** Two examples of basic activity types involving a group of four users.

**Field Recording.** Exploring their environment, users make audio-visual recordings (i.e., sounds or videos, but also still images) of particular objects or places.

**Sketching.** While it might also be utilised for recording some part of the environment, the sketching activity goes beyond that inasmuch as the users employ their devices to create an aggregate drawing on a single digital canvas together, as illustrated in Fig. 1b.

**Object Interaction.** In the simplest case, objects (both virtual or real) are collected, dropped or just marked at a specific location (PoI or AoI). The objects or object markers are kept in an inventory that allows further interaction, such as to trade, distribute or even combine them in between the members of a group.

**Quiz.** A question which, in the collaborative case, might for instance pass an automatic majority voting process before evaluation. A competitive mode, where a winner is determined from the group after a series of questions, is also possible.

**Puzzle.** The construction (or reconstruction) of a fragmented object by users on a (shared) screen, where the pieces might need to be collected first. The object can be not only an image, but any kind of media or audio-visual content.

**Framing.** Mostly used in combination with other activities, framing requires the members of a group to position themselves with correct orientation around an object or location. Figure 1a exemplifies this with a regular shape defining the area around a landmark building. However, that can be a complex polygon necessitating more users. The object can also be virtual.

These types can be combined and sequenced into dynamic, context-aware activities, such as to find and mark all occurrences of an object within a certain area, fast-paced races, paperchases and so on.

Albeit in certain, simpler cases individual data can be transmitted directly to a server, one user generally aggregates the result for the group to store and forward it. This is both for concentrating load in the ad-hoc network instead of other more costly connections, as well as for resilience to network failures.

### 2.3 Buffering Levels

In order to provide a high degree of flexibility, CollaTrEx offers several buffering strategies on both global, i.e., web-based, and local, i.e., ad-hoc, network level. The rationale behind this is two-fold: on the one hand, connection losses should not hamper the seamless experience; on the other hand, supporting advanced collaboration in remote locations without permanent or sufficient connectivity is an explicit design requirement for the framework, which is particularly relevant in connection with academic education (e.g., field trips in geography).

### 3 The CollaTrEx Prototype System

We have built a prototype system that comprises a front-end implementation for iOS-based tablet devices and a web-based back-end solution for the provision, management and creation of the various activities. The paramount goal was to design a generic, yet simple architecture that allows for easily incorporating extensions to accommodate both new types of activities and future technologies.

#### 3.1 Back End

Recent advances in cloud computing allow for the rapid development and deployment of web applications and services using a platform-as-a-service (PaaS) approach. A clearly discernible, related trend is an API-first strategy that makes use of the HTTP protocol with a RESTful URI design and JSON-encoded messages to provide a single unified entry point for clients and third parties.

Due to its flexibility, effectiveness and reduced complexity, we chose to follow this approach and implemented a web service based on a relational database which provides a RESTful API for fetching the necessary information. The service itself is written in Python using Django and the Django REST Framework which particularly accelerate the development of all CRUD (Create, Read, Update, Delete) operations.

Underlying the back end solution is a PostgreSQL database which, similarly to other database systems, also supports certain location-specific data types via a plug-in mechanism. Many non-relational or NoSQL databases furthermore permit more elaborate location-specific queries. However, in order to maintain full control over the implementation, we store location information such as latitude, longitude, altitude, and heading individually. Furthermore, static and dynamic database entities are distinguished which leads to more purposeful caching while optimizing bandwidth utilization.

Most web-based applications are developed on a single, monolithic code base which, with growing requirements and feature sets, becomes increasingly challenging to maintain over time. Also, to be able to accommodate arbitrary activity types, the system requires an essentially technology-agnostic architecture.

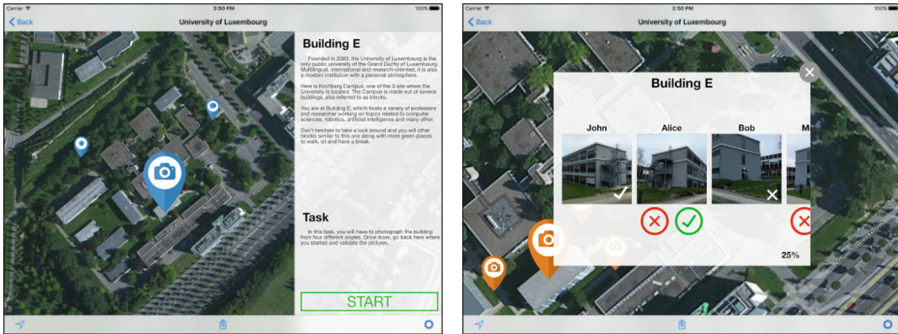
To address the associated long-term complexity and provide the flexibility and scalability needed, we propose a microservice architecture instead which decouples each activity into a separate service with its own database and technology stack scaling independently from others. This allows for efficiently handling any type of activity, as well as large variations in their popularity, i.e., easily scaling also with the changing demand for specific activities.

#### 3.2 Front End/Tablet Application

The tablet application prototype is a native iOS app written entirely in the Swift programming language. It provides a minimal, yet intuitive user interface that focuses on the essential to support an effective learning experience, in particular with regard to exploration and collaboration aspects.

The central element is a map view where, aside from indicating the users' position, the different PoIs linked to the various activities are marked by pins with activity-specific symbols. These pins are colour-coded to reflect the activity status, e.g., blue (available), orange (ongoing), red (failed), green (completed), or grey (yet unavailable). Currently, Apple Maps data is employed in the background, but also alternative providers such as OpenStreetMap or Google Maps can be used for the map overlays.

Figure 2 comprises two screenshots of the application, showing part of the University of Luxembourg's Kirchberg campus with the available or ongoing activities. The navigation bar at the top and the tool bar at the bottom provide quick access to the history, the list of available activities and important settings.



(a) Map screen with a selected PoI and an overview of the concomitant activity. (b) Master screen (aggregation step) of the collaborative image capturing activity.

**Fig. 2.** Exemplary screenshots of the native, iOS-based tablet application. (Color figure online)

In Fig. 2a, three different activities are available of which one – a collaborative image capturing activity symbolized by the camera icon – is selected. This is done by tapping on the respective pin, which is then enlarged while a semi-transparent view slides in from the right to reveal the details about the selected activity. A swipe gesture to the right clears the view and places the focus back on the map.

The screenshot in Fig. 2b shows the aggregation step of the collaborative image capturing activity, which is a hybrid of the framing and field recording activities introduced in Sect. 2.2. The users John, Alice, Bob etc. have all taken and transmitted their pictures of the E building from various assigned positions and angles around the structure, and now the head of the group validates or rejects the images before the activity can be completed.

In case of connection issues, the buffering techniques described in Sect. 2.3 are employed and the aggregation step is postponed. Generally, the ad-hoc communication is handled via the Multipeer Connectivity Framework, but also the web-based back-end solution can be utilized for synchronizing the data.

## 4 Related Approaches

Mobile, ubiquitous or pervasive learning have gained serious momentum with the ever-increasing number of smart mobile devices, and many corresponding approaches have been proposed in recent years. However, explicit collaboration aspects are mostly related to the creation of content for later playback and sharing, not to in-situ collaborative activities as part of an experience or narrative.

The Seek‘N’Share [6] platform for collaborative mobile learning, for instance, superficially bears a resemblance to our framework, but there are fundamental differences in the underlying objectives and their implementation. Notably, it is less process- but submission-oriented; the individual learners gather material in single-user scenarios, and the actual collaboration concentrates on a final documentation step where the learning outcomes are summarized in a common presentation. As an entirely web-based platform, Seek‘N’Share furthermore does not target offline or remote exploration scenarios.

The framework for locative media experience developed within the SHARC project<sup>1</sup> provides an offline mode for its SMEP player, but direct collaboration is also limited to the distributed authoring aspect [7].

Similar location-based educational narratives can be generated using platforms such as the University of Wisconsin-Madison’s ARIS<sup>2</sup> or the Massachusetts Institute of Technology’s TaleBlazer<sup>3</sup> which focus on augmented reality games.

Another recent platform that supports the collaborative authoring of location-based content is Wandering [8]. It allows for generating interactive learning objects which can, e.g., contain questions that need to be answered in writing or by sending an image related to that specific location, similar to the single-user variants of the quiz or field recording activities discussed in Sect. 2.2.

Elements of the collaborative activity types introduced there can be found in some less research-oriented or commercial products which are mostly non-educational games, i.e., serving entertainment purposes only.

Geocaching<sup>4</sup>, while resembling a treasure hunt, already involves direct object interaction and trade going beyond standard capture-the-flag game semantics.

In particular Niantic Labs’ alternate reality game Ingress<sup>5</sup> includes some interesting aspects with regard to object interaction. For instance, the players can link three virtual so-called portals together in order to create triangular fields and claim control over the resulting, fenced geographic region. Albeit based on a simple convex polygon, this mechanism is comparable to our framing activity.

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<sup>1</sup> <http://thesharcproject.wordpress.com/>.

<sup>2</sup> <http://www.arisgames.org/>.

<sup>3</sup> <http://www.taleblazer.org/>.

<sup>4</sup> <http://www.geocaching.com/>.

<sup>5</sup> <http://www.ingress.com/>.

## 5 Conclusion and Perspectives

We have presented the CollaTrEx framework for collaborative context-aware mobile training and exploration, focusing on collaborative activities performed in situ for a more engaging educational experience.

The framework currently comprises an easily extendable web-based back end for the management and creation of the various activities, as well as a simple-to-use iOS-based client application prototype for tablets. To determine the available activities and provide a tailored experience, absolute and relative spatio-temporal context is employed. Furthermore, the CollaTrEx framework offers several buffering levels for seamlessness and an increased flexibility with regards to connection losses, in particular when in remote areas.

Aside from the obvious refining of features, such as providing enhanced tool support for editing and online supervision, different map extensions or additional activity types, there are various potential directions to develop CollaTrEx further. For example, while not the focus of the framework, integrating the explicit creation of learning materials is an interesting option. Also image recognition techniques, as employed in recent augmented reality systems [9], might be worthwhile for establishing an even finer-grained context.

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