Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

IKG
Institut für Kartografie
und Geoinformation

ETH Zurich, Campus Hoenggerberg

Enhancement of Esri's World Topographic Map and Web Map Application development

Interdisciplinary Project Work
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Lead
Prof. Dr. Lorenz Hurni
lhurni@ethz.ch

ETH Assistance
Dr. Christian Häberling
christian.haeberling@karto.baug.ethz.ch

Roland Schenkel
schenkel@karto.baug.ethz.ch

ESRI Assistance
Thomas Koblet
t.koblet@esri.ch

Marianne Rüegsegger
m.rueegsegger@esri.ch

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Authors
René Gander
ganderre@student.ethz.ch

Martino Isidori
isidorim@student.ethz.ch

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I Preface

This work was created in the context of the interdisciplinary project work during the 3rd Semester of the master program in *Geomatics* at *ETH Zurich*, in which "at least two professorships or one professorship and an external partner are involved" (WIESER, 2013). In this case, a collaboration with *Esri Schweiz AG* was entered.

This document reports the used approach to achieve the enhancement of *Esri*'s *World Topographic Map* and to create a web map application. This work gave us the possibility to create a product for the *Esri* company that may be published as part of the official *World Topographic Map* and the *Campus Basemap Tour*[1]. Furthermore, it was an extraordinary experience working with some new products of *Esri* and combining them with other software and operative systems.

The project was carried out in the *Institute for Cartography and Geoinformation* (IKG) led by Prof. Dr. Hurni. Dr. Christian Häberling and Roland Schenkel supervised the interdisciplinary project work, in collaboration with Thomas Koblet and Marianne Rüegsegger from *Esri*. Special acknowledgements are directed to Ueli Fergg of *ETH Immobilien,* who had provided the spatial dataset of the campus of *ETH Hoenggerberg*, Dr. Ionut Iosifescu and Christian Sailer for the *ArcGIS* software support and Olaf Smith and Claudia Matthys for the virtual GIS server setup.

[1] Source: Campus Basemap Tour.
http://www.arcgis.com/apps/MapSeries/index.html?appid=ff385871b7f44a0f88f0217dac3d6c7a
(last accessed 10 January 2017).

II Abstract

The topic of this interdisciplinary project work is to enhance *Esri*'s *World Topographic Map* by enhancing the campus of the *ETH Hoenggerberg* and to create a web map application for the *ETH Hoenggerberg*. Concerning the map enhancement, a section of the *World Topographic Map,* containing the area of the *ETH Hoenggerberg,* is provided by *Esri* in form of an *ArcMap* template. Based on a current overview plan and a field inspection of the campus, this template is updated and enhanced, whilst maintaining the existing style of the map. Thereby, the enhancement is comprised of added vegetation, paths, roads, parks, places and buildings. Furthermore, zoom-level-specific labels for the places, roads and buildings are introduced.

For the creation of the web map application, *ArcGIS Online* with its built-*in Web AppBuilder* is used. The purpose of the application is to provide an overview of the rooms of the *HIL* building and to indicate the historic development of the *ETH Hoenggerberg*. To achieve that, room data for the *ETH Hoenggerberg* buildings in the *DWG*- and *Microsoft Excel* format is acquired from *ETH Immobilien*. The *DWG* data is converted to polygon shape files and joined with the data from the *Excel* files. The room shape files are nested in a group layer and published as a feature service on the virtual GIS server *http://kartoipa01.ethz.ch*, whereas point features representing points of interest on the campus are published as feature services on *ArcGIS Online*. Finally, the feature services are used within the *Web AppBuilder* to create the application.

The enhancement of the *World Topographic Map* and the creation of the web map application are successfully accomplished. A focus is set on cartographic rules, especially on the readability and simplicity of the map.

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1. Introduction

1.1. Objectives of the work

Maps play an important role in the display of spatial information. New technological possibilities have accelerated the development of maps until the present days. According to Cartwright et al., cartographers have always used new technologies to fulfil the expectations and challenges of today's users (CARTWRIGHT et al., 2007). The evolution of maps is given by the improvement of the technique and institutional practices, but also by the political and social situations (KITCHIN et al., 2011). These cartographic varieties grew over time and can be visualized as a tree (see Figure 1).

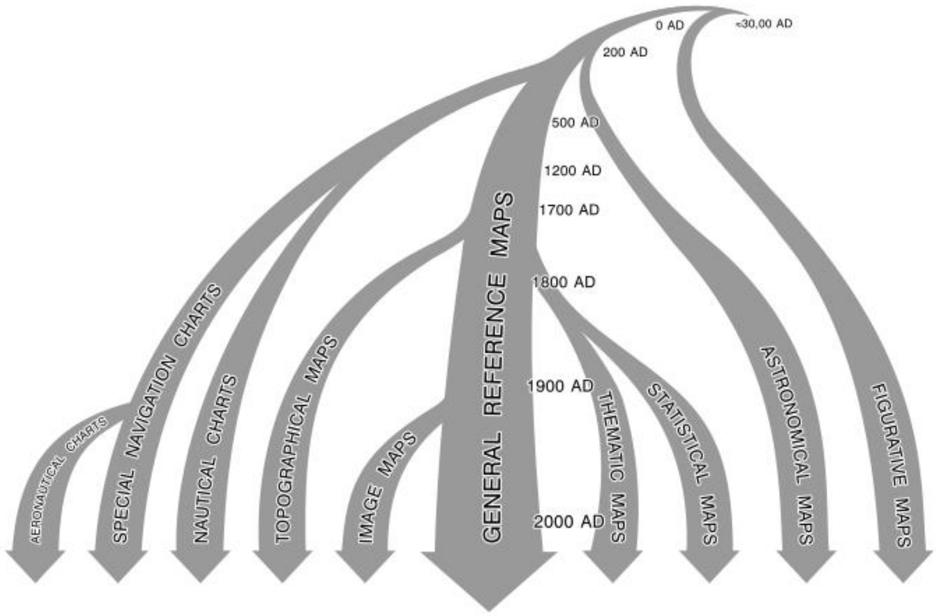


Figure 1: Cartographic varieties[2].

Nowadays, interactive online maps are wide spread. The use of *Google Maps* and other interactive maps are evident examples. They can be found in different forms and structures and contain varying levels of functionality (MACEACHREN et al., 2011).

Most interactive online maps use the same foundation to display spatial information: the basemaps. They represent the very basic layer of a map, on which further information can be embedded. The *Environmental Systems Research Institute* (*Esri*), an international company founded in 1969, is designated to develop software in the sector of geographic information systems (GIS). They also provide web GIS and geodatabase management solutions. Inter alia, they offer a *World Topographic*

[2] Source: Kitchin, R., Dodge, M., Perkins, C. (2011): Introductory Essay: Conceptualising Mapping. In: Kitchin, R., Dodge, M., Perkins, C. (eds.) The Map Reader: Theories of Mapping Practice and Cartographic Representation. Hoboken, New Jersey. John Wiley & Sons. 1-7.

Map, which "[…] includes boundaries, cities, water features, physiographic features, parks, landmarks, transportation, and buildings" (ESRI, 2016/1). This map is designed to be used as a basemap. In the context of this work, *Esri* provided the opportunity to propose an enhancement for the campus of *ETH Hoenggerberg* (see Figure 2) within the *World Topographic Map*.

Figure 2: Campus of *ETH Hoenggerberg*: Aerial imagery[3].

Given this context, two main independent goals were established for this work: the proposal of a possible enhancement of the *World Topographic Map* by enhancing the campus of *ETH Hoenggerberg,* and the creation of a web map application for the *ETH Hoenggerberg,* using *Esri's Web AppBuilder*. The latter is intended for visitors, students or staff of the *ETH*. The purpose is to provide an overview of the rooms of the *HIL* building and the rooms' equipment. Furthermore, a visualization of the historic development of the *ETH Hoenggerberg* is implemented and interactive pictograms indicate the points of interest on the campus. Regarding the enhancement of the *World Topographic Map*, no restrictions were set by *Esri*. Nevertheless, the incorporation of the existing style of the *World Topographic Map* was regarded as appropriate. The enhancement itself is achieved by integrating and verifying either missing or already existing features respectively. Figure 3 displays the main goals, sub-goals and the consequent results of this work.

[3] Source: CNES, Spot Image, swisstopo, NPOC – https://www.geo.admin.ch/en/home.html (last accessed 2 January 2017).

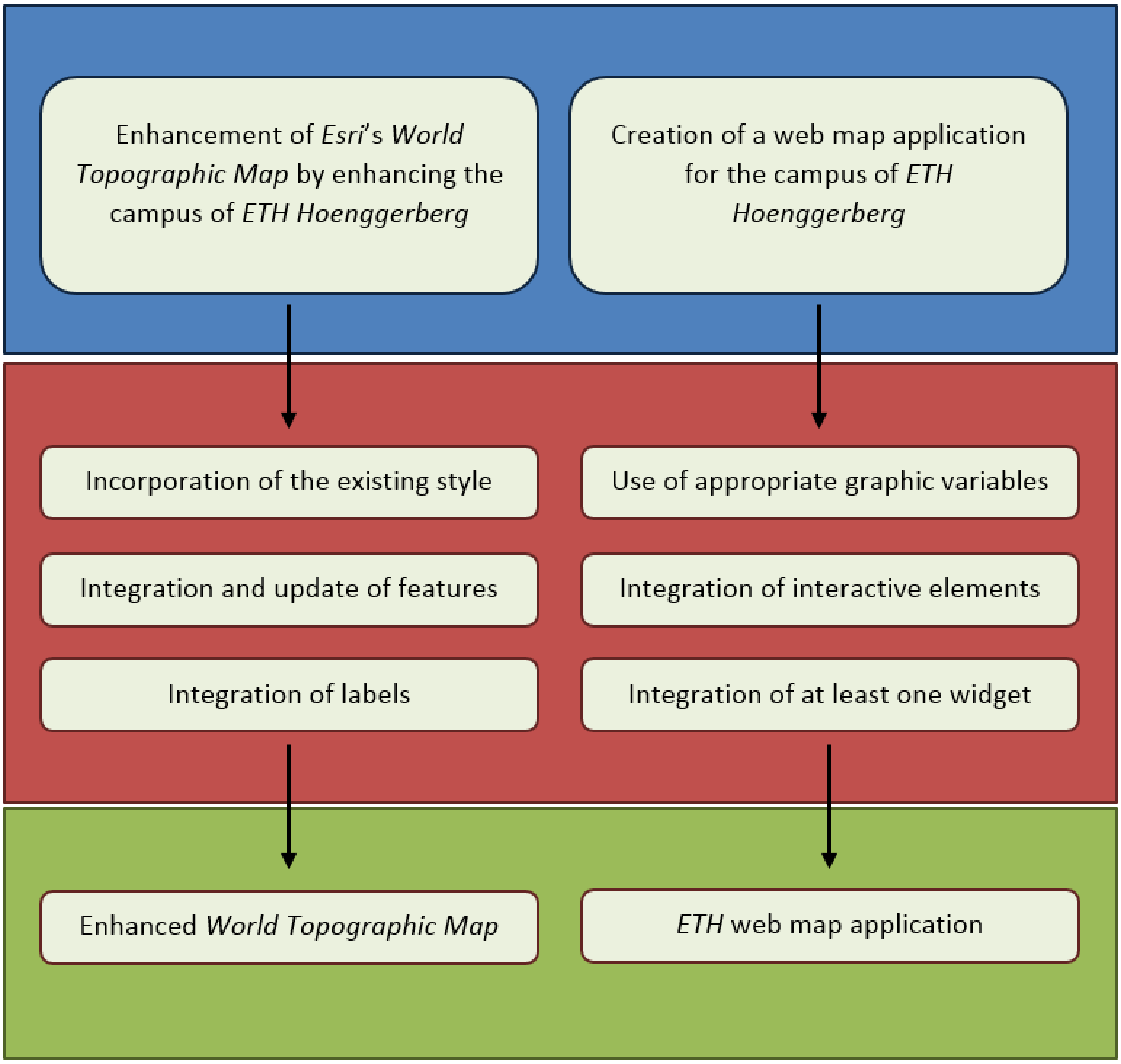


Figure 3: Main goals (blue), sub-goals (red) and results (green) of this work.

When creating a web map application, it is important to consider the level of interactivity, targeted audience and the underlying data relations. Figure 4 depicts the relation between the user audience, data relations and level of interaction depending on whether the map provides exploration, analysis, synthesis or presentation. Due to the presenting nature of the web map application for the *ETH*, only basic interactions such as turning layers and pop-ups on and off are supported and a public audience is targeted. This requires to know the underlying data structure well (MACEACHREN et al., 2011).

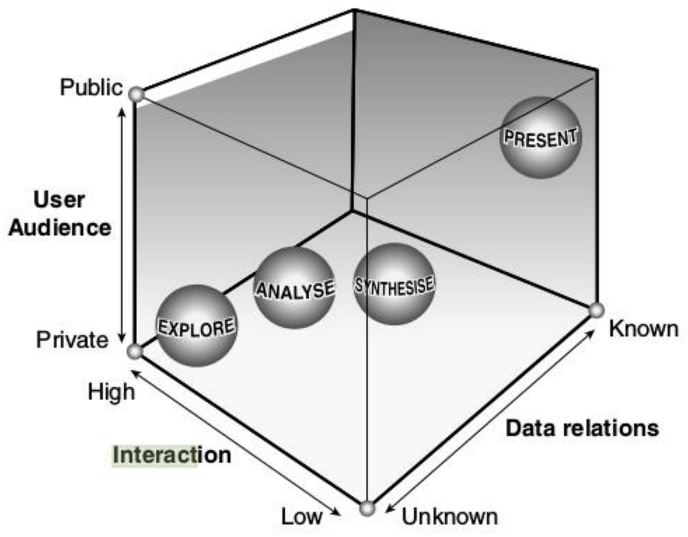


Figure 4: Relation between the targeted user audience, interactivity and underlying data for different map purposes[4].

1.2. Overview of the contents

The interdisciplinary project work, performed during the autumn semester 2016 within the third semester of *Geomatics' Master* degree, treats the enhancement of *Esri*'s *World Topographic Map* and web map application development, focusing on the area of the campus of *ETH Hoenggerberg* in Zurich.

In the introductive chapter, the objectives of the map enhancement and the development of the web map application are explained. The second chapter handles the fundamentals for the map enhancement and the web application creation. A description of the state of the art is given for both topics. The acquired basic data are listed and described as well as the tools used to achieve the premises.

Methods and procedures are treated in the third chapter, where thoughts and steps to reach the objectives are exposed and explained. The individual steps are commented and the resulting decisions are explained.

In the next-to-last chapter, the final products of the enhancement of *Esri*'s *World Topographic Map* and the development of the web map application are discussed.

In the last chapter, the conclusions of the work, the achievement of the objectives and the possible future potential and developments of the created products are depicted.

[4] Source: MacEachren, A. M., Kraak, M-K. (2011): Exploratory Cartographic Visualisation: Advancing the Agenda. In: Kitchin, R., Dodge, M., Perkins, C. (eds.) The Map Reader: Theories of Mapping Practice and Cartographic Representation. Hoboken, New Jersey. John Wiley & Sons. 83-88.

2. Fundamentals

2.1. State of the art

2.1.1. Esri's World Topographic Map

Esri's *World Topographic Map* is a freely accessible and continuously updated digital map, which can be used worldwide by everybody. The GIS community provides the data for the development of this map and everybody can contribute to the further development of the *World Topographic Map* with their own data by means of the *Community Maps Program* (ESRI, 2015). This specific basemap was created by combining different sources, amongst others the *U.S. Geological Survey* (USGS), *U.S. Environmental Protection Agency* (EPA), *U.S. National Park Service* (NPS) and the *Food and Agriculture Organization of the United Nations* (FAO). For some regions of the map, data was obtained from *OpenStreetMap* contributors (ESRI, 2016/1).

Figure 5: *Esri*'s *World Topographic Map*: General overview.

In the context of this work, only the sector of the campus of *ETH Hoenggerberg* is dealt with (see Figure 6). The representations of the campuses within the *World Topographic Map* are not strictly regulated. Figure 7 and Figure 8 indicate different implementation possibilities. The *Agricultural University* in Krakow uses raster data (Figure 8) to conduct a local enhancement, whereas most other universities use vector data (Figure 7). Identifiable are also differences in the level of detail regarding features and labels.

Figure 6: *Esri*’s *World Topographic Map*: Campus of *ETH Hoenggerberg*.

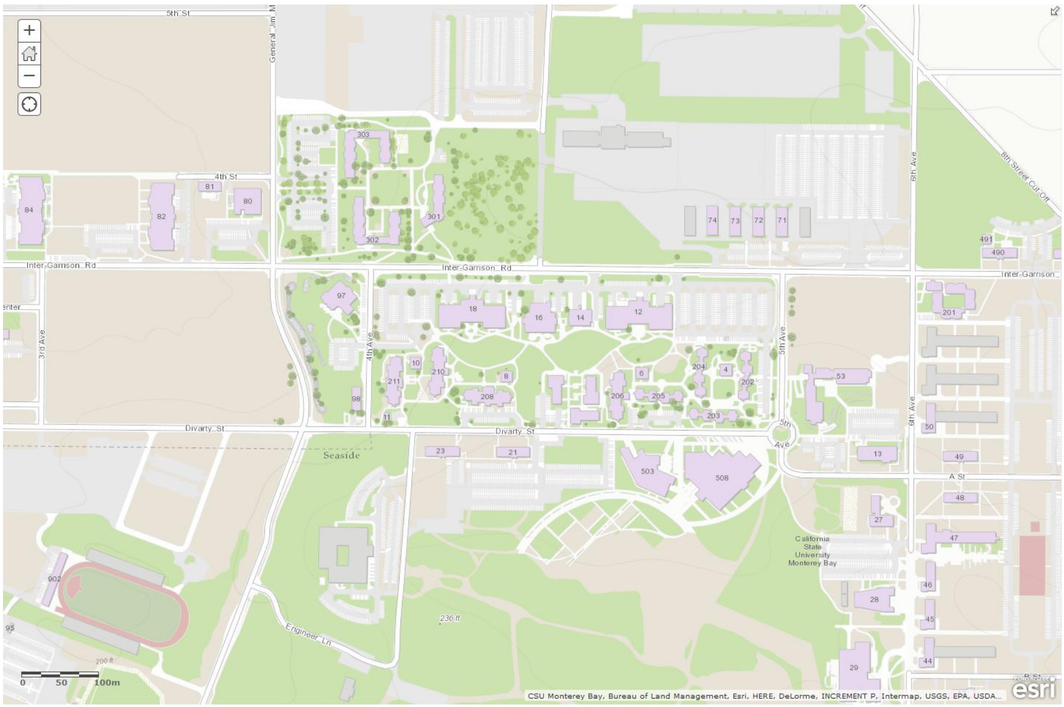


Figure 7: *Esri*’s *World Topographic Map*: *California State University*, Monterey Bay.

Figure 8: *Esri*'s *World Topographic Map*: *Agricultural University* in Krakow.

2.1.2. Web map application

The creation of a web map application through the *Web AppBuilder* does not require any knowledge of the underlying infrastructure. Nevertheless, it becomes a necessity if geographical data should not be published on the *ArcGIS Online* infrastructure, but on an external GIS server instead. The *Web AppBuilder* uses a three-tier client-server infrastructure as design pattern (PERRY, 2014), see Figure 9. Such an infrastructure allows to access services on a GIS server (logic tier) through the internet via a client (presentation tier). The GIS server can also request data from a database (data tier) (FU et al., 2011).

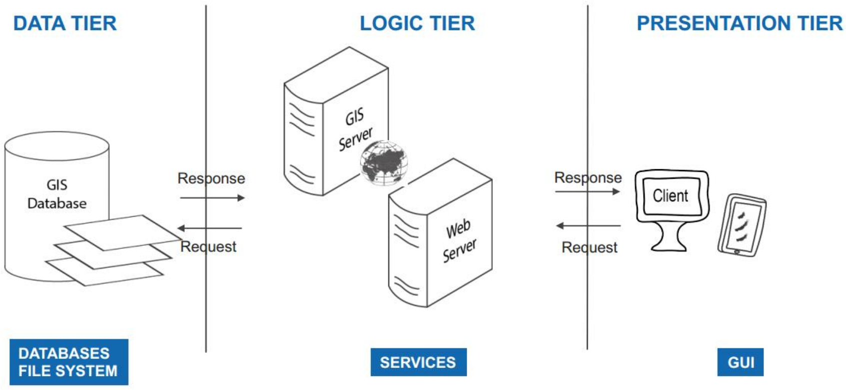


Figure 9: Architecture for service-oriented mapping applications: Three-tier architecture[5].

[5] Source: Panchaud, N. (2016): Server-Side Techniques. Cartography III. ETH Zurich.

In the context of this work, the most important part of this architecture are the GIS services, provided by a GIS server within the logic tier. The *Open Geospatial Consortium* (OGC) regiments standards for the different GIS services. Particularly important for this work is the *Web Feature Service* (WFS), with which access to distributed geographical features can be provided (STROBEL et al., 2016). The data used in the development of the web mapping application was published as feature services on the virtual GIS server *http://kartoipa01.ethz.ch* (the room plans of the *HIL* building) and on the *ArcGIS Online* account (locations for the pictograms, buildings of the *ETH Hoenggerberg*). Within the *Web AppBuilder*, the feature services published on *ArcGIS Online* were directly available, whereas the external published feature services (room plans) were accessed via the URL to the virtual GIS server.

2.2. Basic data

For the enhancement of *Esri*'s *World Topographic Map* and the web map application of the campus of *ETH Hoenggerberg*, different sources and files were aggregated.

Concerning the map enhancement, an *ArcMap* template of the *World Topographic Map* in the *MXD*-format for the region of *ETH Hoenggerberg* was provided by *Esri*. This template was used to enhance the region of *ETH Hoenggerberg*. The complex hierarchical structure of the template is shown in the diagram of Figure 10. It is based on four main levels, representing certain zoom levels. Each of these levels is divided into the same three sub-groups: the bottom-, middle- and top group layer. Each group layer contains the same subordinate feature specific layers. For simplicity, the diagram only shows the feature layers of the zoom level 19. The most important feature layers for this work are the layers *Tree_xK* (trees), *RoadCenterline_xK* (roads), *BuildingsFootprint_xK* (buildings) and *Park_xK* (parks), where the "*xK*" denotes a specific zoom level. Different categories for buildings are provided, but in this specific case of a campus, the "Education" class is used for all *ETH* buildings. There are various types of classifications for the roads, as shown in the table below (Table 1). They are classified by type and level.

TYPE	LEVEL
FERRY	-
FREEWAY/MOTORWAY	First and Ground Level, Subsurface
HIGHWAY	First and Ground Level, Subsurface
LOCAL	First and Ground Level, Subsurface
MAJOR ARTERIAL/A ROAD	First and Ground Level, Subsurface
MINOR ARTERIAL/B OR C ROAD	First and Ground Level, Subsurface
RAMP	First and Ground Level, Subsurface
RECREATION (1ST ORDER):	First and Ground Level, Subsurface
4WD - RECREATION (2ND ORDER)	First and Ground Level, Subsurface

Table 1: *Esri*'s *World Topographic Map* template: Type and level of roads

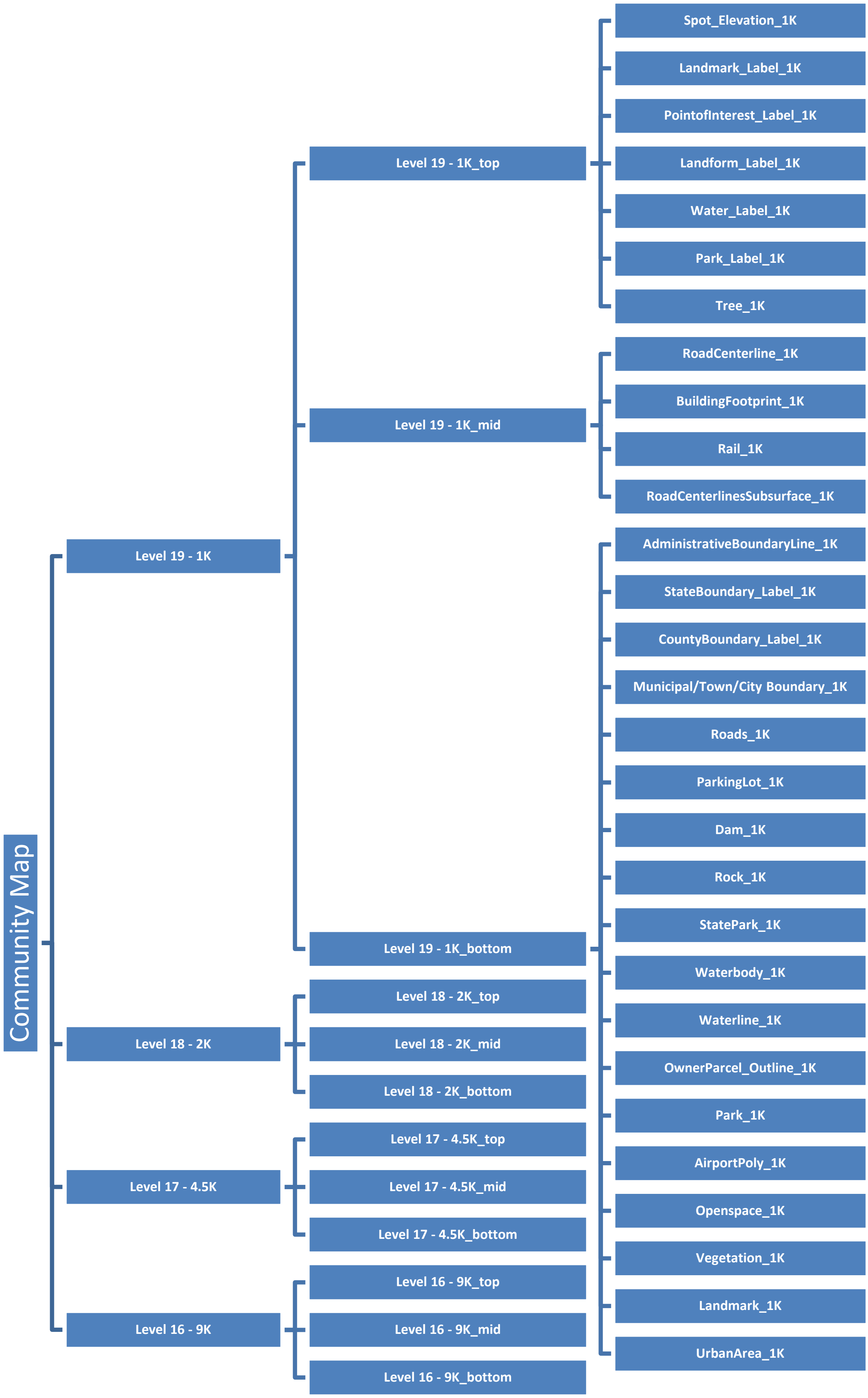


Figure 10: *Esri*'s *World Topographic Map*: Structure.

Furthermore, an official plan of the campus *ETH Hoenggerberg* (ETH, 2016/1), provided by *ETH Immobilien*, is used to update the footprint of newly created buildings and for the labeling of roads, places, parks and buildings (see Figure 11).

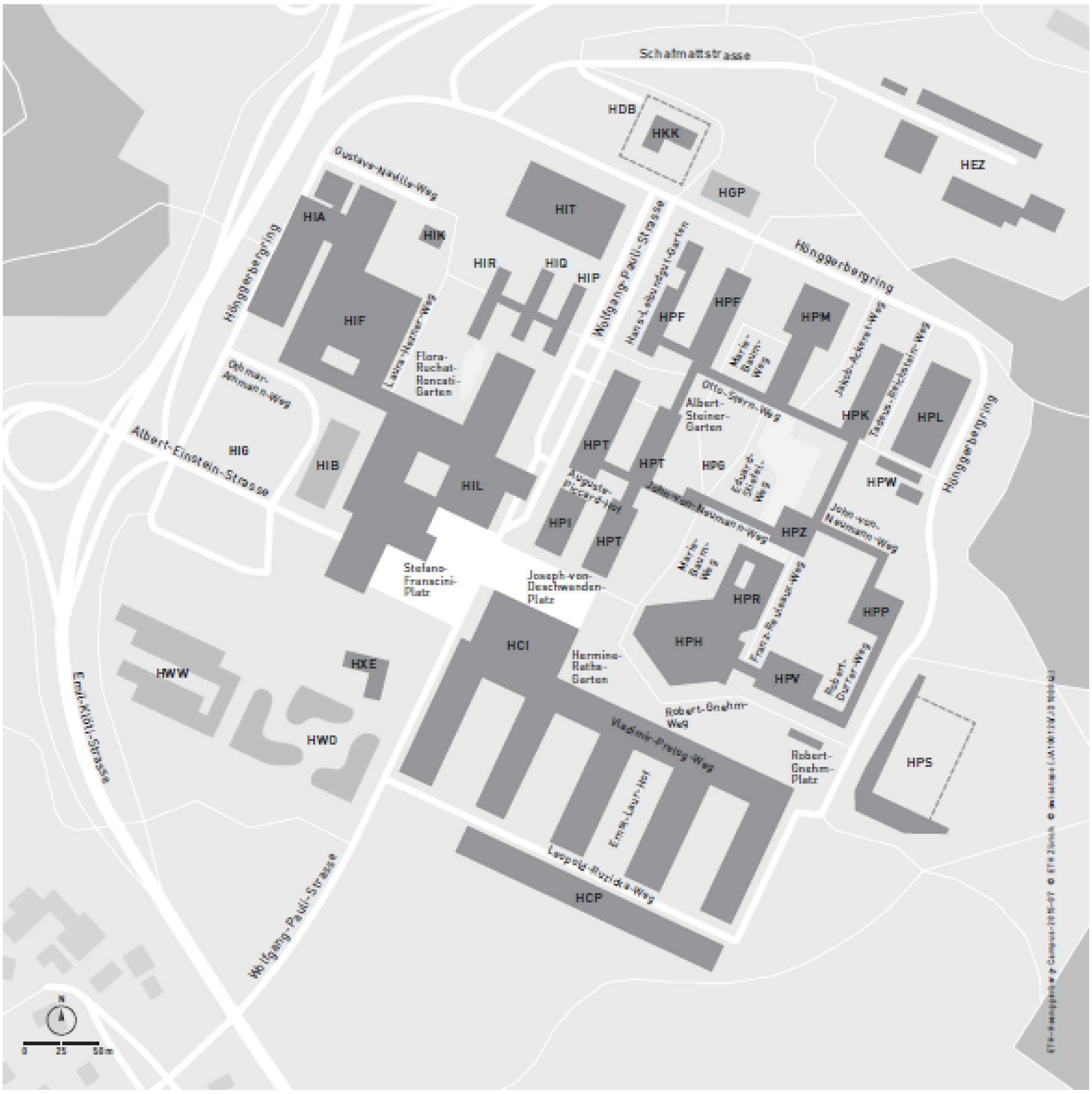


Figure 11: Overview plan Hoenggerberg – *ETH Immobilien*.

For the web map application, room outline data for the buildings on the campus were acquired from *ETH Immobilien* in the *DWG*-format. Additionally, *ETH Immobilien* provided *Microsoft Excel* data (*XLS*-format), containing metadata about the *HIL* rooms such as equipment, number of seats and official room type classification.

2.3. Tools used

The modifications of the *World Topographic Map* and the conversion of data for the web map application were conducted in *ArcMap* 10.4.1. Regarding the creation and configuration of the web map application, *ArcGIS Online* and its built-in *Web AppBuilder* were used. For the hosting of the room plan features, *Windows Server* and *ArcGIS for Server* 10.4.1 were used on a virtual server. *Apache HTTP Server Project* was used to setup accessible pictures for the web map application in *ArcGIS Online*.

ArcGIS Online is a simple and user-friendly "[…] cloud-based mapping platform" (ESRI, 2017/1). Through *ArcGIS Online*, it is possible to create and share maps in a simple and intuitive way, without the use of a programming language, installed software or locally saved data. This means that the data is always available once uploaded in the cloud of *ArcGIS Online* or made available through a GIS Server. One can decide whether the uploaded data will be publicly available or only within the organization. *ArcGIS Online* can suggest a specific visualization for the uploaded data or the user can adapt it according to his needs. The information can be displayed in 2D or 3D separately and, if necessary, a combination of the two can be used (ESRI, 2017/2). *Esri* provides several geoprocessing tools that can be used to conduct analysis on the available data. Furthermore, imageries, basemaps and other various products of and about the world are available and continuously updated. All these maps can be freely used as a base for applications and modified according to the desired requirements (ESRI, 2017/3).

The *Web AppBuilder* is part of *ArcGIS Online* and has the purpose to enable the creation of web map applications. The web applications are based on *HTML* and *JavaScript* and can therefore run on all devices supporting those technologies, such as computers, tables or smartphones. Accordingly, applications adapt themselves to different screen sizes, operative systems and web browsers. Various predefined widgets are available and ready to use within the *Web AppBuilder* (ESRI, 2017/4). Figure 12 shows the available widgets during the conduction of this work (December 2016).

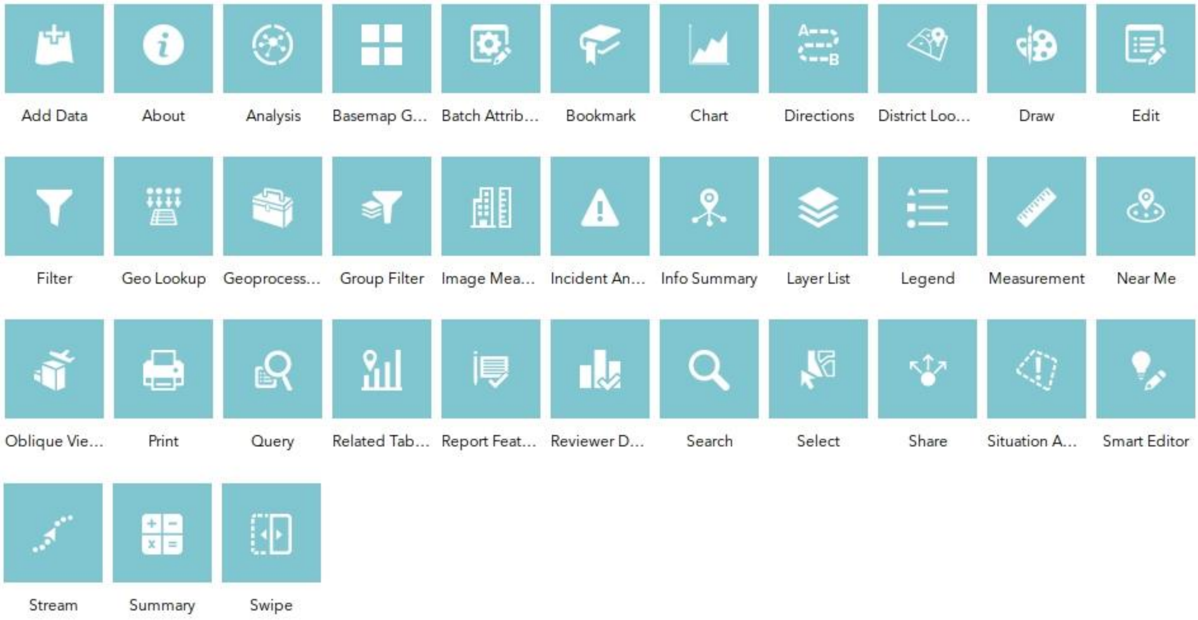


Figure 12: Available widgets in *ArcGIS Online – Web AppBuilder*.

The structure of the user interface is defined by so called themes. Figure 13 shows predefined application themes within the *Web AppBuilder*. Depending on which kind of application is created, different themes are available. Finally, it is important to note that the finished web map application can be hosted on the cloud provided by *Esri* or run on an own server (ESRI, 2017/4).

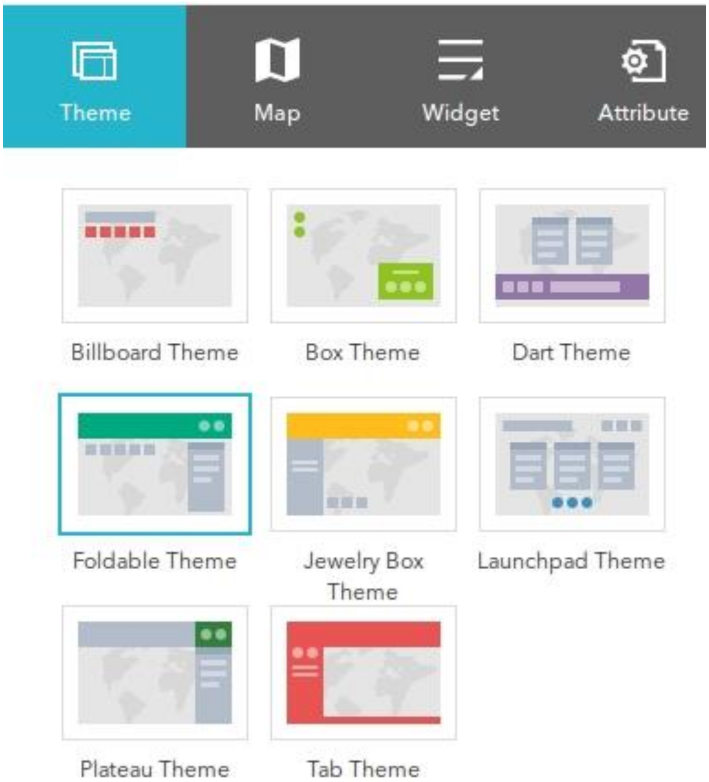


Figure 13: Available themes in *ArcGIS Online – Web AppBuilder* (December 2016).

If necessary, e.g. to gain flexibility for the configuration of the themes and widgets, the *Web AppBuilder for developers* can be used. This software allows to download, modify or create the *JavaScript* codes and upload the alterations of the web map application (ESRI, 2016/2). In this work, the *Web AppBuilder for developers* was not used.

3. Methods and procedures

In this section, the applied workflows for the enhancement of the *World Topographic Map* and the web map application are presented. The general procedure for both topics can be categorized into three main steps: data acquisition, data processing and finally the integration of the data in the map or the web map application, respectively. Thereby, data processing refers to the applied editing on the original data to retrieve the needed data format. The data integration comprises the use of the processed data to derive the desired result.

3.1. Enhancement of the World Topographic Map

The analysis of already enhanced campuses within the *Campus Basemap Tour*[6], a web application showing different educational institutions worldwide, and the *World Topographic Map,* revealed two fundamental different approaches, which have been used to locally enhance the *World Topographic Map*: firstly, by overlaying a raster image, representing the enhanced state of the map over the concerned area or secondly, by modifying the vector data of the *World Topographic Map* for the specific area. The raster approach does not require the actual local vector data of the *World Topographic Map*, e.g. in form of a map template, but has several disadvantages compared to the vector approach. The raster approach lacks in the flexibility to adapt to future changes around the area of concern. It is also not possible to set a visibility scale for specific map features within the campus, which may impede the readability of the map. Furthermore, the raster approach entails an unsmooth alignment with respect to the surrounding features due to the discretization, and also needs to be georeferenced. Finally, the integration of raster data in an inherently vector based map is regarded to be fundamentally problematic due to the different data types. For the reasons mentioned above, the vector based approach was chosen for the enhancement. In Figure 8, the raster approach is depicted for the *Agricultural University* of Krakow.

The enhancement of the *World Topographic Map* required the knowledge of the current situation of the state of the buildings, roads, vegetation, places, etc. on the campus of *ETH Hoenggerberg*. Therefore, a detailed comparison of the existing features in the map and the actual situation was conducted based on the provided map template, the overview plan of the *ETH Hoenggerberg* and the field inspection of the campus described in the chapter *Fundamentals*. Due to ongoing construction activities around the *Students Village*, no valid maps for this region existed and the field inspection was therefore indispensable for the correct representation of the paths and vegetation in this area. The

[6] Source: Campus Basemap Tour.
http://www.arcgis.com/apps/MapSeries/index.html?appid=ff385871b7f44a0f88f0217dac3d6c7a
(last accessed 10 January 2017).

overview plan functioned as a reference plan for the integration of missing buildings and roads, whereas the information gained through the field inspection mostly concerned missing trees and paths. Using the edit function in *ArcMap*, the results of the field inspection were directly integrated in the map template by creating appropriate features or deleting/moving existing features to match the current situation.

Because *ArcMap* could not handle the *PDF*-format, the overview plan of the *ETH Hoenggerberg*, shown in Figure 11, was converted into the *PNG*-format using *Adobe Illustrator*. To maintain the resolution of the *PDF* plan, the overview plan was tiled up into six regions and separately converted into the *PNG*-format. The regions were merged for the final plan in the *PNG*-format. Due to the lack of a coordinate system for the plan, it was georeferenced according to the inherent coordinate system of the provided map template, the *Web Mercator Auxiliary Sphere* projection, using the georeferencing tool in *ArcMap*. An effort was made to distribute the pass points for the georeferencing as homogenous as possible over the area of *ETH Hoenggerberg*. Furthermore, the georeferencing was configured to be based on a similarity transformation. By doing so, the level of distortion was minimized. Figure 14 shows the distribution of the six pass points used for the georeferencing process.

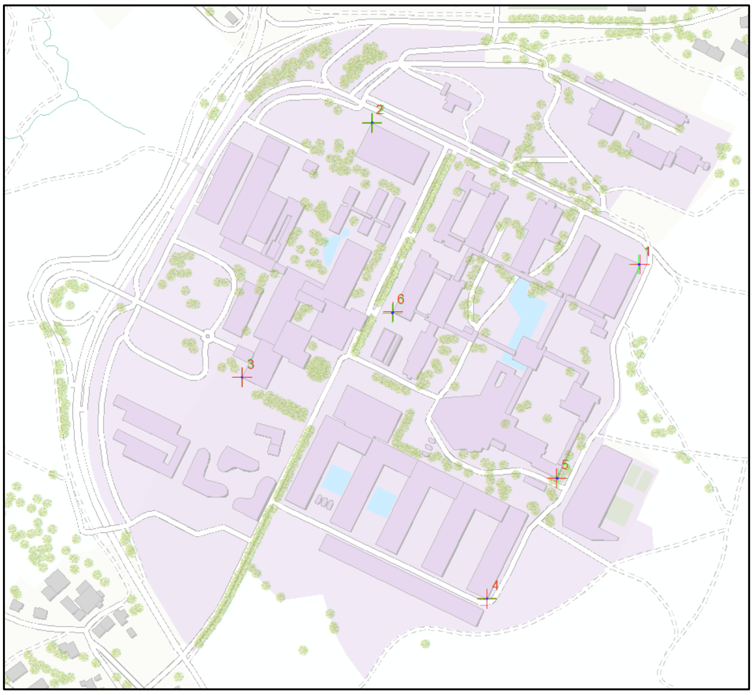


Figure 14: Campus of *ETH Hoenggerberg*: Pass points used to georeference the overview plan.

Finally, the verification of existing buildings and roads and their relative positions, as well as the digitalization of new or missing buildings and streets, was conducted based on the georeferenced overview plan. Buildings and roads were digitalized by drawing polygons and lines in the map template respectively, as shown in Figure 15. The provided map template used different attribute fields in the attribute table to set the style of representation for the different features in the map. E.g. the area of the campus and the buildings had the designation "Education" to them, which lead to the violet representation in the template. Therefore, appropriate field values for the specific attribute fields were inserted to ensure the same style for the newly created polygons and roads as for the existing features. Because the road's appearance was defined by their classification, which is another field in the attribute table, the values of the classification had to be changed for some roads to achieve the desired graphical representation. In the end, the following classifications were used in the campus of *ETH Hoenggerberg*:

- *Major Arterial/B or C Road*: principal roads in the middle of the campus (Wolfgang-Pauli-Strasse).
- *Local*: all the other asphalted roads, accessible by cars.
- *Recreation* (1st order): roads used by cars and pedestrians.
- *4WD - Recreation* (2nd order): track normally just for pedestrians.

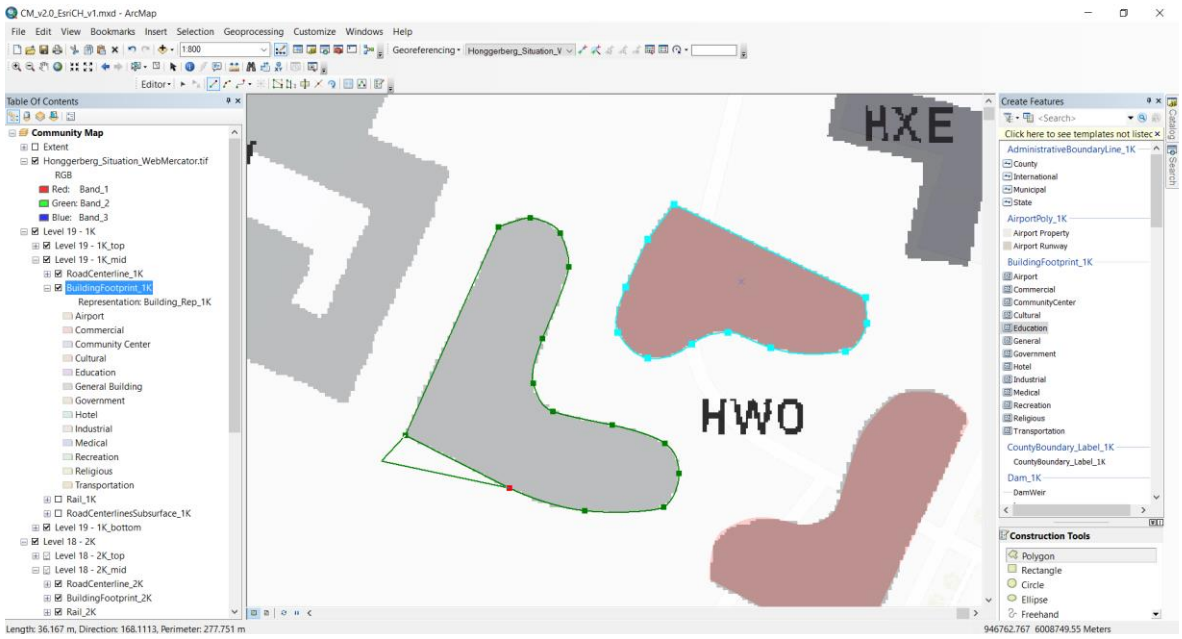


Figure 15: Digitalizing buildings according the underlying overview plan of the *ETH Hoenggerberg*.

Furthermore, places and vegetation were added using a predefined feature style.

The roads, buildings and places were supplemented with labels, whose visibility is depending on the current zoom level. Like the style of the features, the labels were also defined via the attribute table. The labels for the roads were adapted whilst taking the curvature of the roads into account. This means that the labels follow the curvature and are centered on the road, as depicted in Figure 16. Furthermore, the option for spreading the characters of the labels was enabled to enhance the readability of the labels.

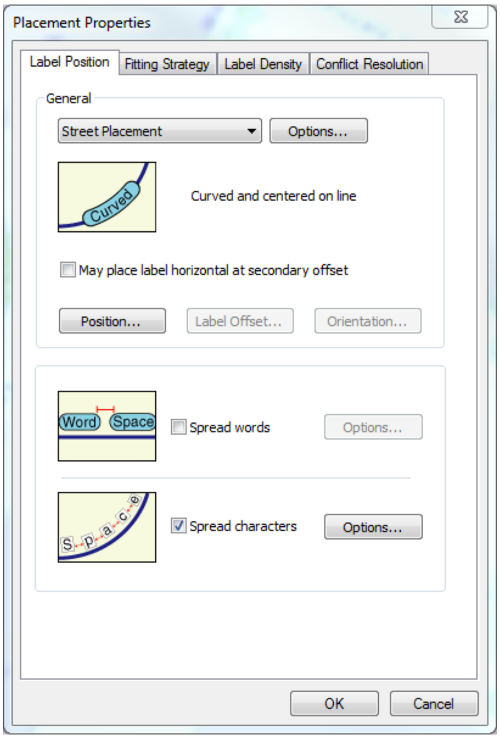


Figure 16: Roads' labels placement properties.

Some buildings were composed of multiple polygons, leading to multiple labels for these buildings due to the multiple entries in the attribute table. Figure 17 illustrates the applied option to display only one label within a certain radius for the buildings. This was especially important for the region of the *Students Village* and the *HCI* building.

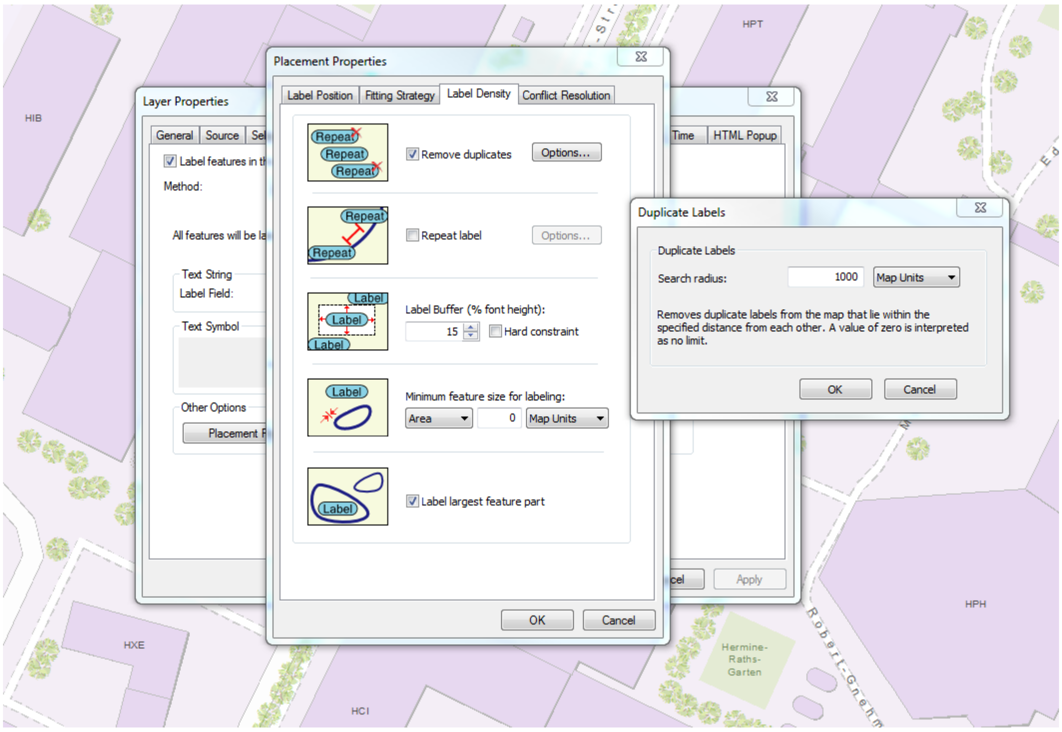


Figure 17: Buildings' labels placement properties.

Figure 18 summarizes the general workflow for the enhancement of the *World Topographic Map*. Because all features were modified within the map template, the reworked version of the map template represents the proposed enhancement of the campus of *ETH Hoenggerberg*.

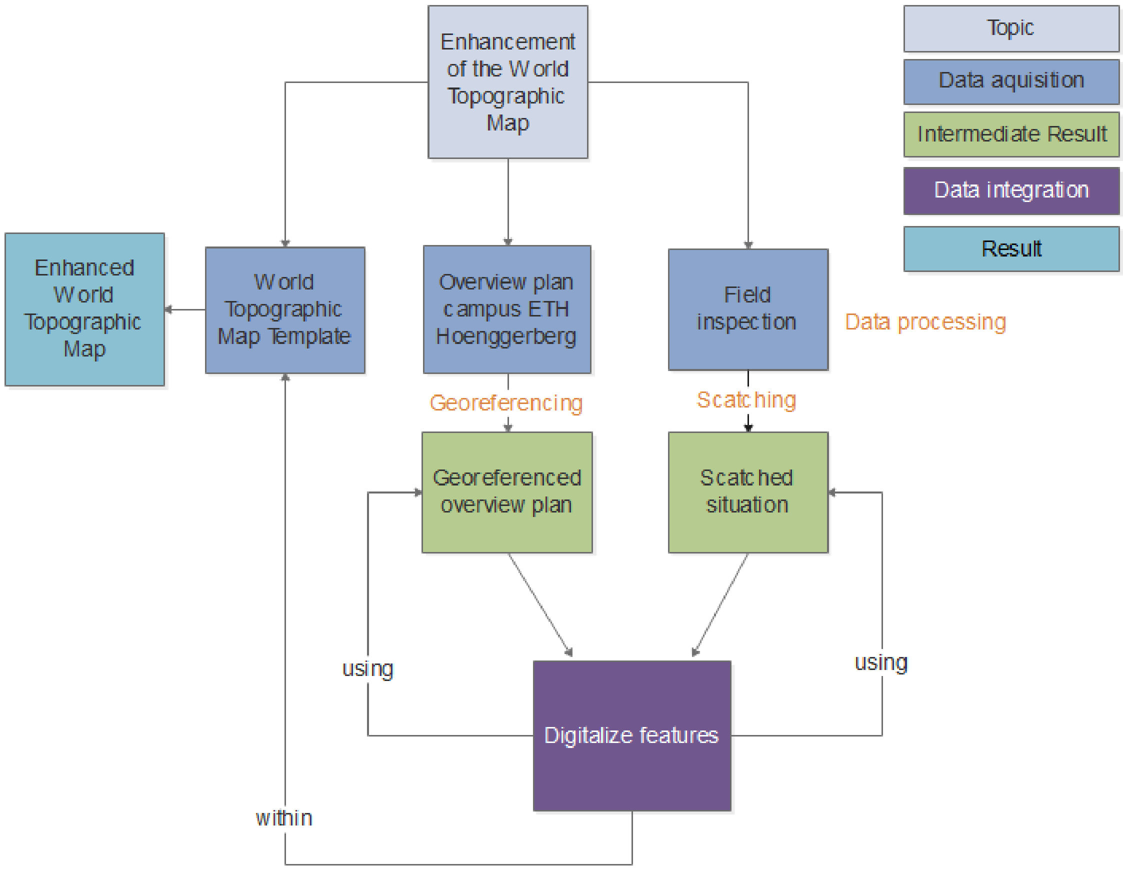


Figure 18: Overview of the main processes involved in the enhancement of the *World Topographic Map.*

3.2. Web map application development

The creation of the web map application was conducted in the *Web AppBuilder* of *ArcGIS Online*. All data required to create the application according to the goals stated in the introduction, was sourced from *ETH Immobilien*. The data was comprised of level specific geometrical plans of the *HIL* rooms in the *DWG*-format, a room list of the *HIL* building including among others room equipment and room designation (*Microsoft Excel* file) and finally a list of the date of the portfolio entrances of the different buildings of *ETH Hoenggerberg* (*Microsoft Excel* file).

3.2.1. DWG data conversion

Although *ArcGIS Online* allowed the use of a wide range of data formats, the *DWG*-format was not supported. Therefore, the first step was to convert the level specific room plans of the *HIL* building from the *DWG*-format to *an ArcGIS Online* compatible format. The polygon shape file format was chosen, because it allowed to bind room specific information to a specific polygon in the shape file via the attribute table. The information in the attribute table was needed to configure feature specific interactive elements, such as pop-ups. Figure 19 shows the workflow for the data conversion from the *DWG*- to the shape file format in *ArcMap*.

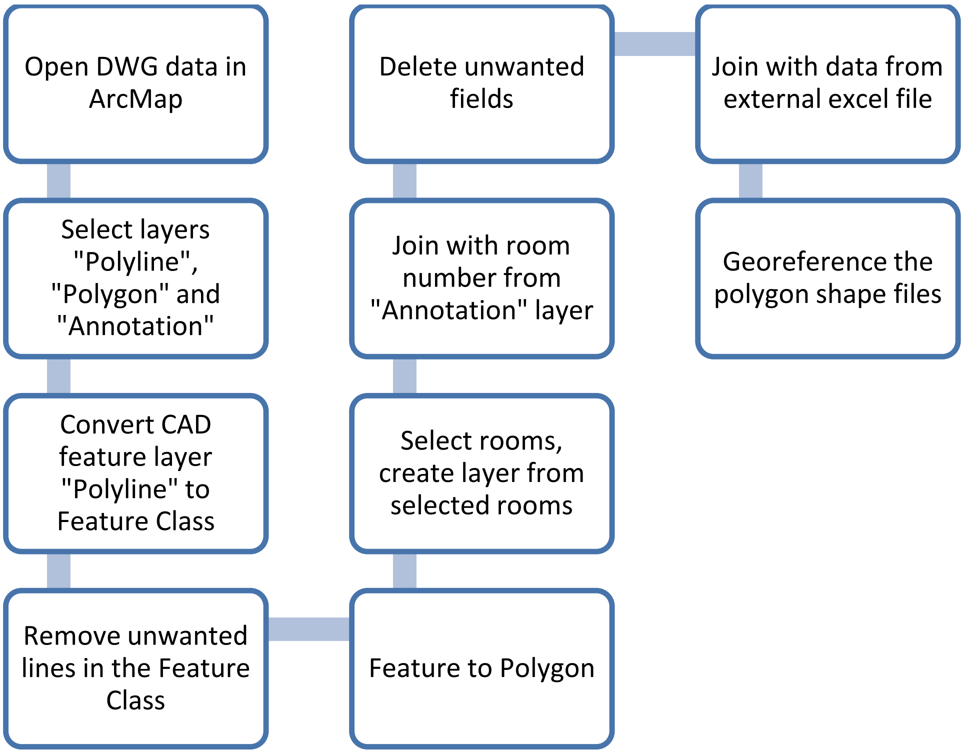


Figure 19: Applied workflow to retrieve the desired polygon shape files from the *DWG* data.

Firstly, the *CAD* room plans in the *DWG*-format were opened in *ArcMap*. Inherently, *ArcMap* created different layers corresponding to the layers in the *DWG*-format. It is important to note that these layers are not treated as feature class layers, but represent simply drawing layers. Only the *Polyline*, *Polygon* and *Annotation* layers were kept for further use. The *Polyline* layer contained the lines of the *DWG* plan. Almost all geometrical features were defined as lines in the *DWG*-format. Some exceptional features like elevators and stair cases were stored in the *Polygon* layer. The *Annotation* layer contained all the descriptive text supplementing the plan, such as the room numbers, the plan designation, the plan date, the revision date and the title of the plan. The discarded layers contained non-relevant information for the application, such as the *ETH Zurich* logo, or did not contain any information to begin with.

To derive a feature class layer from the *DWG* plan, the tool *Copy Features* was applied to the *Polyline* layer. This tool copies the features from the input layer to a new feature class layer[7]. Because each feature in the derived feature class layer was now treated as a line feature, the removal of specific unwanted lines, such as grid lines arising from the original *DWG*-format, was carried out. To enhance the readability of the plans and considering the goals of the application, an effort was made to generalize the plan by further deleting line features. Small pillars, as well as door representations were for example deleted.

The tool *Feature to Polygon*[8] was applied to convert the line features to polygon features, resulting in a polygon shape layer. To get rid of unwanted polygons, such as corridors or star cases, the room polygons were selected and the function *Create layer from selected features* was executed, resulting in a separate layer containing only polygons representing rooms.

In a next step, the room numbers stored in the *Annotation* layer were appended to the derived room polygons attribute table by making a join based on the spatial location of the rooms and the respective room number. Thereby, the room number of the *Annotation* layer was assigned to the corresponding closest room polygon. The join also created new fields in the attribute table, which were deleted in such a way that only the room number, the feature *ID* (FID) and the *Shape* field were kept. The attribute table was complemented with additional information about the rooms stored in an external *Microsoft Excel* file. This was achieved by performing a join between the polygons attribute table and a table retrieved from the *Excel* file containing general room information. The table was generated by applying the conversion tool *Excel to table*[9]. Before converting the *Excel* file to the table, the German expressions were translated into English within the *Excel* file. Furthermore, entries included in the *Excel* file, but not in the polygons attribute table, had to be deleted to ensure a one to one correspondence and therefore the feasibility of the join via the room number.

The procedure depicted above was applied for each level of the *HIL* building, resulting in eleven level specific polygon shape files, representing the room plans. As a last step, the polygon shape files were georeferenced using the provided *World Topographic Map* template. Unfortunately, it was not

[7] Further information: Copy Features.
https://pro.arcgis.com/de/pro-app/tool-reference/data-management/copy-features.htm
(last accessed 10 January 2017).
[8] Further information: Feature to polygon.
https://pro.arcgis.com/de/pro-app/tool-reference/data-management/feature-to-polygon.htm
(last accessed: 11 January 2017).
[9] Further information: Excel to table.
https://pro.arcgis.com/de/pro-app/tool-reference/conversion/excel-to-table.htm
(last accessed: 11 January 2017).

possible to use the default georeferencing tool on two vector data sets. Because of that, the *Spatial Adjustment* tool was used to conduct the georeferencing, see Figure 20.

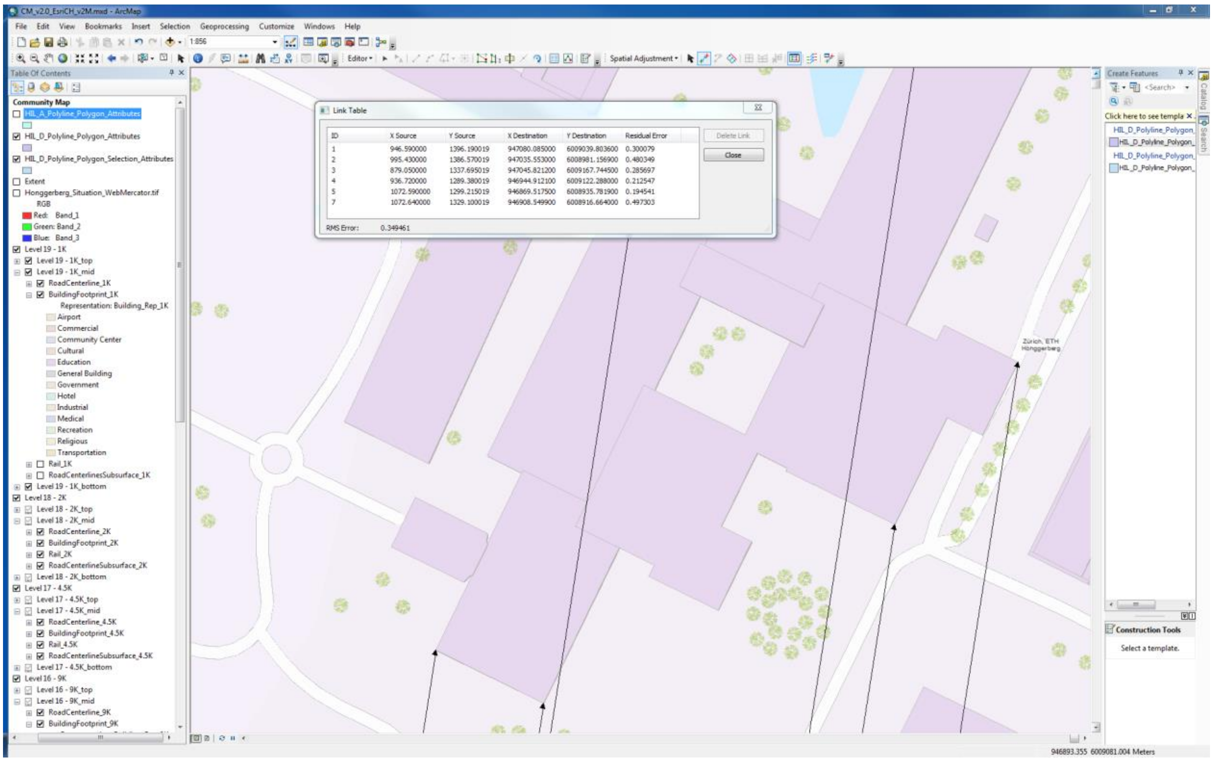


Figure 20: *Spatial Adjustment* of the rooms of the *HIL* building based the enhanced *World Topographic Map*.

3.2.2. Creation of the web map application

To use the prepared polygon shape files within the *Web AppBuilder*, they needed to be published as feature services either directly on the *ArcGIS Online* account, or on an external GIS server. Essentially, there were two possibilities to publish a feature service within the *ArcGIS Online* account. The first one was to publish the local layer by compressing the layer files into a *ZIP*-format and uploading it to the *ArcGIS Online* account. The second solution was to publish the feature service directly via the *ArcMap* internal publish functionality. The first approach was applied.

It was intended to publish only one feature service for the *HIL* rooms instead of eleven feature services, representing each level separately. This had the advantage that the group structure would also be integrated in the legend widget, leading to a better understanding of the application. It was achieved by grouping all polygon layers in a group layer within *ArcMap* and publishing the group layer as a layer per se. Because *ArcGIS Online* automatically ungroups group layers published as a feature service on the *ArcGIS Online* account, an external virtual GIS server (*http://kartoipa01.ethz.ch*) was set up. The ports 6080, 6443, 4000-4002 and 4004 were opened for external access (ESRI, 2017/5). By doing so, the room plans could be added as a feature service to the *ArcGIS Online* account by calling the URL of the external feature service on the virtual GIS server, without losing its grouped structure. Unfortunately, the use of an external feature service containing group layers limited the available configuration options in *ArcGIS Online*. The availability of the different configuration options is depicted in Figure 21.

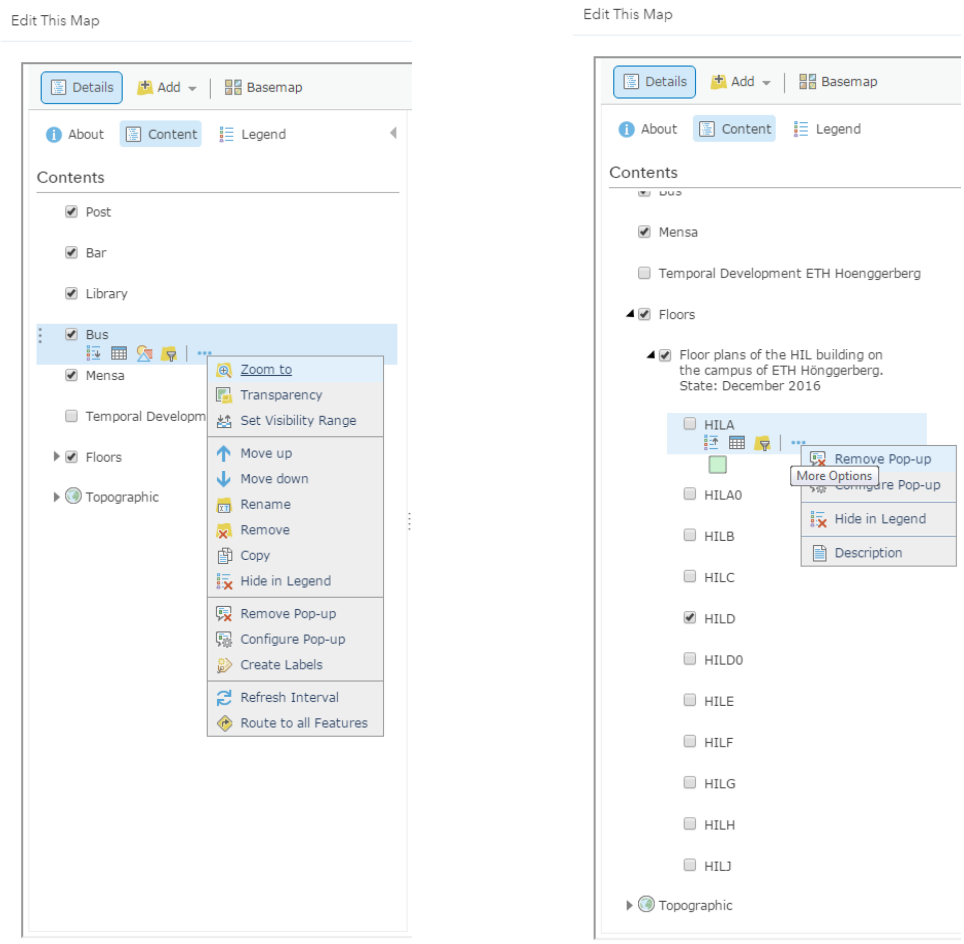


Figure 21: Options available within the *Web AppBuilder* for a feature layer (left) and for a group layer imported from an external *ArcGIS Server* (right).

Once added to the *ArcGIS Online* account, feature services were also available in the *Web AppBuilder*.

The display of points of interest of the campus *of ETH Hoenggerberg* within the application required to publish point feature services, representing the locations of the points of interest. The point features were created in *ArcMap* and published as a feature service on the *ArcGIS Online* account. For each class of point of interest, e.g. library or refectory, a unique pictogram was designed in *Adobe Illustrator* and stored locally as an *SVG* image. The pictograms were designed focusing on shape- simplicity and recognition. Within the *Web AppBuilder*, the pictograms were assigned to the point features using the *Symbol* functionality. Again, there existed a different approach to add the pictograms to the *Web*

AppBuilder: the symbology could have been defined directly within the *ArcMap* document and therefore inherently belong to the feature service after publishing it on the *ArcGIS Server*. It is important to note that an external GIS Server would have needed to be used for this approach, because *ArcGIS Online* neglects the set symbology in a feature service directly published via *ArcGIS Online*. But the inclusion of the pictograms in *ArcMap* pixelated the pictograms. Therefore, the *Symbol* functionality within the *Web AppBuilder* was preferred. To prevent overlapping pictograms for small scales, a visibility threshold was defined, so that the pictograms only appeared at a small zoom scale. Furthermore, pop-ups for the room plans and pictograms were added via the *Configure Pop-up* functionality (see Figure 22). The pop-ups were configured in such a way, that they displayed the information stored in the fields of the attribute table as a descriptive text. For the pop-ups of the pictograms, self-made pictures of the specific points of interest, stored on the GIS server *http://kartoipa01.ethz.ch,* were included by accessing them with the respective URL (made accessible through *Apache*). On click on a specific room or pictogram, the corresponding pop-up shows up.

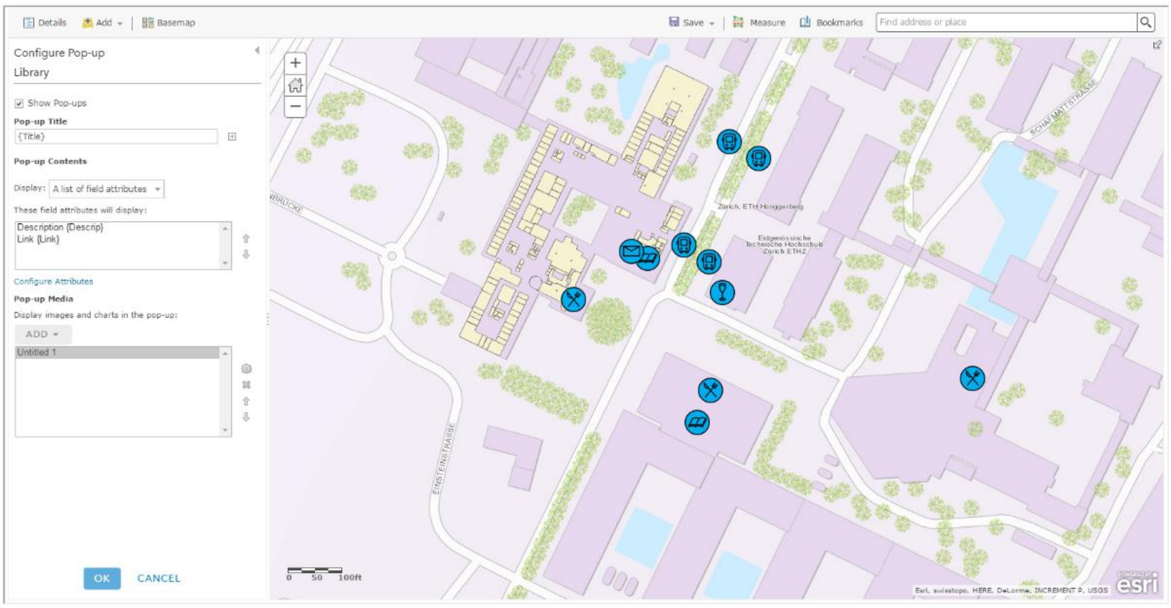


Figure 22: *Configure Pop-up* in the *Web AppBuilder*.

Further functionality was introduced to the application with the implementation of different widgets. The widgets were separated into two categories: the map internal widgets and the supplementing widgets. The map internal widgets, placed on the top within the map, represent the core widgets of the application, displaying results as new information on the map. In contrast, the supplementing widgets complete the application with useful side functionality. They were placed on the top right corner of the application, outside of the map, indicating their complementary nature.

Regarding the map internal core widgets, four widgets were implemented: the *Search*-, *Layer List*- and *Time Slider* widget. The *Layer List* widget was used two times. The *Search* widget[10] was integrated in the application (renamed to *Search room*) to provide the user the possibility to search for rooms of the *HIL* building. As shown in Figure 23, it was configured in such a way, that the user could either enter the building (*HIL*), the level (e.g. *G*), the room number (e.g. *15.1*) or any combination of the three. Any rooms containing the entered values are suggested to the user. By clicking on one of the suggestions or by pressing enter, the search widget zooms in on the specific room and displays further information about the room in a pop-up.

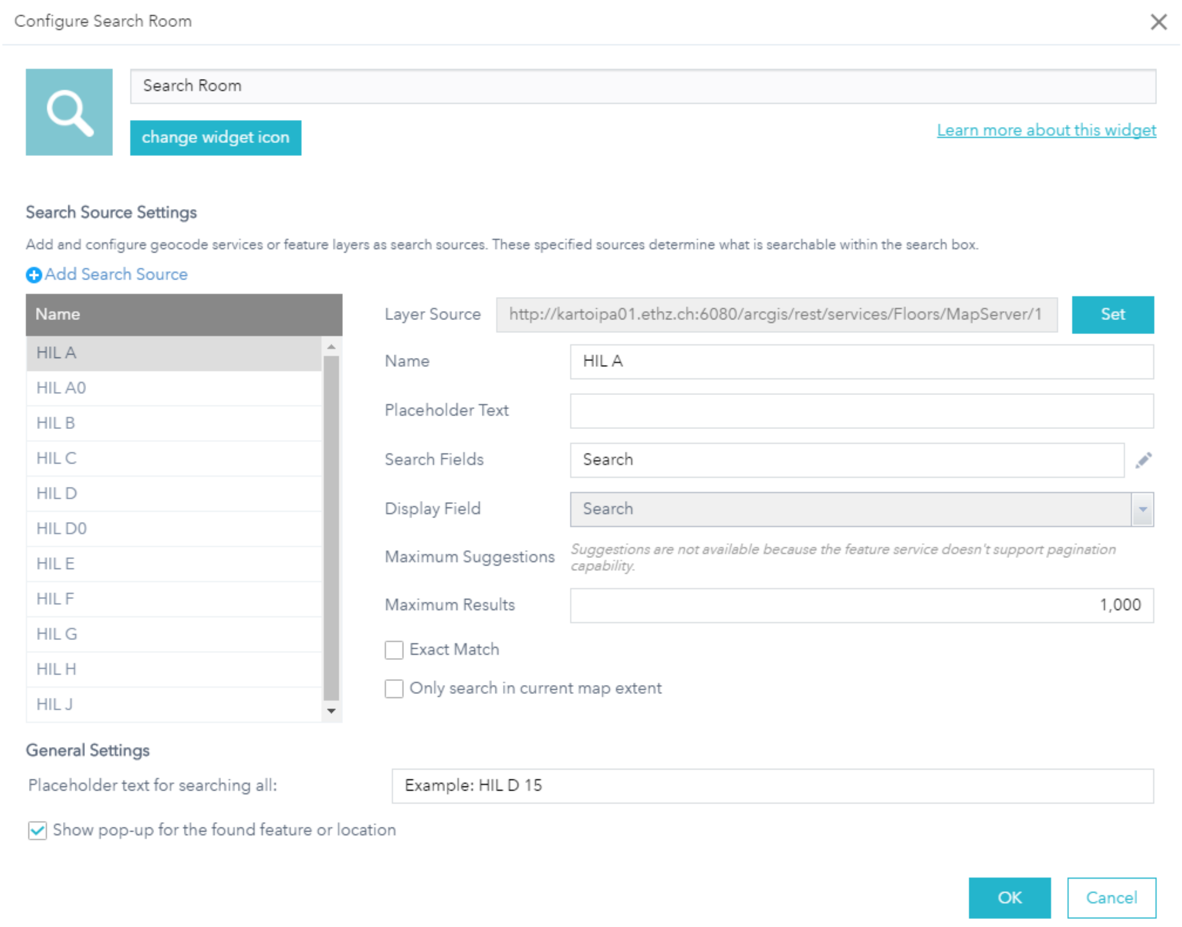


Figure 23: Configuration of the *Search* widget.

Additionally, the *Layer List* widget[11] was used to provide the option to turn feature layers on and off. The configuration of the widget allowed to choose which layers would be shown and to set possible actions for the included layers. In the first *Layer List* widget, only the room plan layers were integrated

[10] Further Information on the Search widget:
https://doc.arcgis.com/de/web-appbuilder/create-apps/widget-search.htm (last accessed on 10 January 2017).
[11] Further Information on the Layer List widget:
https://doc.arcgis.com/it/web-appbuilder/create-apps/widget-layer-list.htm
(last accessed on 11 January 2017).

and the possibility to make them transparent was selected. This widget was renamed to *Select floor.* The option to make room layers transparent was regarded as a necessary step, because multiple room plan layers can be activated at the same time, resulting in a stacking of layers on the same area. The transparency counteracted the restricted possibilities to handle such a situation.

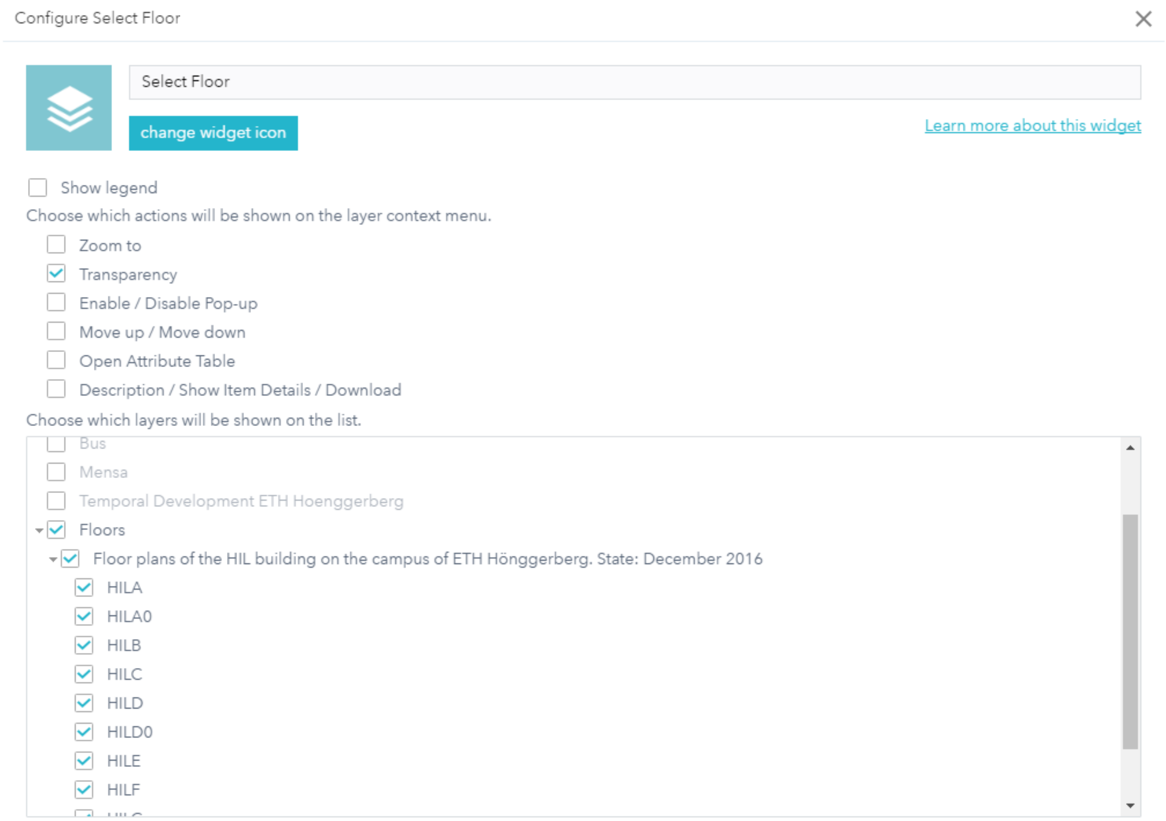


Figure 24: Configuration of the *Layer List* widget associated to the display of the room plans.

For the second *Layer List* widget, a layer containing the buildings of the campus of *ETH Hoenggerberg* and time stamp of their entrance in the portfolio was selected. This layer was needed to run the last core widget, the *Time Slider* widget[12]. The introduction of the *Layer List* widget for this layer allowed the separation of the *Time Slider* widget from the other widgets, which was necessary due to the overlap of the results from the *Time Slider* widget and the room plans. Furthermore, a new symbol for the button of the second *Layer List* widget was created in *Adobe Illustrator* to prevent misunderstandings with the first *Layer List* widget, which used the default symbol. The created symbol represents a combination of default symbols of the *Time Slider*- and the *Layer List* widget as shown in Figure 25.

[12] Further Information on the Time Slider widget: https://doc.arcgis.com/it/web-appbuilder/create-apps/widget-time-slider.htm (last accessed on 11 January 2017).

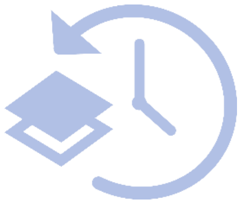


Figure 25: Created *Layer List* widget symbol.

The *Time Slider* widget was introduced and configured according to the portfolio entrance date of the buildings. By activation, the buildings appear on the map depending on the date of portfolio entrance, augmenting the application with information about the temporal development of the *ETH Hoenggerberg*.

The supplementing widgets comprised the *Print-*, *Info-* and *Legend* widget[13]. The *Info* widget contains text which shortly describes the individual widgets. Furthermore, the source of data and authors of the map are mentioned. This widget was set as visible when starting the application to ensure a good understanding and clear data sourcing. The *Print* widget allows the user to print the current section of the map. A wide variety of layouts (landscape, portrait, A3, A4, letter etc.) and formats (*PDF*, *SVG*, *PNG*, etc.) are supported. Finally, the *Legend* widget was implemented. It automatically updates itself according to the features visible within the map. By default, adding text to the legend is not supported, only the layer names are automatically displayed. Therefore, the layers were labeled accordingly. To structure the legend, the room plans were published as a feature service in such a way, that they appear within the *Legend* widget subordinate to the *HIL* building. This was achieved by publishing the room plans as nested layers within a group layer which itself was nested within another group layer. Because the group layer names appeared within the *Legend* widget, the inability to include self-written text in the legend was bypassed by labeling the layers and group layers accordingly and publishing them on an external GIS server. The latter was necessary because of the inability to publish group layer feature services on *ArcGIS Online* directly.

The *Web AppBuilder* allowed to define a color theme for the application. Among others, this color is applied to the top bar of the application. The official *ETH* color *ETH 1*[14] was chosen. Consequently, the affiliation to the *ETH* was emphasized and the contrast between the *IKG* logo and the top bar was increased.

[13] Further information about the widgets on:
http://doc.arcgis.com/en/web-appbuilder/create-apps/make-first-app.htm
(last accessed on 11.01.2017).
[14] CMYK color model: CMYK 100 | 70 | 0 | 30.
Source: https://www.ethz.ch/services/en/service/communication/corporate-design/colour.html
(last accessed on 07.01.2017).

4. Results

4.1. Description of results

4.1.1. Enhancement of Esri's World Topographic Map

The enhancements for the *Esri*'s *World Topographic Map* are divided in different zoom levels. Buildings, roads, parks, places and vegetation are adapted depending on the zoom level as already seen in the diagram of Figure 10.

The basemap is characterized by a general violet area that designates the educational sector of the map. The same is valid for the buildings. There are different types of roads. The campus has essentially four types of roads as described in the template provided by *Esri*:

- *Major Arterial/B or C Road*: principal roads in the middle of the campus (Wolfgang-Pauli-Strasse).
- *Local*: all the other asphalted roads used by cars.
- *Recreation* (1st order): road used by cars and pedestrians.
- *4WD - Recreation* (2nd order): track normally just for pedestrians.

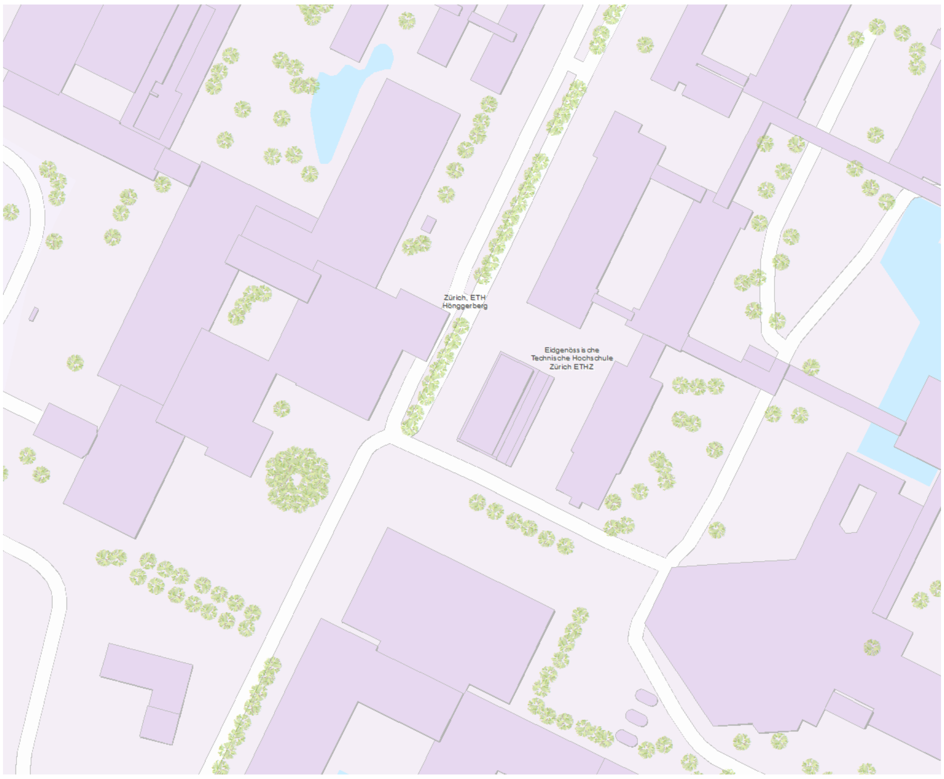
The *Esri*'s *World Topographic Map* is enhanced with newly constructed buildings. The *HWW* and the *HWO* (*Students Village*), the *HCP*, the *HGP* and the *HIB* buildings are embedded. Figure 26 shows the comparison between the original dataset received from *Esri* (figure left) and the enhanced version (figure right). As displayed from the figure below there are multiple improvements already in this level (level 17). In this zoom level, the general description of the campus of *ETH Hoenggerberg* is not visible anymore. It is replaced with the labels of the buildings. New vegetation is added and in the same way also parks and places. Parks and places will be explained further in details later in the description of the further zoom levels.

Figure 26: *Esri*'s *World Topographic Map* (zoom level 17): Original (left) and enhanced version (right).

In the following figure (Figure 27), the next zoom level (level 18) is presented. The buildings are labeled down to this scale of 1:4'500. As visible in the enhanced figure, in the *Students Village*, there are three different buildings that have the same denomination (*HWO*). This denomination is not repeated for each building, because of the chosen properties described in the previous chapter "Methods and procedures". Just the major arterial and local roads are labeled in this zoom level. The labels of the roads follow the path of the road itself. The labels on the buildings as well as in the roads are not static, but dynamic. This means that if for example just a corner of a building is displayed, the label will be placed exactly on this building's corner.

Figure 27: *Esri*'s *World Topographic Map* (level 18): Central sector of the campus of *ETH Hoenggerberg* (original on the top and enhanced on the bottom).

The last zoom level (level 19) is the most important regarding the details. The figure below (Figure 28) depicts this zoom level. The labels present on the roads, places and parks are introduced down to a scale of 1:1'500. The labels of the different objects also have different font styles. The font's style of the roads is the same as the original, whereas for the parks and places the font style is decreased by one point. Furthermore, the font for parks is green colored, whereas the font for places is black colored.



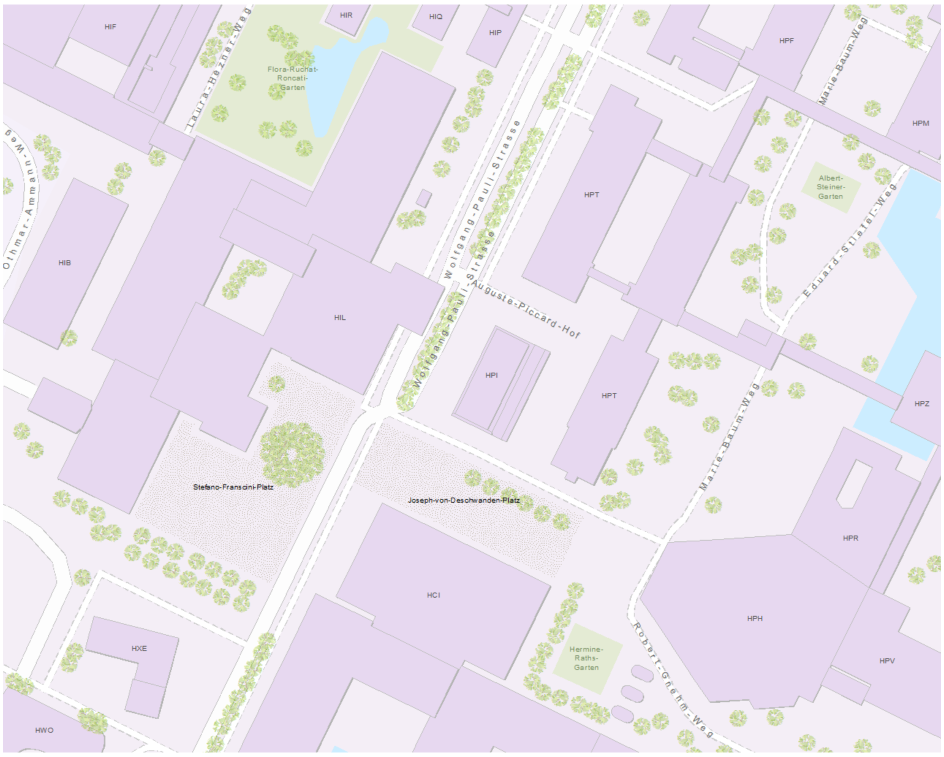


Figure 28: *Esri*’s *World Topographic Map* (level 19): Central sector of the campus of *ETH Hoenggerberg* (original on the top and enhanced on the bottom).

4.1.2. Web map application

The web map application provides an adaptive (for all types of dispositive) (ESRI, 2016/3) interactive map of the campus of *ETH Hoenggerberg*. The background used for this application is the *Esri*'s *World Topographic Map*[15].

In the top bar, general information about the application is present. The logo of the *Institute of Cartography and Geoinformation* (IKG) together with the name of the web application "ETH Hoenggerberg Campus App" and the type of project "Interdisciplinary Project Work, Autumn Semester 2016". Always in the top bar, on the right, the legend button is available together with a print function and an information button, where general information about the application is clarified.

All floors of the *HIL* building can be enabled as operational layers with the *Select Floor* widget. Thanks to the external *ArcGIS Server*, the layers can be selected or deselected as a group layer with an explanation of the floors as shown in Figure 29.

On the bottom left, a meter bar is displayed.

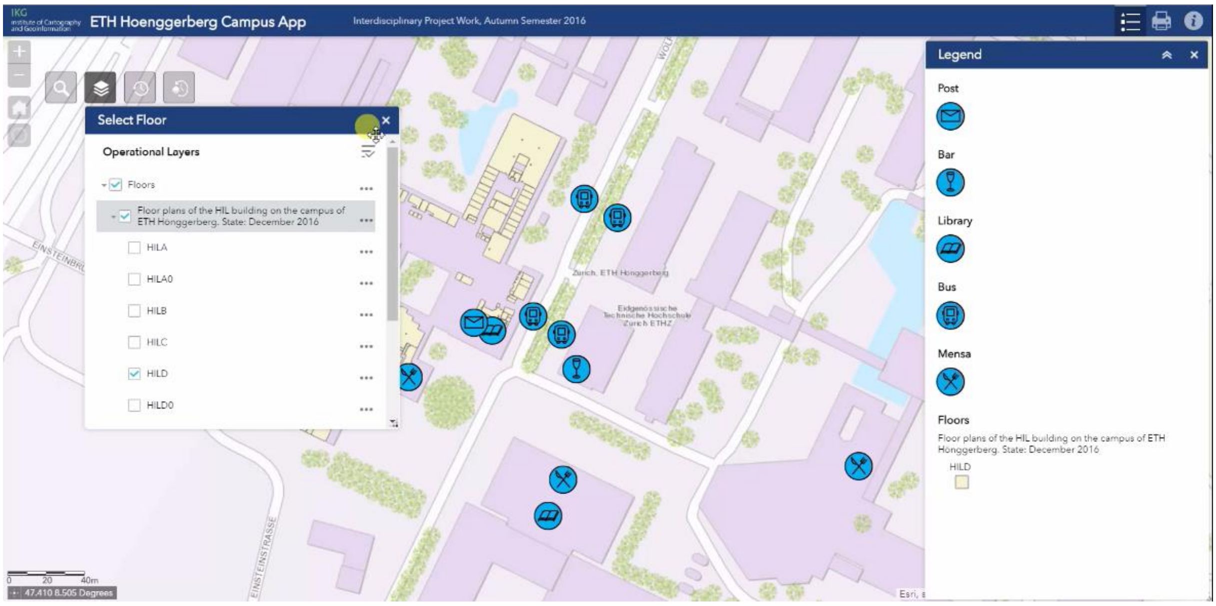


Figure 29: Web map application: Operational layers and legend.

This web map application provides a search functionality for the rooms of the *HIL* building as shown in Figure 30. To gain more flexibility with the search engine, different forms of key words can be entered. In the table below (Table 2) some examples are described.

[15] The version shown in the figures is not the enhanced *World Topographic Map* during this project.

KEY WORDS	EXAMPLE	RESULTS
BUILDING	HIL	All rooms displayed per level and room's number
LEVEL	D	All rooms in the designated level
ROOM'S NUMBER	53	All rooms in each level with the same room's number designation
LEVEL + ROOM'S NUMBER	D 53	All rooms with this designation (if more available)
BUILDING + LEVEL + ROOM'S NUMBER	HIL D 53	Zoom into the selected room

Table 2: *Search* widget: Examples.

Each room is a polygon feature that contains information about it. The information about the selected rooms is displayed on click in form of pop-up that includes the designation of this room, the room type, number of seats and available materials. The most represented room types of the *HIL* building are: shaft for transportation, archive, general corridor, magazine, elevator, exercise room, installation room, toilet, electrical power supply, general office room and classroom.

Available materials comprise, amongst others, black- and/or whiteboard (with square meter specification), quantified projection surface(s), etc.

Figure 30: Overview of the web map application.

The interactive pictograms, which appear at a specific zoom level, indicate points of interest such as libraries, bus stations, refectories, etc. They are structured so that they are visible and easy to recognize and remember. By selecting one of these pictograms, a pop-up window appears, which describes the specific point of interest together with one or more self-taken pictures and a link to official web-site. In Table 3, the included pictogram types are displayed. As shown in Figure 29, the pictograms are not grouped in the legend as group layers.

	Library
	Refectory
	Bistro
	Shop
	Post
	Bus stop

Table 3: Points of interest.

An animated historical visualization of the campus of *ETH Hoenggerberg* can be displayed. The *Time Slider* is a widget that allows to show a further layer on the web map application that includes time properties. The purpose of this animated layer is to display the campus development (portfolio entrance) since the year 1965, as shown in Figure 31. To activate this functionality, it is necessary to first activate the operational layer of the temporal development that is placed on the right of the *Time Slider* widget. As said before, the legend will display just the visible layer.

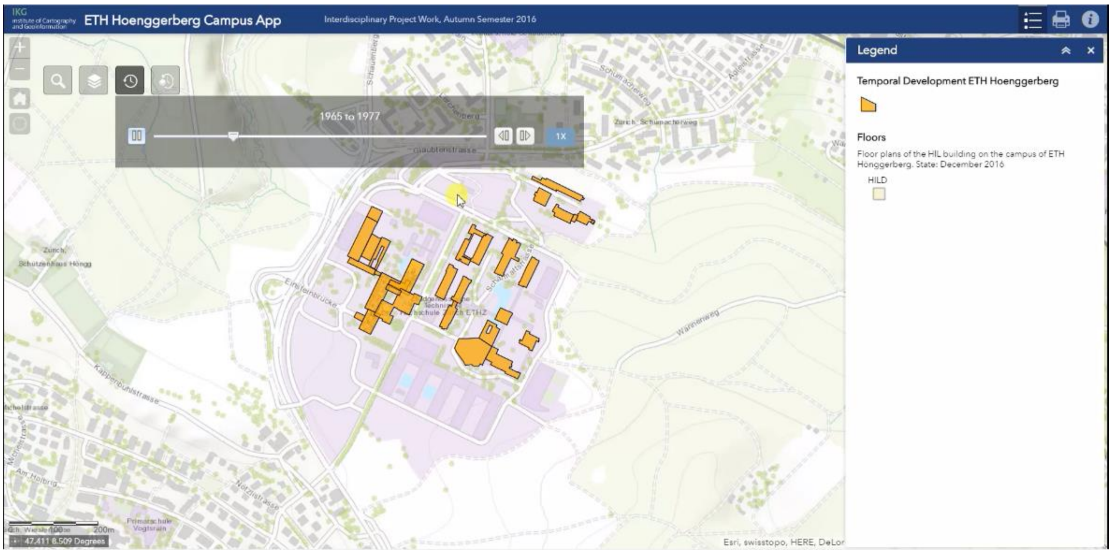


Figure 31: Web map application: Temporal development *ETH Hoenggerberg*.

4.2. Interpretation of results

The *Esri*'s *World Topographic Map* of the campus of *ETH Hoenggerberg* is ready to be delivered and published as an integral part of the *Esri* project. The *ETH Immobilien* must give its endorsement for the public release of the data relating to the shape of the buildings. The endorsement also concerns the web map application for the public release of the rooms' shapes and the related information. The basemap follows the same styles as the rest of the *World Topographic Map*.

The web map application is finished for the *HIL* building and is ready for further development for the other buildings.

5. Outlook

5.1. Overall conclusions.

The interdisciplinary project work was interesting and gave the opportunity to work on a product that may be introduced in the *World Topographic Map*. The engagement on this project helps us as students to work by means of new applications delivered by *Esri* for different type of topics. It gives the chance to learn about different application systems in communication between each other like *Server* and the *Client-Side systems*.

ArcGIS Online and its *Web AppBuilder* offer a simple solution for people, who want to configure an interactive web map and giving the creator as well as the user of the map a good degree of freedom by incorporating interactive elements. A momentary disadvantage of this application is the impossibility to create group layers out of separate published feature services. This is only possible using an external *ArcGIS Server,* but entails limited modification functionality within *ArcGIS Online*, as described in the chapter “Methods and procedures”.

5.2. Achievement of objectives.

All the previously arranged objectives were achieved. The basemap of the campus of *ETH Hoenggerberg* for the *Esri*’s *World Topographic Map* was enhanced with new buildings, roads, parks and vegetation, corresponding to the actual situation. Regarding the web map application, the interactive web map, specifically built for the *HIL* building, is ready to be used. Especially by means of *ArcMap*, *ArcGIS Online*, *ArcGIS Online – Web AppBuilder* and *ArcGIS for Server*, it was possible to create a standard, complete and user-friendly interface.

5.3. Potential future work.

At the *ETH Zurich*, particularly on the campus, there are always changes. For this reason, the basemap can be constantly improved by adding newly constructed buildings and roads and adapting the vegetation. Just now, roads, places and vegetation around the new buildings of the *Students Village* are not entirely finished yet. Therefore, the application could be updated to the actual situation in the future.

Another step is to enhance also the *ETH Center* with the same style as the campus *ETH Hoenggerberg* by adapting the renewed and the restored buildings and the corresponding labels.

The same can be done for the *University Zurich* and the university of applied sciences and arts in Zurich. This way, a style's hegemony for all the educational institutions of the city could be achieved.

For the web map application, there are many possible extensions. The first one is to enhance the interactive map by adding room plans and their corresponding information for other buildings. New information like diagrams could be added, e.g. the development of the number of students per year from the foundation of *ETH* in the year 1855 (ETH, 2016/2) to nowadays. The *JavaScript* code could be adapted manually by means of the *Web AppBuilder for Developers,* adding more flexibility to the interface and automatically joining the *Time Slider* widget together with the temporal development layer of the campus. Another improvement is to transform the checkboxes of the floors in the *Layer List* widget to radio buttons, so that the floors can be switched without having to deselect the previous selected floor. The search function could be modified with *JavaScript* code to automatically enable the floor on which the searched room is present.

One could also incorporate social media services like *Facebook* and *Twitter* in the application to publish news or comments on the campus.

A further possibility is to write an interactive web map using *Google Maps API*, *JavaScript* (JS), *Cascading Style Sheets* (CSS) and *HyperText Transfer Protocol* (HTML), to have more flexibility adapting the interface on the client side.

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7. Signed declaration of originality

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