CO3: Digital Disruptive Technologies to Co-create, Co-produce and Co-manage Open Public Services along with Citizens

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# D3.4
# Final release of CO3 technological prototypes

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| **Dissemination Level** | | |
|---|---|---|
| PU | Public | x |
| PP | Restricted to other programme participants (including the Commission Services) | |
| RE | Restricted to a group specified by the consortium (including the Commission Services) | |
| CO | Confidential, only for members of the consortium (including the Commission Services) | |

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# Table of Contents

# 1. Management Summary

CO3 is about the evaluation of risks and benefits of five disruptive technologies: Distributed Ledger Technology, Map-based Citizen Networks, Interactive Democracy, Augmented Reality, and Gamification. The evaluation of the technologies is based on pilot implementations in an online platform. The context of the evaluation is the co-creation, co-production and co-management of public services by citizens as partners of Public Administrations.

The main development of the CO3 platform was completed with work package 2 in December 2020. Throughout the year 2021 Task 3.3 continued the development foreseen as iterative improvements based on feedback from the pilot sites leading to the final release of the CO3 platform prototype in December 2021. This document accompanies the final prototype of the CO3 platform.

The previous deliverables D2.1, D2.2, and D2.3 give a chronological account of the development work and design decisions in great detail. In contrast, this document focuses on technological achievements. We elaborate on what we built on and what has been created during the course of the project. We also take previous recommendations by the reviewers–to the extent they refer to technical aspects or the role of the technical partners–into account.

The development fully adhered to the implementation specifications for the involved disruptive technologies specified in D2.1. Based on the agreed integration paradigms, the development of the components was organised in a modular way and coordinated by dedicated technical video conferences while the consortium as a whole has been informed about the progress in fortnightly video conferences. The COVID-19 pandemics had no impact on the main development timeline per se but partly changed the objectives: Originally the CO3 platform was to put emphasis on interactions in proximity. Consequently proof of presence was foreseen as a requirement for many transactions. The situation on the ground required an adjustment in such as to allow remote activities wherever useful. In order to not lose sight of the original aim and to enable the concept of augmented commoning areas (ACAs) for future applications such adjustments were done in a configurable way maintaining the originally foreseen control structures.

The iterative development of the CO3 platform was partly based on dry runs executed by pilot site staff members and during workshops, and–ever since the pilot start–actual input from pilot site users. During the first phase, numerous field tests in collaboration with the three pilot sites made it possible to detect problems and refine the platform components with respect to the real needs of the pilot sites following the perspective of the co-production and co-management of the project. Since the start of the pilots, feedback from pilot site users on their experience has been reported. The technical partners responded by incorporating the feedback into the development process.

This document takes off with a recap chapter on combining multiple disruptive technologies introducing the disruptive technologies and the respective applications, the idea of a modular platform with dual interfaces, as well as necessary supporting components. The main chapter highlights the technological achievements clustered by functionality across the platform. The next chapter elaborates on the design decisions. A sustainability focused outlook and a chapter on the software output of the project follow suit.

# 2. Five Disruptive Technologies - One Platform

## Applications and the technologies they implemented

The ***Civic Social Network FirstLife*** has been developed by the University of Turin. It constitutes a map-based citizen network. FirstLife, as other civic technologies, is oriented to be used as a coordination instrument by different stakeholders for sharing information about what has a public relevance at a local and city level for a plurality of people. However, it excludes contents related to the users' personal life, which instead are predominant in the most popular social networks. Moreover, as a crowdsourcing platform, FirstLife allows the collection of information from users, integrating it with heterogeneous data sources, such as open data and sensor inputs. The latter can contribute to build a richer informative environment, enabling the discovery of new insights about the city. The conceptual model offered by FirstLife is extremely flexible and allows the deployment of the platform in a wide range of scenarios. The modular infrastructure behind FirstLife, based on standard technologies and standard communication interfaces (like REST APIs) allows its easy integration with different components.

The ***Exchange System based on Blockchain*** is one of the entirely new CO3 modules and has been developed by Unit 8 in cooperation with the University of Turin. Blockchain technology is a ledger database distributed by and accessible to all the nodes of a peer-to-peer network, which serves as an irreversible and incorruptible archive of a continuously growing lists of transactions. The CO3 blockchain allows users to create Tokens, Vouchers, Coupons and interact with economical building blocks like Crowdsales and Coupon Boxes.

The ***Democracy Software LiquidFeedback*** facilitates decision-making and opinion formation by creating an innovative setting with a straightforward process for suggestions, initiatives, and competing alternatives within a transparent workflow. An open-source software that powers internet platforms, LiquidFeedback is a unique democracy software used by municipalities, political parties, social movements, associations, private organisations, and companies. It facilitates an integrated deliberation process to empower citizens, members, and employees to participate in democratic decisions important to their organisations. LiquidFeedback promotes democratic participation and self-organisation to redefine the future of society.

The ***Augmented Reality App*** is an entirely new CO3 module which has been designed and developed by Geomotion Games in collaboration with pilot partners. Augmented Reality (AR) is the experience of the environment where real world objects are enhanced by computer-generated information. AR can be largely implemented in many economic and social activities. In the scope of the CO3 project, the AR App is the primary access point to the Augmented Commoning Area (ACA), a key concept in the framework of CO3, which aims at condensing the overall complexity arising from the interplay between the objective of promoting widespread forms of co-creation, co-production and co-management of urban commons and public services.

The ***Gamification Engine*** is a newly developed layer for the platform. Gamification aims at stimulating the active participation and interest of users so as to reach certain predetermined objectives set by whomever employs this method. In the context of the CO3 platform, a cross

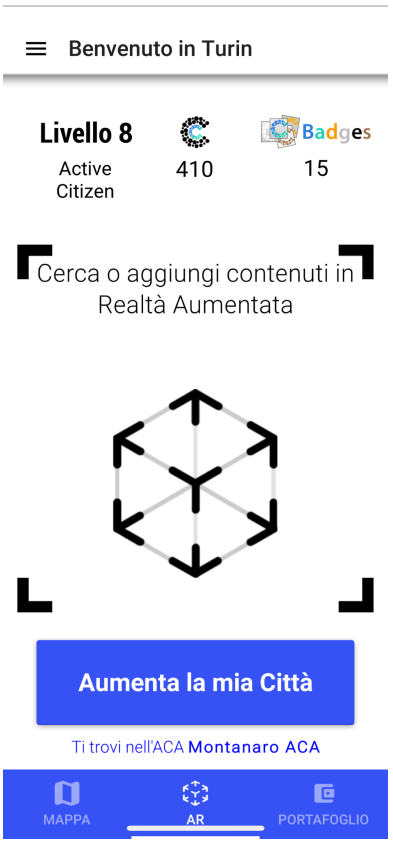
cutting gamification layer rewards participants with points, badges, as well as their resulting place in the leaderboard. The solution has been created in cooperation between LINKS and the University of Turin. The highly configurable gamification engine is part of the OnToMap data hub, which also serves as a supporting component for data integration between components.

## An open platform with a modular architecture

The CO3 platform is built based on independent applications using the following integration techniques: Deep-linking, view embedding and API calls. From the perspective of the user, the platform appears as highly integrated modules. The architecture will further be discussed in Chapter 5 in the context of sustainability beyond the scope of the project.

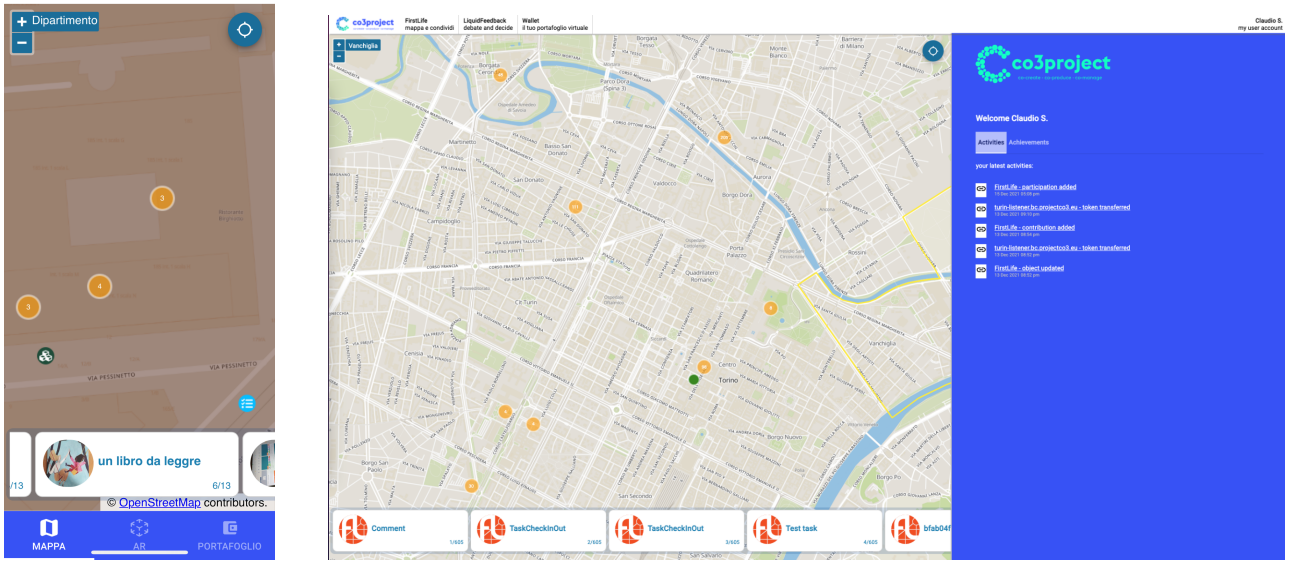
## Dual interface web based vs. mobile app

The focus of CO3 was to interweave the 5 disruptive technologies forming a uniform platform with a mobile app as the primary access point for users. However, a native Android and iOS mobile application that makes heavy use of visual elements and 3D augmentation is—by principle—subject to certain accessibility restrictions. While most people can use the mobile app very intuitively and will benefit from the deep augmentation which visually integrates virtual objects into the real space using 3D overlay technology, other people cannot access the platform due to technical or physical restrictions. For example, the 3D overlay technology requires modern smartphones, daylight as well as good eyesight and a high level of coordination.




Therefore, another access point for users has been made available. Users can alternatively access many of the platform features using a regular web browser on almost any internet enabled device, including a map-based user experience. This also makes the usage of widespread accessibility supporting technologies easier. Additionally, the mobile app includes a map that can be used with smartphones that do not support 3D technologies to navigate among entities.

Some administrative features, such as user management or reporting tasks, are exclusively available using the web browser taking into account that such tasks are regularly executed in office situations and require a lot of text input from a keyboard.




*mobile web view (left side) vs. desktop map view (right side)*

## Supporting components

To build a uniform platform combining the disruptive technologies, certain supporting components were needed. These components do not provide the disruptive technologies by themselves, but they help to “glue” everything together.

### CO3UUM

The CO3 Unified User Management (CO3UUM) provided by LiquidFeedback acts as an identity server. Other CO3 and third-party software may use the CO3UUM service to verify identities. This allows organisations or public administrations to build an extensible ecosystem of internet applications. The implementation supports role accounts for stakeholders, e.g. NGOs. The Unified User Management (CO3UUM) provides a Single-Sign-On. Logged in users are recognised by all applications which also allows a CO3 application to trigger actions in other applications. It also provides the meta navigation bar which is used by the web based components.

### OnToMap

This component supports semantic data interoperability among CO3 applications. Moreover, it offers a logging service that fuses the traces of user actions collected by the CO3 applications to provide a unified view of users’ behaviour. As such, OnToMap was the logical choice for adding a configurable Gamification engine that manages the attribution of rewardings to CO3 users based on their observed behaviour.

### LandingPage / AreaViewer / UserArea

The LandingPage is part of the desktop view. It allows access to CO3 with a web browser including mobile browsers. It also allows being more inclusive. The LandingPage has two main components:

- AreaViewer, a map-based view integrating information about the activities in the current instance of CO3. The activities reported in this component come from events collected by the OnToMap component. This component can be personalised and included in different applications for visualisation and navigation purposes.
- UserArea, a menu to collect direct links to the user's last activities in the different CO3 components.

The UserArea component also integrates the gamification engine user interface, allowing on one side the pilot administrators (those who belong to the gamification manager role) to personalise the gamification rules, and, on the other side, the citizen to explore collected badges and points.

### InputMap

The InputMap component provides embeddable and customizable map views for displaying information and entering geographic coordinates for creating geolocated entities in other components.

### FirstLife Tile Server

InputMap, AreaViewer, and the map components included in the mobile app require access to a common source of geographical data to render an interactive layer on a web map. In order to provide fast and standard access to web map components from all CO3 applications, a tile server developed and deployed by the FirstLife team is available.

The FirstLife TileServer provides geographical entities in vector tile format[1], an open source format widely used to provide vector tiles. The geographical data is based on OpenStreetMap. The TileServer is an ExpressJS application based on TileServerGL and different libraries and tools developed by Mapbox and OpenLayers communities.

### FirstLife Resource Server

FirstLife entities can be enriched with second-layer entities like comments, images, documents, polls, and the list of the tools is constantly growing. Within the CO3 project, a Resource Server has been implemented and integrated in FirstLife, the mobile app, and other CO3 components: it is able to store, process and expose multimedia content that users can use to enrich FirstLife entities. Supported content types include images, documents, 3D models, audio and video files. The resource server can store both personal and public files, and it is able to represent topic-based collections of resources.

[1]For specification, see: https://www.mapbox.com/vector-tiles/specification/

# 3. Technological Achievements

## Augmented discovery

The very basic feature of the CO3 platform is to discover virtual objects which are placed in the proximity of the user. This can be done using several levels of augmented reality. The deepest augmentation is the Augmented Reality 3D view, which visually overlays the real space captured by the user's smartphone camera with virtual objects. Other forms of augmented discovery include showing virtual objects on a map of the proximity of the user. The augmented discovery is the place where the disruptive technologies of the CO3 project come together and converge on the user's device. This functionality is built on top of OnToMap which acts as a central hub for collecting and exchanging geolocated object references between all CO3 applications.

**Creating an Augmented Reality Blockchain Coupon:**
https://www.youtube.com/watch?v=d8oX4OUkiXk

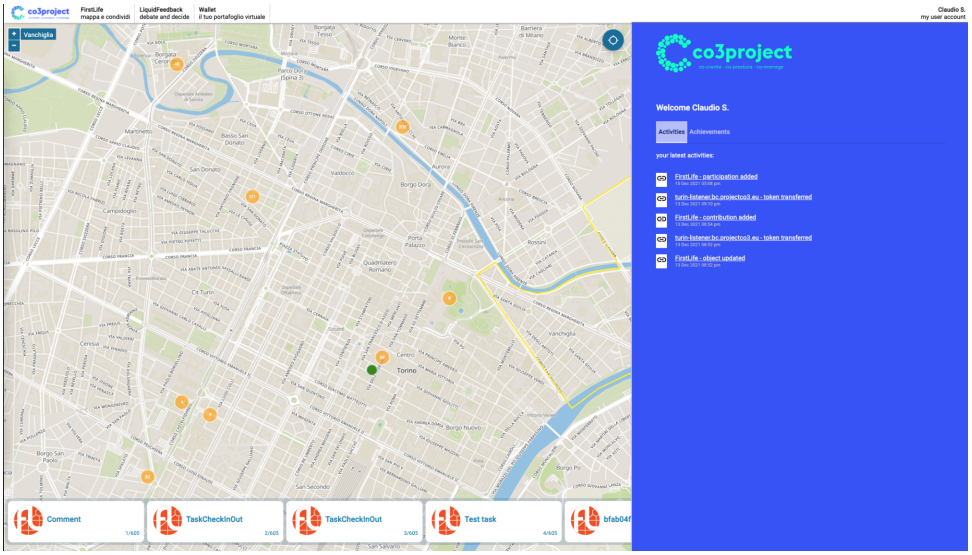
**Importing a 3D Augmented Reality model:**
https://www.youtube.com/watch?v=5PndNFNqswA

### View social interaction, deliberation and wallet objects in augmented reality

The user can discover 3D augmented reality objects that have social interaction, deliberation, or wallet activities attached. These content types originate from the respective components and are made available to the user through the CO3 App. The 3D objects appear in the AR camera view with an icon that has a link allowing the user to further interact with the content.

### Display geographical objects on landing page

The objects which can be discovered using the 3D augmented camera view can also be discovered using the 2D map view using any regular web browser. The virtual objects appear as an icon on the map with a link for further user interaction.

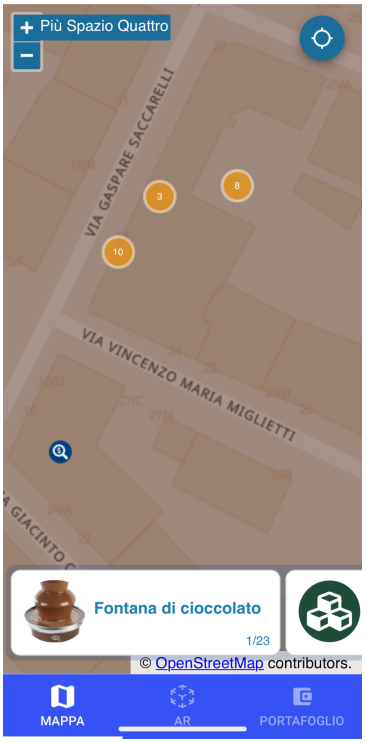


### Easy switch between different augmented views

Users can easily switch between different augmented views, namely between the 3D camera view and the 2D map view through the navigation menu on the CO3 App.

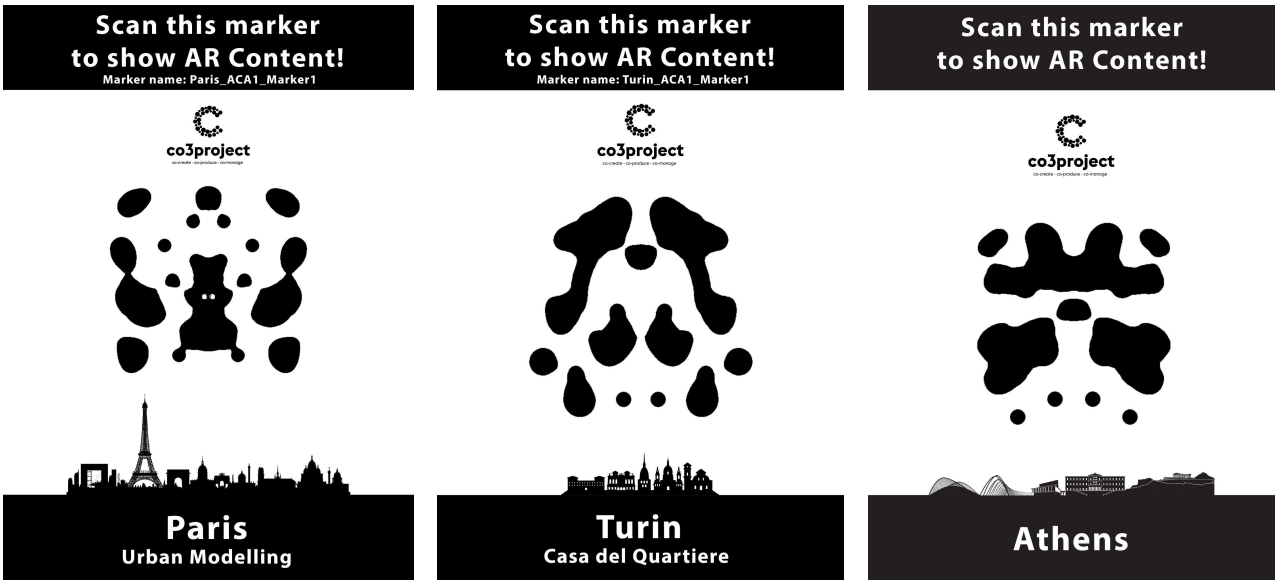
### The user can choose the range of its localization

Users are able to zoom in and zoom out according to their preference using the map included on the CO3 Mobile App. When too many objects are in the visible area, the icons will automatically be clustered and folded. This is needed to solve the information overloading problem providing the user clear information about the number of entities in a specific area. When viewing a cluster, the user can reveal the details of the entities it contains with a zoom-in operation.




### Marker for easy AR access

Augmented reality 3D objects can be anchored to real-life using AR Markers. Markers have been created especially for each pilot and can be placed in real-life environments.
When users scan the AR Marker with the CO3 AR App, the Augmented Reality 3D object is retrieved and shown on the smartphone screen allowing them to interact with the related activity.




*AR Markers created for each pilot*

### QR code reader

QR code integration mechanism to make transactions quicker and easier by beneficiaries.

Users are able to send transactions to other users and find them easily by scanning the QR code they can find in the section “receive transaction”. The QR code scanner can be found in the “send transaction” section by clicking on the menu button.

## Augmented mapping and content creation

To be able to discover the virtual objects in the proximity of the users, these must be placed first. The main interface for augmented mapping and content creation is the CO3 mobile app. Users may add several types of virtual objects and connect them with reality. This feature set makes extensive usage of features of FirstLife, LiquidFeedback and OntoMap as well as of the newly developed blockchain based features.

### Add virtual objects with augmented reality

The user can press the “Augment my city” button and then scan an AR Marker and add a new entity represented in the AR space by a 3D model. Considering the different artefacts represented in the three pilots, the user is able to add multimedia objects, 3D objects, collaboration objects (like tasks, activities, or deliberations), as well as blockchain based objects (like tokens, coupon boxes and crowdsales).

### Tag real-life objects

Virtual objects discussed in the previous section can be attached to real life objects using the CO3 Mobile App. This allows to tag objects in the real world with additional information in the virtual space creating the foundation for the Augmented Commoning Area (ACA).

### Geolocate a real-life object

All objects are automatically geolocated within a specific ACA, an area with boundaries already defined by the operators of the platform, e.g. a public administration, and represented internally as FirstLife entities, enabling a multimodal retrieval and interaction from the mobile app as well as from the web based version of the platform through all components of CO3.

### Drop and collect virtual blockchain objects

Users can drop different kinds of virtual objects through the CO3 Mobile App, e.g. coins or vouchers. Other users can find these virtual objects and pick them up. Users can store collected virtual objects in their personal wallet. This is achieved by deep links from the CO3 Mobile App into the wallets.

### Social interaction in augmented reality

Users can attach, and interact with, a FirstLife interaction called “Civic Collaboration”. A Civic Collaboration activity allows commenting, adding images, documents, and other attachments.

### Deliberation and voting in augmented reality

Users can create and interact with LiquidFeedback deliberations from within the augmented reality. Upon completion of a deliberation, they can also access the voting form to cast a ballot with their preferences.

### Interact with blockchain objects in augmented reality

Users can attach, and interact with, a Wallet/blockchain interaction to an AR 3D object through the CO3 AR App. While the CO3 AR App is attaching all necessary information to the objects to position them in the AR space, the CO3 Wallet is attaching functionality of the Exchange system based on Blockchain. For example Users can start positioning a Crowdsale in the AR Space and are then directed to the wallet to define which tokens they would like to collect and the set the duration of the campaign and so on.

## Area boundaries

Augmented Commoning Areas (ACAs) are defined by the space they occupy in the real world. Everything inside the boundaries of this space belongs to the augmented commoning area, and nothing can be outside this space.

### Define area boundaries

Geofence an area with a polygon (no bounding box approach). An ACA can be defined and designed by administrators as a polygon, by using the FirstLife web-based desktop version. The defined area is used together with geolocation to certify the presence of a user in a specific ACA and to limit the area in which FirstLife entities can be placed.

### Restrict mapping in an area/setup protected mapping

The user that is geolocated into an ACA is able to insert 3D AR contents only within the ACA boundaries. This can be done both from the mobile app (thanks to the proof-of-presence capability) and from the web version of the CO3 platform.

## Presence mapping

In the concept of the augmented commoning area, the creation of content shall only take place when the user is in the proximity of the location where the new content shall be linked to. This way, the augmented commoning area ensures that only the people actually using this area in reality are allowed to shape the virtual world connected with this space.

### Presence indicator

The CO3 mobile app provides information to other applications if a user is currently within the boundaries of an ACA to allow restricting actions to physical presence where required.

### Presence mapping

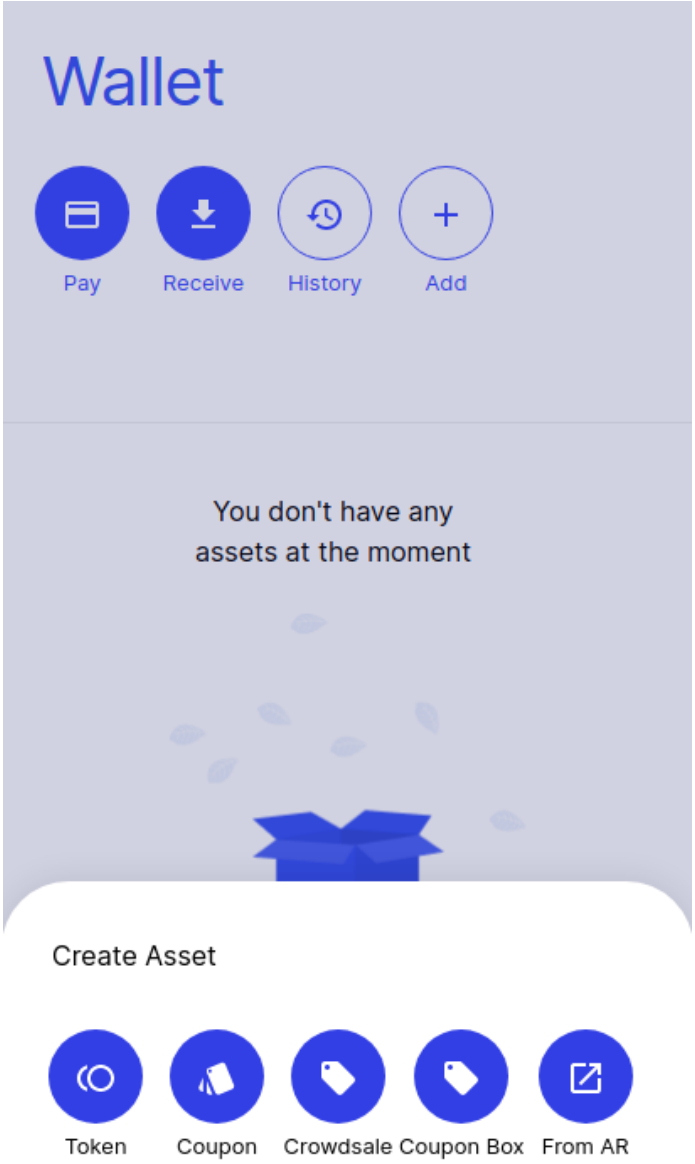
Creating an augmented reality 3D object using the mobile app is restricted to physical presence.

### Disabling Presence mapping

The previously discussed restriction of certain activities to physical presence can be waived by configuration of the ACA. This option has been added as a response to pandemics related restrictions. This decision will be further elaborated later on in this document.

## Personal wallet

The personal wallet is the interface for users to access and use the blockchain. This component has been developed from scratch for the specific needs of the augmented commoning area while having general usability in mind.




### Wallet creation

The user can create a wallet for storing tokens.

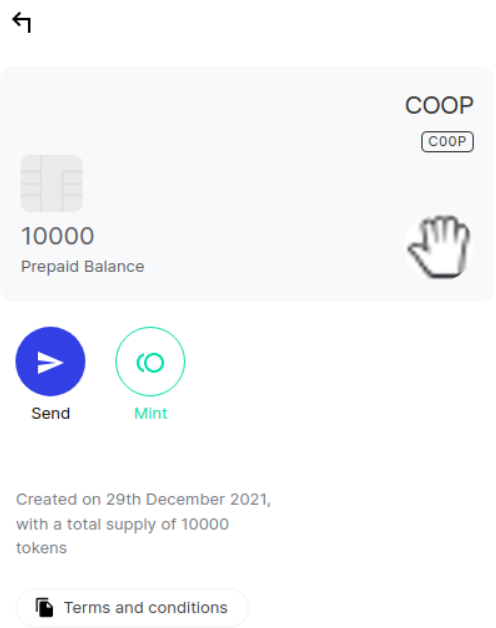
The user creates a new wallet and, for security reasons, users are prompted to back up the mnemonic immediately or import the mnemonic from an already existent wallet. If choosing the first option the wallet would be backed up and secured, if choosing the second option the already existing wallet would get imported, replacing the newly created one.

In addition, the blockchain account is registered in the centralised user management CO3UUM to establish a connection between the co3uum and blockchain-based account system. This enables UX improvements like search by CO3UUM name and similar features.

Each user has a role associated and each role has specific permissions associated. The permission to create coins, coupons, and crowdsales is available only for certain roles, whereas the permission to exchange coins or coupons and participate in crowdsales is available to anyone.

### User to user token transfer

Users can also use the wallet to transfer tokens to another user easily, by either scanning the QR code from the other user's device if both users are on the same location or, if the users interact remotely, by sharing the deep links connected to the user's QR code or by typing their names in the search field.




### Remote token transfer

Although the CO3 Wallet interface was originally designed to focus on physical interactions between users and in an augmented shared physical space, two types of remote token transfers were added.

1) Transfer request via Deep-Links

   In this case users can tab on their QR Code and send the deep link containing a sending request to another user using their preferred messaging infrastructure from emails to instant messengers. This method has the advantage that it is easier for users to verify the receiver because they know each other's email address, phone number or other identifiers in existing services.

2) Transfer via search by name

   Each CO3UUM Account has a public name associated, the wallet enables users to search for a public name and send assets directly. This method has the disadvantage that users have very little information to ensure the receiver is really the person they would like to address, other than the public name, but offers a high level of convenience for users who know each other's public names.

### Transaction history

Users are able to see the transactions they have made through the wallet, including the tokens sent and received. All the transactions are recorded and can be consulted in this list, in which the senders' address, timestamp, amount of tokens and token symbol are shown. If one transaction is clicked on the list, the disclosed details open up, including the name of the sender and receivers' address, in addition to the other details. The transaction history can be easily exported in an open format, edited and further processed.

### Creation of fungible and non fungible tokens

Both coins and coupons are represented as standard ERC20-compliant contracts; the difference between the two is the presence of decimals in the former and not in the latter. Coins are intended to model the behaviour of (complementary) currencies, while coupons are used to be digital twins

of atomic objects, like goods, or discount coupons. Issued tokens can be Standard or Mintable. Standard tokens are issued with a fixed supply that cannot be changed afterwards. Mintable tokens are, instead, issued with an initial supply of 0, and new tokens can be issued at a later stage by the creator of the token.

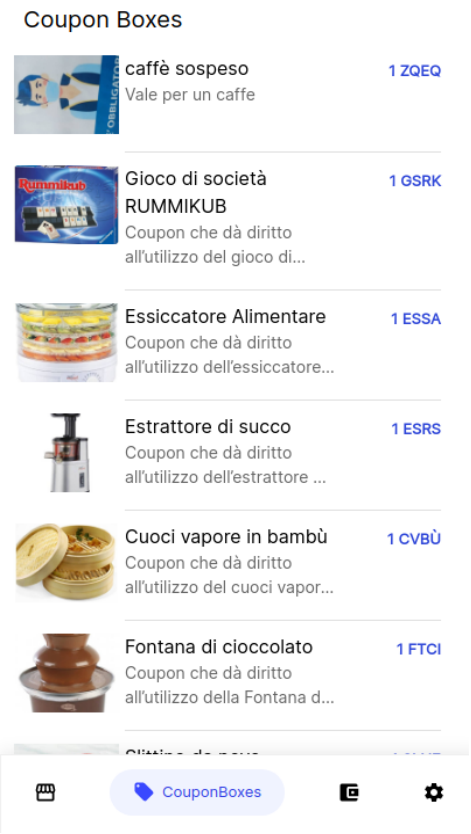
The users can purchase or get the coupons and with them get access to events, props or goods of different kinds. It is up to the creator of the coupon to decide what it is offered. The creator of the coupon needs a specific role assigned in order to do so. The created items are by nature decentralised but always associated with an ACA.

### Crowdsales

Crowsales sets coupons available to users upon purchase with the native coins created by users, e.g event organisers or local associations. Crowdsales offer a limited number of coupons for a set amount of token each. They set a goal of the coupons to be purchased in order to be considered "successful" and to allow the offered event to be carried out. In order to purchase the coupons the users need to own the native fungible tokens. They have to get those tokens from the event organisers prior to participating in the crowdsale. Any user can participate in the crowdsales but only the event organisers can create them.

### Coupon Boxes

Coupon Boxes offer coupons to the users without having to be bid on and not requiring a purchase through fungible tokens. The user can get the coupons either on the spot or remotely upon no specific requirement. The amount of coupons given through the coupon boxes is subject to the number available. The process of creating a coupon box is similar to the one of the crowdsale but no price or goal is required. Coupon boxes can be created in situ, scanning the location with the AR app or remotely directly from the wallet, adding all the details manually.




### Storage of private keys in the wallet

Upon opening the wallet for the first time the users are asked to enter the 12 word mnemonic seed in the given input fields. If the user does not have one then he/she can generate one using the UI interface. The mnemonic is used to generate the required private keys and serves to import the wallet. The wallet's content will also get imported when newly logging in.

### Recovery of lost private keys

If the private key is lost from the wallet the user can enter the mnemonic and then the wallet is able to recover the lost/deleted private keys.

### Import and export of wallet data

Users are able to import and export their wallet between devices by entering the 12 word mnemonic in the input fields available, right after logging into the wallet with their credentials. The new key is then updated and the already existent wallet can be used.

## Blockchain contracts

For decentralised systems based on blockchain technology, smart contracts contain the application and business logic defining the rules for economical interactions between the different participants.

### Crowdsale contract

The wallet allows users to set up a crowdsale and accept tokens using it. The wallet also allows other users to participate in the crowdsale. The creator of the crowdsale can use the wallet to set up logic for the crowdsale. A limit of coupons to be purchased has to be set and a coin has to be assigned for the coupon's purchase. The users need to own an enough amount of native coins in order to participate in the crowdsale.

### Vending machine contract

The vending machine contract allows the user to exchange b/w 1 pair of tokens. The VM Contracts provide a general exchange mechanism, allowing users to deploy an instance of the contract and define the exchange parameters. Usually the contract can be topped up with one kind of token, the exchange rate can be defined and which tokens are accepted as input.

### Pick-up contract

A special case of the vending machine contract are Coupon boxes where users don't require any input token but are only issued tokens for everybody who finds the box in the AR space or directly through the CO3 Wallet interface.

### Token & coupon contracts

Token contracts within the CO3 blockchain exchange system are used to represent coins and coupons. Both coins and coupons are represented as standard ERC20-compliant contracts, the difference between the two is the presence of decimals in the former and not in the latter. Coins are intended to model the behaviour of (complementary) currencies, while coupons are used to be digital twins of atomic objects, like goods, or discount coupons.

### Notification of contract setup

Possibility to notify users when a certain crowdfunding activity or campaign is launched.

# Blockchain middleware

While blockchain systems are optimised for storing data in a persistent and verifiable way, they are not very efficient for reading data or aggregating data. This leads often to a poor UX in systems based on blockchains, with slow user interfaces. To address these issues the CO3 project is using a middleware layer that serves as an aggregation layer for data stored in the blockchain system and can actively push data to other services like the gamification layer based on OnToMap. Main purpose of the middleware is to make blockchain based data more accessible for other applications of the CO3 platform.

## Blockchain GraphQL interface

The GraphQL interface allows querying account based blockchain data through a modern GraphQL interface, this empowers applications to specifically receive the data they need in their user interfaces.

## Blockchain REST API

In addition to the GraphQL interface, the middleware features access to the blockchain data through a more established REST API. While the GraphQL interface allows to minimise requests and data transmitted by allowing application specific data queries. The REST API has the advantage that many applications are already using other REST API and makes the integration easier, for other applications of the CO3 Platform, as well as 3rd party apps.

## Aggregation of blockchain data for augmentation, activity log and gamification

In addition to aggregation services, the middleware listens to blockchain-based events, like the deployment of a new contract or the interaction with existing contracts. Once the events are collected the relevant information can be forwarded to 3rd party applications like the gamification engine. The gamification engine is using the information to hand out new badges to users or send out notifications about achievements.

## Reflecting businesses updates in the blockchain

The aggregation layer is used by other components to query data about crowdsales or coupon boxes.

# Advanced deliberation and voting

## Use of blockchain tokens for deliberation and voting

Deliberation and voting can be done based on the amount of assets users are holding of a specific coin. Owning a specific type of coin means owning a corresponding part of a cooperative or company. Someone who owns the double amount of coins comes with the double amount of voting weight. This allows people to build virtual cooperatives or companies where the influence of the owners is defined by the shares they hold.

### Variable voting weight for deliberations and decisions

To support voting based on assets owned in the blockchain, deliberation and decision making in LiquidFeedback has been extended with a variable voting weight. Every user can have a different amount of influence on the outcome. Beneath the token based voting, this also enables the usage for organisations where participants regularly have different voting weights, e.g. joint stock companies or cooperatives.

### Deliberation and voting for augmented commoning areas

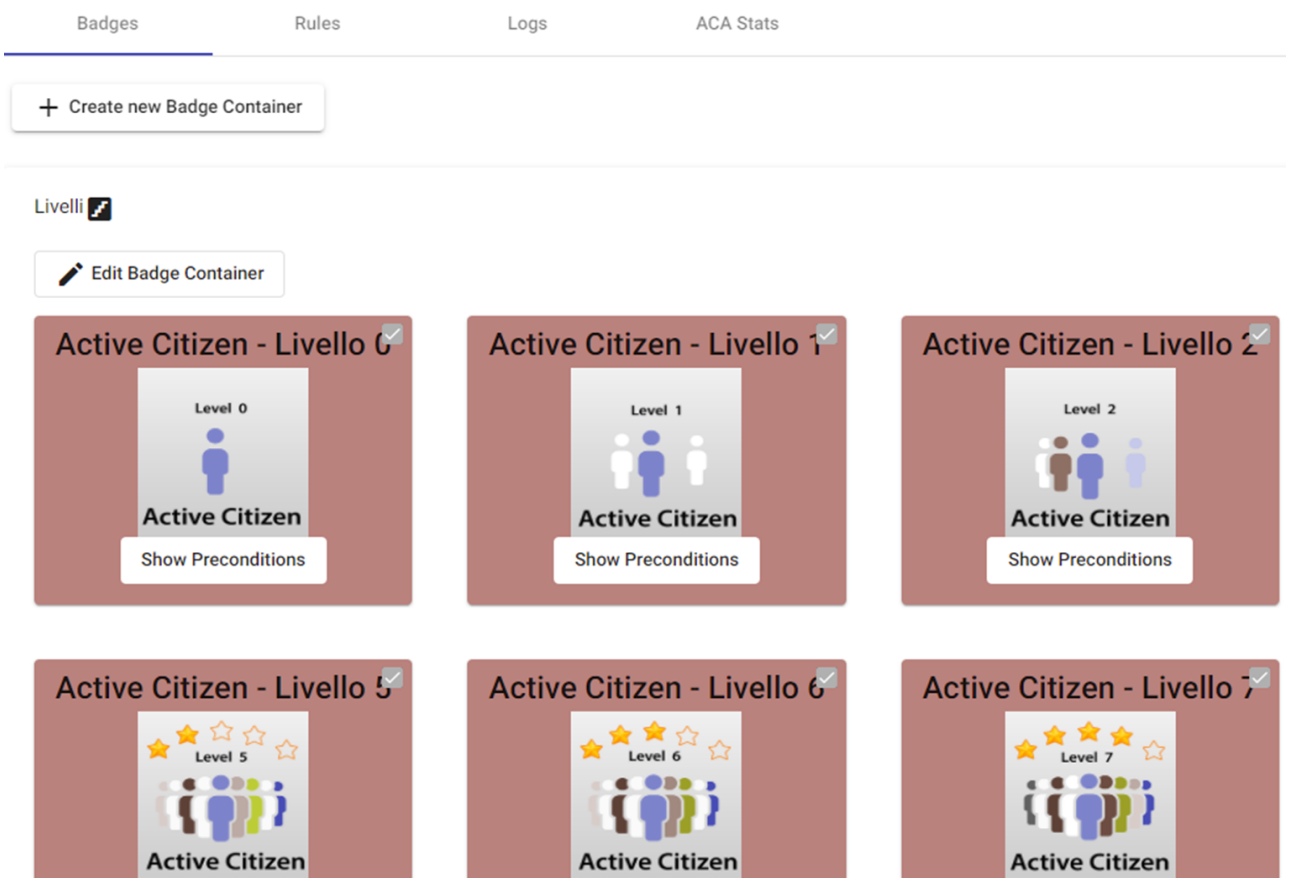
Whenever in CO3 a new augmented commoning area is created, an own space is created in LiquidFeedback for deliberation and decision making related to the matters of this augmented commoning area. Only people who joined the augmented commoning area are eligible to participate here.

### Deliberation and voting on geolocated objects

Decision making can also be connected to geolocated objects, i.e. an initiative can be attached to a virtual object (that in turn is connected to an object or a location in the real world).

## Gamification

Through gamification, citizens are accompanied and driven in their evolution from casual encounters to commoners, through several steps as visitors, fellow contributors and co-creators.



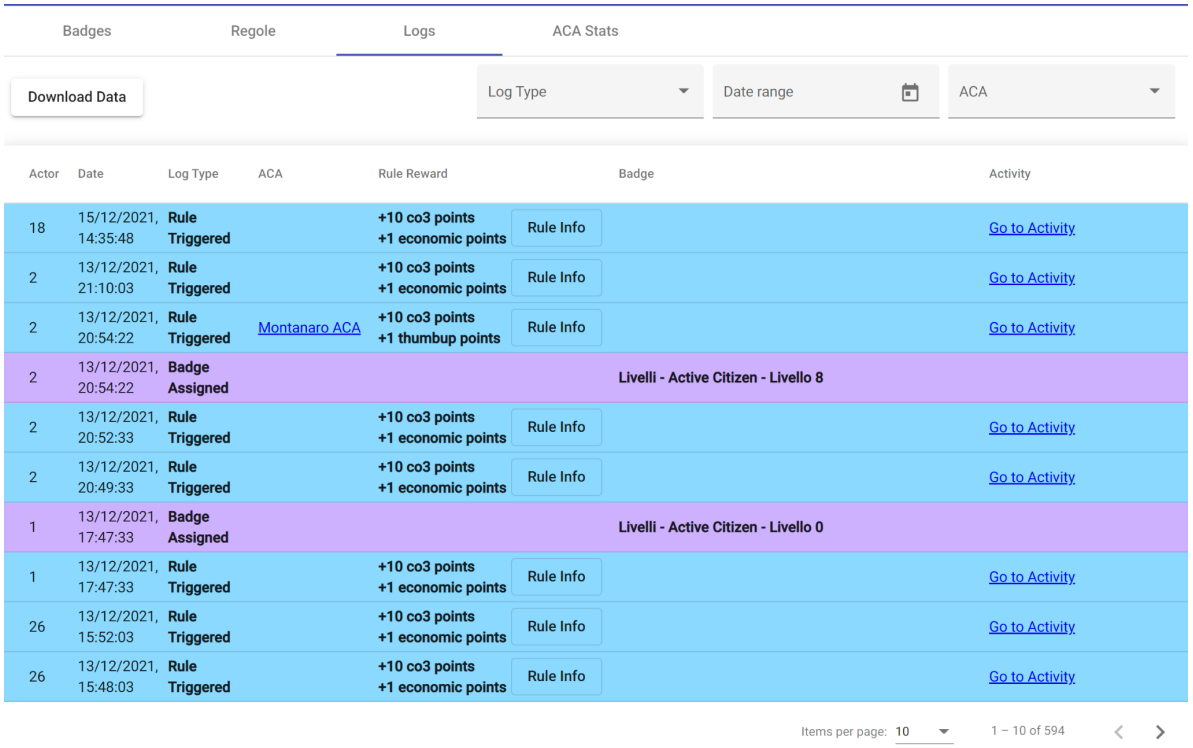
The Gamification Engine, through its dashboard for admins, allows a complete customization for pilots, so that pilot managers can co-design each aspect of the gamification, identifying

- the goals,
- the actions that will allow to achieve the goals,
- the intermediate objectives,
- the awards and their combination,
- the levels through which make the "journey" easier, and
- the thematic, metaphors and visuals to tie elements together.

## Gamification engine

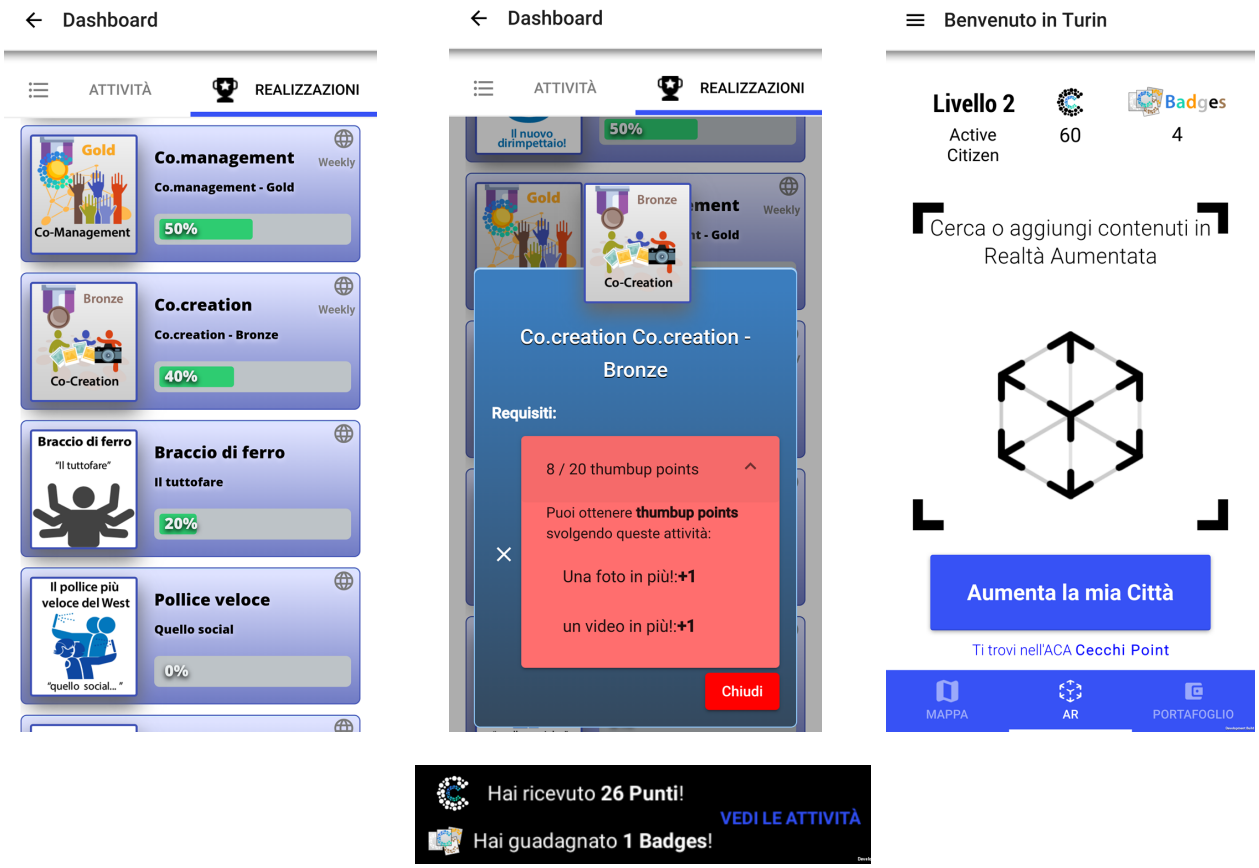
This component analyzes the user actions tracked within the CO3 platform to reward users with points and badges, depending on how active they are, as individual actors or as groups of people such as ACAs. The Gamification Engine is based on a declarative representation of reward policies, which are defined as condition-action rules and specify the types of action to be rewarded and how, in terms of badges and points. The novelty of the Gamification Engine is its configurability, which enables the pilot administrator to customise gamification rules: the gamification dashboard for administrators supports (through a web-based interface) both

- the monitoring of user achievements, and
- the specification and revision
    - of the conditions for applying rewards,
    - of their timing, and
    - of the type of award to be granted.
    - The Gamification Engine maintains a log that stores all the attributions of rewardings and can be inspected by the user for transparency purposes.



### Gamification visualisation in mobile app

The visualisation of the user's progression within the gamification is provided in the CO3 Mobile App through three means: at the completion of an activity that provides some rewards, a pop up alert informs the user of the new achievements; the upper part of the main screen always shows the user's current level and the amount of achieved CO3 points and badges; the dashboard section (accessible from the main menu in the upper left corner) allows the user to browse within all achievements and activity logs, and get all the details about the current status and how to progress into the gamification.




### Gamification information on the landing page

The visualisation of the user's progression within the gamification is provided also from the landing page of the CO3 website; once logged in, all the information available from the app (user's current level, total amount of achieved CO3 points and badges, and all the achievements and activity logs) are available also from the 'activities' and 'achievements' tabs in the blue area on the right side of the landing page.

## Multimedia content

To give the users a wide range of ways to express their ideas, the CO3 platform supports not only textual content but also various types of multimedia content.

### Attach a picture/photo to a real-life object

When users anchor an Augmented Reality 3D Object to a real-life object using the CO3 AR App they can take a picture and attach to it. The picture attached can help future users to find this AR 3D Object. Like a hint.

### Assign photo to geolocated objects

The user can upload a photo of a FirstLife object. The new object will be represented and can be retrieved both in the 2D map view as well as in the AR space

### Add comment to visual content

When the user of the CO3 AR App retrieves an Augmented Reality 3D Object inside an ACA, the related interactions are shown allowing them to add comments, deliberations or wallet transactions.

### Resource server

The resource server is able to store, process and expose multimedia content that users can use to enrich first-level entities. Supported content types include images, documents, 3D models, audio and video files. The resource server can store both personal and public files, and it is able to represent topic-based collections of resources.

## Activity log

### Aggregation of events

All components send an event stream to OntoMap. OntoMap provides semantic interoperability and serves as a cross platform catalogue. This also facilitates the augmented reality 3D view and the 2D map view.

### Activity log API

The OnToMap Logging Service manages a log of the user activities occurring within the CO3 platform by fusing the traces generated by the CO3 applications (e.g., block-chain, voting and crowdsourcing events) into a unified view that can be exploited to measure user engagement and activity within a pilot through the Gamification engine. The logger translates the information it receives to an interlingua format supporting the integration of heterogeneous data. Data interoperability is based on the specification of an ontology representing the types of data handled by the applications, and on mapping rules used to translate the information provided by applications to the interlingua format. This approach supports a seamless integration of new applications within the platform.

### Activity Log in the mobile app

Registered users in the CO3 AR App can see the history of all their activity through the Dashboard and the Activity Log. In it they can see all the interactions thanks to the integration with OntoMap.

### Activity Log on the LandingPage

The Landing Page shows events (interactions with all components) based on the data provided by OntoMap. In detail, the AreaViewer represents all the events in a map, while UserView allows the logged user to see the list of their actions, in all CO3 components.

## Single sign-on

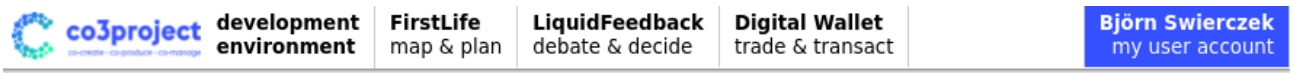
A single sign-on is crucial for the user's experience of an integrated platform. It would generate a lot of friction if the user had to log in again and again for each component. In CO3, the user is logged into all platform components at once. This also enables secure cross component use such as providing functionality from other components without additional logins to be performed by the user. Large parts of the user management software, including the user registration and accreditation module–called unified user management–were already existing as part of LiquidFeedback. The preexisting components of CO3 had already implemented the single sign-on functionality.

### All applications use single sign-on

Additionally, the single sign-on feature has been implemented in the Wallet and the mobile app. The latter makes extensive usage of the cross component authentication and authorization to access content and functionality from other components using the current user’s identity.

## Shared navigation bar

All web based components of the platform implemented a shared navigation bar provided by the single sign-on component. This creates a unified look and feel and provides direct access to the features enabled for a specific installation of the platform. The user account settings are always available from the top right corner of the screen.




## Groups and privileges

Not all activities on the platform shall be available for everyone, e.g. specific features are intended to be used only by official representatives of a municipality or by verified entities. To assign such

privileges, the already existing organisational units supported by the unified user management have been extended for use in CO3.

### Role groups

The organisational units have been extended in such a way that specific units can be marked as a role group. These groups are not visible for users but still can be used to attach privileges to a group of people.

### User-defined groups

Users can join and leave a self-defining group. These groups can be open or restricted by the approval of the group creator. Self-defining groups are fed into the global authorization scheme. Self-defined groups can be used the same way as authority defined groups for features requiring privileges such as voting rights.

### Platform wide availability of the groups

Role groups as well as authority and user-defined groups are available throughout the platform to allow applications to determine if a specific user is a member of a specific role group and therefore allowed to perform a certain activity on the platform. The required permissions can be defined per installation of the platform and feature.

# 4. Design Decisions

## Accessibility

In the early stages of the CO3 project, it has been discovered that there is a contradiction between a deep augmentation of virtual and real objects on one hand and a high level of accessibility on the other hand. This stems from the fact that a deep augmentation can be reached by visual augmentation. The most comprehensive way to present virtual objects as an overlay to the reality which is currently achievable is without doubt the camera based 3D augmentation using a smartphone. But this comes with two different types of restrictions in regard of accessibility:

- People need to have access to a modern smartphone capable of camera based 3D augmentation. This restriction will fade over time, as more and more old devices will be replaced by newer ones.
- People need several physical capabilities, in particular good eye-sight as well as a high level of mobility and coordination to be able to turn the device around to perceive the whole environment.

Less demanding than the 3D augmented views are 2D views using a map. Most user devices are already capable of displaying maps and people do not need to point the device around. Nevertheless, they still need good coordination to move and zoom the map and screen readers still have issues providing map based information.

The most accessible way to present augmented information is to simply show text content which is relevant to the surrounding, e.g. of a specific augmented commoning area. Nevertheless, the perceived level of augmentation is very low with this approach.

CO3 aims to support different levels of augmentation, which is reflected in the different interfaces offered to discover and interact with the same information set: The CO3 mobile app supports 3D and 2D views on mobile devices as well as the web interfaces additionally providing textual information on any device.

## Privacy

The concept of the augmented commoning area, the architecture of the CO3 platform and all CO3 components follow the privacy by design principle. The main technique to achieve privacy by design is to limit the collection and the processing of data to what is necessary for any given implemented functionality. We deliberately refrain from merging data from third-party sources or using unnoticed tracking methods. Data is only used for the purposes of the CO3 platform itself but not for anything else. All components and the platform as a whole are designed in such a way that it can be completely operated by the organisation using the platform, either by an internal IT department or with the help of external partners. This allows the organisation to fully control the data flow.

Data is only collected after the user gives an informed consent. Graduated deletion concepts allow to comply with requests from users or authorities to remove specific or all data regarding a user or a group of users. No references to persons are stored in the blockchain, as this technology–by principle–comes with certain limitations in terms of erasability. Instead, the connection of blockchain activities to persons is stored only in the CO3UUM component which allows to delete these references whenever needed by the operating organisation.

## Security

Security is woven into the architecture of the CO3 ecosystem. Any communication between CO3 components is encrypted with state of the art cryptography using industrial standard procedures. Furthermore, data exchange between CO3 components requires authentication, either by the user or component initiating the data transfer or by both depending on the nature of the data exchange. Authentication is implemented with strong cryptography and using procedures which have been tested and proven in the field for several years. User passwords are stored after encrypting with state of the art cryptographic procedures.

## Presence vs. remote

In the beginning of the second year of the project, we faced the challenges arising from the COVID-19 pandemics. We quickly realized that one of the main paradigms of the project was in conflict with the physical restrictions applied by all countries: The requirement to be in presence to add content to the virtual environment corresponding to the real space. To overcome these intended limitations while maintaining the advantages of it, it has been decided to make some features optionally available without presence. This can be configured and changed over time to reflect changes in the situation.

## Blockchain proof of authority

The CO3 project blockchain is based on a Proof-of-Authority (PoA) consensus. The user has a role assigned and based on this role the permissions will change. Regular users won't be able to add nodes whether administrators and beneficiaries (pre-authorized nodes) will be able to create and add new blocks to the chain.

# 5. Sustainability Beyond the Scope of the Project

## Modular architecture

The main technical strategy to ensure sustainability of the software developed during the project is the modular architecture of the platform. Each component of the platform has its own purpose and can be exploited standalone or with a subset of the other platform components. Since only one developer team is responsible for one component, the dependencies between different organisations could be reduced. At the same time, each developer team and their respective organisation can profit from maintaining and extending their components in the future. Thanks to the standardisation of the interfaces, it is still easy to bring all components back together in joint projects. We believe this kind of cooperation brings a European spirit into software development.

## Open standards

The CO3 platform as well as every component consistently make use of open standards. Particular attention was paid to ensuring that the standards used are not covered by patents and can be freely used. Standards used for communication between components of the CO3 platform are HTTPS, TLS, REST, GraphQL, and JSON. Distributed authentication and authorization is done by implementing OAuth2. Using open standards contributes to the sustainability beyond the end of the projects as it allows recombining the components more easily with other software and it increases the maintainability by technicians not involved in the creation of the software.

## Open source

All components of the CO3 platform are published with a permissive open source licence, i.e. MIT- or BSD-licence. By deliberately avoiding viral licences like the GPL, a very high level of exploitability for a wide variety of scenarios is enabled and licence conflicts while merging with other software are minimised to the extent possible. The complete list of all released CO3 components with the corresponding download sources can be found in the following chapter.

## Exploitation plan

The modular architecture of the CO3 platform is also reflected by the exploitation plan which foresees several combinations of CO3 components for practical application. Depending on the requirements of a specific scenario, a subset of components can be chosen.

# 6. Software Components and Documentation

## FirstLife

FirstLife allows users to interact with a map by searching in a specific area, creating entities and enriching them by adding comments, descriptions and images.

Main information page:
https://firstlife.gitlab.io/co3/

Installation instructions:
https://gitlab.di.unito.it/co3-project/frontend

Source code:
https://gitlab.di.unito.it/co3-project/frontend

## Blockchain Exchange System

The exchange system based on blockchain allows the creation and facilitates the use of tokens, coupons and exchange mechanisms to enable co-creation, co-production and co-management.

Installation instructions:
https://github.com/apeunit/co3-wallet/blob/master/README.md

Source code:
https://github.com/apeunit/co3-wallet

Software dependencies:
https://github.com/apeunit/co3-wallet/blob/master/package.json

Licensing information:
https://github.com/apeunit/co3-wallet/blob/master/LICENSE

## LiquidFeedback

LiquidFeedback powers internet platforms for proposition development and decision making.

Main information page:
https://liquidfeedback.org/

Project homepage:
https://www.public-software-group.org/liquid_feedback

Installation instructions:
https://www.public-software-group.org/mercurial/liquid_feedback_frontend/file/tip/INSTALL.html

Source code (Core):
https://www.public-software-group.org/mercurial/liquid_feedback_core

Source code (Frontend):
https://www.public-software-group.org/mercurial/liquid_feedback_frontend

Software dependencies (Core):
https://www.public-software-group.org/liquid_feedback_core

Software dependencies (Frontend):
https://www.public-software-group.org/liquid_feedback_core

Licensing information (Core):
https://www.public-software-group.org/mercurial/liquid_feedback_core/file/tip/LICENSE

Licensing information (Frontend):
https://www.public-software-group.org/mercurial/liquid_feedback_frontend/file/tip/LICENSE

## CO3 mobile app

The CO3 mobile app provides augmented reality features and integrates access to other CO3 components.

Access to iOS Beta (Testflight):
https://bit.ly/co3-ios

Access to Android Beta (Google Store)
https://bit.ly/co3-android

Source code (master branch):
https://drive.google.com/file/d/1t2gxa7kuzvO3BnlcSoe8oeE17g1oRgdd/view?usp=sharing

## OnToMap (including gamification engine)

OnToMap Logging Service and Data Hub supports semantic data interoperability, cross-application logging of user actions, data sharing and achievements management for gamification within the CO3 platform.

Main information page:
https://ontomap.eu/projects/co3

Installation Instructions:
https://ontomap.eu/projects/co3#installation

Source code:
https://gitlab.com/ontomap/ontomap-co3

Software dependencies:
https://ontomap.eu/projects/co3#licenses

## LandingPage

The CO3 Landing Page is a component which displays data about user activities that are collected by the other front-end applications of the platform.

Main information page:
https://firstlife.gitlab.io/co3/

Installation instructions:
https://gitlab.di.unito.it/co3-project/landing-page

Source code download:
https://gitlab.di.unito.it/co3-project/landing-page

## AreaViewer

The AreaViewer is a web map based application providing a view of aggregated data based on OnToMap. 

Main information page:
https://firstlife.gitlab.io/co3/

Installation instructions:
https://gitlab.di.unito.it/co3-project/areaviewer

Source code download:
https://gitlab.di.unito.it/co3-project/areaviewer

## InputMap

The InputMap provides a unified system for spatial input.

Main information page:
https://firstlife.gitlab.io/co3/

Installation instructions:
https://gitlab.di.unito.it/co3-project/inputmap

Source code download:
https://gitlab.di.unito.it/co3-project/inputmap

## FirstLife Tile Server

Sources of cartographic information are indexed as tiles (x, y, z) with the format of SVG, GeoJSON or image (PNG, JPEG). The source can be locally stored or remotely retrieved (handled by the local storage).

Main information page:
https://firstlife.gitlab.io/co3/

Installation instructions:
https://gitlab.di.unito.it/co3-project/tileserver

Source code download:
https://gitlab.di.unito.it/co3-project/tileserver

## FirstLife Resource Server

Main information page:
https://firstlife.gitlab.io/co3/

Installation instructions:
https://gitlab.di.unito.it/co3-project/fileserver

Source code download:
https://gitlab.di.unito.it/co3-project/fileserver