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Sketching in Situ

Sketching 3D Augmented Reality Features with Mobile Devices

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Foreword

During the realization of this research, many people support me with their guidance, support and knowledge for the completion of this project. First I have to thank CONACYT(Comisión Nacional de Ciencia y Tecnología, National Commission of Science and Technology) for funding my master degree studies. I would like to thank my supervisor Dr. Ir. Ron van Lammeren for his guidance and knowledge, and GIS specialist Aldo Bergsma of the Laboratory of Geo-Information Science and Remote Sensing for helping with the setting up the server and his knowledge in the Layar application. I want to thank to my friends for providing me with a nice work environment and support. Finally I thank my family for their support and believe.

Abstract

Augmented reality (AR) is a technology that just started to be used in prototypes to enhance specific characteristics from the real world. Some of these prototypes are the mobile devices such as smartphones, which are common used for many users around the world. Urban planners, architects and urban designers usually have to do a sketch before initiating any kind of project, so how about using augmented reality for this purpose. This project designs an application to create augmented reality features in the outdoors by using mobile devices. In order to achieve this task, the Outdoor Sketch Application (OSA) is created, this applications consists in a tree tier architecture design: client, service and data. The client send data input to the service to process it and store it in a server so that the client can observe the display in his/her mobile device. The sketched objects were displayed in the augmented reality environment. In order to observe how accurate the application is, the horizontal accuracy of this application was tested by doing several measurements with the mobile device. The test is divided in three parts: a statistical test, a visual inspection and a 2D sketch. The statistical sketch proved that the X and Y GPS measurements of the mobile device are not accurate, the visual inspection of the AR models in the device show that the AR models are accurate at some extend and the 2D sketch test proves how inaccurate a sketch can be. The OSA shows that AR models can be created in situ via AR application, the accuracy of the procedure is reliable in the context that the objects are sketched from a 2D environment to a 3D environment. The 2D sketch test shows the reliability of a sketch. Sketch by definition is a quick way to graphically demonstrate an image, a concept or design.

Keywords: Sketching, Augmented Reality (AR), AR features, 3D Modeling, Smartphones, GPS, Service Provider.

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Chapter 1 Introduction

1.1 Background

Any city with continuous modifications in the urban environment, but the community sometimes it's not aware of the city projects that are in motion, it could be useful for the community to help in the creation of the urban environment they desire to have, urban planners can have an idea the community wants and desire to have, and the planners can modify it as well, until the project is accepted.

Nowadays, the use of mobile devices is becoming part of the life style of the average person, in the extent that we seem to monitor and control everything in a remote way with different kind of apps that are in the online market.

Most of the smartphone applications available by the online market work with Location Based Services (LBS), the services are used for navigation purposes and they form part of mobile applications and computing (Arning, Ziefle, Li, & Kobbelt, 2012). According to Steiniger's lecture notes, LBS provide location of the user, the possible existing places around the user and navigation advice in case of how to reach these places. In the notes are described the LBS components which are the following (Steiniger, Neun, & Edwardes, 2006):

- Mobile Device. The tool for the user to request and handle the data.
- Communication Network. The network transfers the data to the user based on the service request from the mobile terminal to the service provider.
- Positioning Component. The user positions is necessary for processing the service, usually the position is obtained by the mobile communication network or by the GPS receiver in the device.
- Service and Application Provider. It is responsible for the service request processing, which include the calculation of position, finding a route, etc.
- Data and Content Provider. To avoid the storage of data, service providers will maintain all the information requested by users, geographic base data and location information data will be requested from and stored by the network.

Augmented Reality (AR) is a variation of Virtual Reality (VR), whereas Virtual Reality completely immerse the user in a synthetic environment, AR allows the user to see the real world, the virtual objects are superimposed upon and composited with the real world. AR enhances, modify and/or supplements the reality rather than totally replace it (Figure 1). (Azuma, 1997)

Figure 1. Augmented Reality in IPhone®(Arthur, 2010)

Augmented reality has originally been used for visualization purposes by researchers in laboratories. Now it's more common to the public use for advertising and entertainment (Hugues, Cieutat, & Guitton, 2011). Augmented Reality is a technology that is based on mixing computer generated stimuli (visual, sound or haptic) and real world ones (Portalés, Lerma, & Navarro, 2010). It has been introduced in many different areas, mainly to visualize virtual data in real environments; such emerging areas include education, entertainment, media arts, surgery, robotics, media arts, GIS and city planning (King, Piekarski, & Thomas, 2005).

Augmented reality (AR), according to Portales, provides the following characteristics (Portalés et al., 2010):

- The ability to enhance reality. Augmented Reality can generate stimuli (audio, visual, etc.) that can be added to physical environments.
- Seamless interaction between real and virtual environments. An interface seam it's the functional constrain that forces the user to change between a variety of spaces or ways of working, the communication in Augmented Reality between users is a natural way as users can still work with traditional tools and are able to see each other at the same time as virtual data.
- The presence of spatial cues for face-to-face and remote collaboration. Computer generated objects can be spatially distributed in real time according to physical environments.
- Support of tangible interface metaphor for object manipulation. Physical objects can be used directly manipulate virtual data in such an intuitive manner that people with no computer background can still have a rich interactive experience.

AR is been used in smart phones with the purpose to provide an overview for future urban planning, by adding expert and public participation of average users in the development of urban infrastructure (Allen, Regenbrecht, & Abbott, 2011).

In future planning, more enthusiastic responses have been appearing according to landscape planning. However the results are only based on a one-way direction which means that new or changed elements are only presented (such as new construction sites or buildings in progress). Ideas related to create new features or to change existing features, could not exist when visiting a terrain and be implemented visually. One of the first attempts to sketch or design an object that do not exist yet, came from the Kröllers, they had full-scale models of the design built in wood and painted canvas at the desired location so they could judge them properly (Museum, 2006).

Sketching in Augmented reality was proposed for learning support environment, the objective was to display and superposition visualization of the sketched features (Shirouchi, Soga, & Taki, 2010); *In-Place Sketching* refers to sketching in the real world according to the rules of a predefined visual language to create virtual content for 3D augmentation (Hagbi, Bergig, El-Sana, Kedem, & Billinghurst, 2008).

GPS-based AR is used for exploring larger areas which makes a good representation of AR features, though for some specific environments it might have some difficulties, one of the reasons is the overlay of data that can overlap in the camera view, which is produced by the low accuracy and precision of the GPS device in the smartphones (vdMijden, 2011).

1.2 Problem Definition

Although this technology is enhancing the reality, it is not that perfect. In general, mobile devices have usability issues in hardware when they are processing an AR environment, some of these issues are such as small field of view, low screen resolution due the screen size and like any other AR device: visibility issues, capturing, augmentation (Kruijff, Swan, & Feiner, 2010).

AR applications have to deal with problems with accuracy of the GPS in the mobile device and the precision in the location and orientation of the AR features in the real world, plus that it depends of the situation the application is used. Most of the AR applications are used for display the AR features although the features are not fixed all the time, the features change position because of the constant variance of the GPS location.

For making accurate AR systems, it is necessary to develop accurate long-range sensors and trackers that report the locations of the user and objects in the environment. With accurate calibration it is possible to achieve accurate registration in AR systems (Shin, Jung, & Dunston, 2007). These calibration methods are used for marked AR. Marked based AR is the approach that enables the display of AR features by using markers tags (Hugues et al., 2011).One example of calibration is the work from McGarrity and Tuceryan who proposed an interactive calibration approach for an optical head mounted display, which requires the simultaneous alignment of multipoint configurations for calibration (McGarrity & Tuceryan, 1999). This concept was applied as well by Kato and Billinghurst but using an interactive camera for calibration and using multiple points on a grid(Kato & Billinghurst, 1999).

AR systems can be divided in indoor and outdoor AR. Indoor AR systems usually use marks for vision tracking, which is a method to fix 3D AR feature to the marks figures in the real environment and identify them by using a camera or other visual sensor, in order to accomplish stable registration, but outdoor scenes are usually more complex so it is hard to track natural features stably (Milosavljević, Dimitrijević, & Rančić, 2010). For outdoor AR the techniques used usually apply devices that were developed by researchers, the devices vary in different capacities, some are more location based or more focused in display the desired augmented features.

In outdoor localization, the GPS and compass from the mobile devices tend to be sensitive, depending on the location and the accuracy of the sensor, GPS information can be of up to 100 meters or even be unavailable in urban environments and compass readings are strongly affected by magnetic disturbances that are unavoidable in these environments (Arth & Schmalstieg, 2011).

The tracking accuracy of GPS within urban areas is quite low, as soon the user positioned too close to the surrounding buildings (Figure 2). When it comes to visual environments tracking, using feature database requires a lot of processing power of the AR device (Raaphorst, 2012).

Figure 2 Accuracy problems. GPS on mobile phones do not provide enough accuracy in urban areas, which leads to miscalculations in GPS position and the misplacement of AR Features

Some techniques were developed to interpret hand sketches and construct the corresponding 3D scenes, like the work of Bergig and Hagbi, but they require single hardware setup, the advantage is that it allows the sketch interaction; this procedure was developed for marked augmented reality and for indoors. (Bergig, Hagbi, El-Sana, & Billinghurst, 2009). Also the work of Wang show the usability of marked based AR in the design of AR environment by adjusting the placement of the markers to build an AR construction site (Wang, 2007).

Some research projects have been carried in creating geo-referenced models in-situ using mobile AR, but the system was conformed of a single point laser rage-finder augmented and with only with a 3 degrees of freedom (3DOF); vertical, horizontal and depth movement of the device, the device ranges from the user to a location that reflects laser light back to the device. The distance and 3DOF orientation allow a virtual laser point to be placed in 3 space relative to the user(Hoang & Thomas, 2009), what appear to be a effective way for represent AR features and improves the display and location of them,

As well the user could use a camera to manipulate the features, their position, scale or rotation; that could lead to flexible 3D content in sketching, which will probably make the AR environment more interactive to the user allowing to edit the AR feature, but for this a setup is required, which is a CPU, a camera, a specialized software and a screen (Bergig et al., 2009).

In resume, all these works show the improvement in recognising and modifying the display of 3D features in the AR environment, positioning of the displayed features, improving devices to create an AR environment and the diverse methods to produce and improve the display of AR features.

Currently there exists not a device and procedure to sketch and display the sketched AR features in situ (in real world outdoor situation). A method to create AR features in-situ by use of mobile could be used to provide collaborative spatial planning, to let community members show there locational ideas, to show to the community as soon as possible the design of buildings and to improve by modification the design ideas for the future urban environment.

1.3 Objective

Because the no existence of a procedure to sketch and display sketched AR features in situ the objective of this research is:

"Develop an outdoors sketch procedure to create three-dimensional features to be used as Augmented Reality on mobile devices"

1.4 Research Questions

In order to achieve the research objective, the following research questions are analysed.

Question 1 (RQ1). How can 3D features be created directly from/in the real world?

The task consists in to find a procedure to create design 3D features in the real world by using mobile technology available.

Question 2 (RQ2). *How to visualize these features by Augmented Reality?*

It is necessary to look for the most effective way to show the 3D features as augmented reality (AR) to the user

Question 3 (RQ3). How to guard positional accuracy of these 3D AR features?

Taking into account the limits in the accuracy of the mobile devices' sensors, it's necessary to quantify the error in the horizontal and vertical position of created features that this procedure generates.

1.5 Reader instructions

In chapter 2, I'm going to discuss the available technology, concepts of Augmented Reality (AR), applications, concepts of sketching by AR and the design outline of the project, by discussing some of the outlines of the outdoor AR and the possible design of the project. The chapter offers some answers related to question 1.

In chapter 3, the methodology to construct the AR features is discussed in this part, as well the design of the application for and the test of the outdoor sketch procedure. In this chapter questions 1 and 2 will be partly answered; later on, in chapter 4 the developed application will be shown. Chapter 5 also finally answers research questions 1 and 2. In chapter 6, question 3 will be answered with the results from the statistical test in positional accuracy and of a visual inspection of these points converted in AR features. Chapter 7 contains conclusions related to the questions, discussion and recommendations for further study.

Chapter 2 Review

Augmented Reality has been used and recommended in a large and versatile ways (Azuma, 1997; Curran, McFadden, & Devlin, 2011), it is more described as tool that a research topic, when it is researched the purpose it's to upgrade the visualization in the Augmented Reality environment (Hoff & Vincent, 2000) with the use of different algorithms and matrix transformations; or in developing a device to create the augmented reality environment improving the tracking with interaction matrices (Comport, Marchand, Pressigout, & Chaumette, 2006). When augmented reality is used as a tool, it can be used for medical purposes to visualize 3D lung dynamics superimposed directly on the patient's body (Hamza-Lup, Santhanam, Imielinska, Meeks, & Rolland, 2007); or it can be used to enhance the teaching in electrodynamics where 3D electromagnetic field are computed with the finite element method and visualized with the augmented reality display (Buchau, Rucker, Wössner, & Becker, 2009).

2.1 Sketching by Augmented Reality: Concept

To properly combine virtual and real objects in such a way that augmented scene appears to be plausible to the user (Portalés et al., 2010), some characteristics and technologies and systems are necessary to building an Augmented Reality (AR) environment (Wang, 2007):

- Media representation. Refers to the format with which digital/virtual information augments the real world view, ranging from abstract to realistic. 3D objects convey more detailed information; the 3D features are geometrically more complex and the textures of the features have more detail and have less basic design.
- Display device. Visual displays are used to present augmented scenes, a display that shows the real environment with the AR features on it, and two basic merging technologies exist: video based see through and optical see through. While video based see through merges live video streams with computer generated graphics and displays the result on the display, optical see through generates an optical image of computer generated graphics, which appears within the real environment. Video based see through merging typically relies on the use of fiducially markers at known locations, which is not convenient to place in outdoor settings; therefore, video based see through displays is not suitable for outdoor applications. Video based see through also demands greater amounts of computation power and resources for outdoor applications
- Input device. Virtual information is manipulated via an input device. The use of appropriate input by the user interface design is generally considered a good practice. Input device could be as simple as 2D input such as mice and keyboard and could be as sophisticated as embodied input mechanism. Tracking technology. Also called position and orientation tracking, is used where the orientation and the position of a real physical object is required.
- Computing device. The capability of available computing power determines the format of media representation that could be used in AR systems. Outdoor settings impose constraints on the portability of devices and associated power supply.

There is an important achievement for the mobile device technology in the field for AR-based applications. The increasing power of these devices with broadband network, integration of high resolution cameras and low-cost GPS receivers, leads to small equipment and high performance (Portalés et al., 2010).

Sheng et al (2011) use spatially augmented reality for visualization and exploration of natural illumination. They let the user position a set of small scale physical wall within the workspace to sketch the 3D geometry for their architectonic design; images captured by a camera mounted above the scene are processed to detect the wall positions. Gaps between the wall are filled to construct a closed 3D mesh (Sheng, Member, Yapo, Young, & Cutler, 2011).

Sketching has interactive qualities because it can be performed during a discussion, and informative sketches can also be created by inexperienced people to a certain degree (Sareika & Schmalstieg, 2007).

Another example is the work of Hoang and Thomas, their modelling process consists in import a geo-referenced polygonal model of a real building from SketchUp and align the model to the real contra part and perform additional modelling using an OSPLR(3DOF orientation tracked single point laser rangefinder). The augmented rangefinder acts as an absolute 3D cursor and allows the user to construct polygonal models resembling real world features (Hoang & Thomas, 2009)

2.1.1 Layar Application

The Layar app was developed by the company with the same name, the application specializes in mobile augmented reality. The application offers two different types of experiences: geolocation – and vision-based augmented reality.

Geolocation-based AR uses GPS, compass and other sensor in a user's mobile phone to provide display of various geolocated points by using the camera device in the mobile phone, although the quality of the image is based in the in the quality of the camera. Vision-based AR uses many of these same sensors to virtually display digital content in context with real-world objects – like magazines, postcards or product packaging- by tracking the visual features of these objects.

The architecture of Layar platform basically has 5 components:

- The Layar Reality Browser. Mobile device application that can be downloaded from the android market or Google Play.
- The Layar Server. The main component of the Layar service, which provides the interfaces to the Layar Reality Browser, the Layar Publishing site and the external Layar Service providers.
- The Layar publishing Website. A website on which developers can register new layers, manage their layer and accounts.
- The Layar Service Provides. This part is created by 3rd party developers. Layers based on Funda, Hyves, Flicker are examples.
- And the layer Content Sources. It provides the content to be viewed in the Layer Content sources are not necessary separated from the Layar Service Providers, but will in general be different logical entities, as existing geo-coded databases

and web services don't support the Layar Developer API (Application Programming Interface).

The user launches the mobile applications on a supported mobile device, and then the Layar client API will send a request to the Layar Server, based on the request, the Layar Server will retrieve the layer definitions from the publishing website. A list of retrieved layer will be sent by the Layar Server and displayed to the client. The user launches the layer from the list at the mobile device, a getPOIs request is set to the Layar Server which will forward the Layer Service Provider of the layer and return AR content based on the Developer API back to the Layar Server. The Layar Server validates the getPOIs response and sends it back to the client device which displays the getPOIs response (Figure 3).

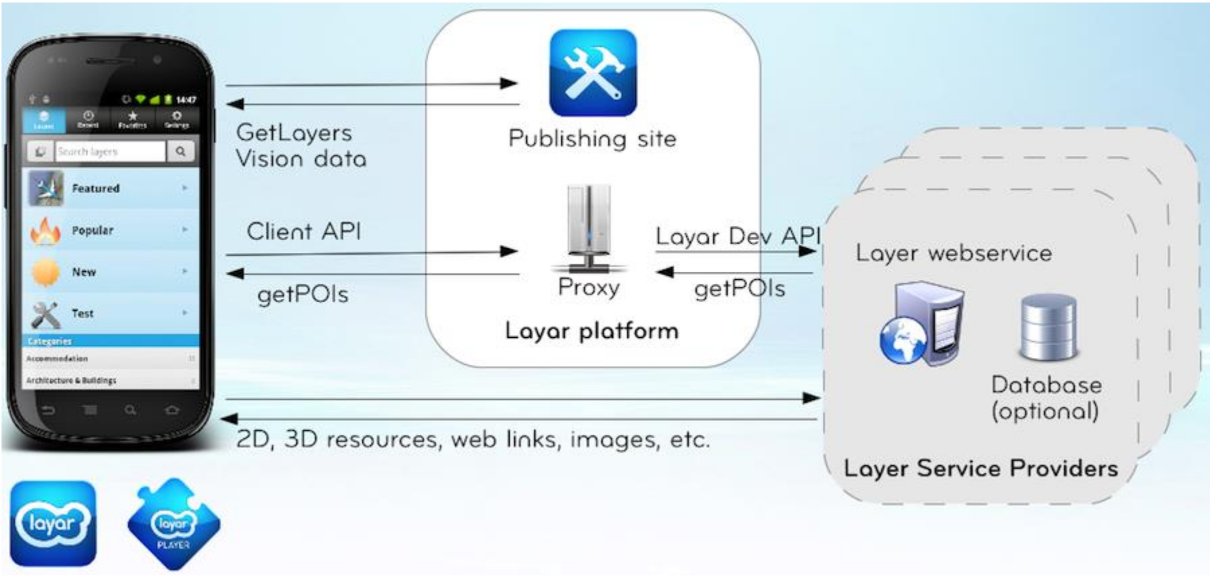


Figure 3. Layar architecture.

2.2 Sketching by AR: Design

The project will use current available Android applications and software to realize the sketching and the visualization of the features. In order to sketch the features, two different use scenarios are plotted, one is the sketch of trees, poles or columns, which are known as point features and the other scenario sketches walls or known as line features.

In the first use scenario the participants may sketch the locations of these stand-alone objects like trees, light poles or columns. We know that some objects are sensitive to orientations and some others are not, and as well that they are static or dynamic. This scenario uses static objects and objects that are not sensitive to the orientations; therefore the user will be able to sketch objects that are not affected by orientation. The design of light poles is not sensitive to the orientation. The desired location to sketch is represented as a single point that can be used as a basic anchor to locate the 3D models of trees and columns. This scenario is design for the purpose that it can represent the attributes of real objects, according the height and GPS location of the AR columns; the columns can be used to represent mineral concentration or contamination levels in a certain field or zone.

For the second use scenario, the objective is to sketch a wall like an object in an unconstructed area. The wall is based on a link between the points and they will define the geometry of the wall. The lines use the points as vertexes and use them to construct the base for the wall. The wall height and width is provided by the user for the data processing and drawing part of the procedure. The provided height, that is used to represent the wall, could be used to represent boundary limits between regions or areas in a project, the wall height could also represent time and the AR feature could represent the movement of an object in time. As well the length of the line could also represent magnitude or any attribute of the object we want to represent with the line feature.

It is necessary to take into account the occlusion problem; when doing a video composition of real and virtual scenes, virtual objects are always mapped on top of the images of the physical environment like in the work of Portales et al (2010) which uses a 3D mask for this, the mask is a simplified 3D model of the buildings that are close to the AR feature, the masks has no effect in the visualization, in contrast, the masks are placed in front the visual model, the former will visually delete parts of the latter (Portalés et al., 2010).

2.3 Conclusions

Designers in almost all professions use a paper and pencil to make sketches during the early stages of design, sketching in general can be considered as tool of thought that enables the mind to capture things with are in flux and iteratively refine them, that is sketching according to Buxton and Shesh (Buxton, 2007; Shesh & Chen, 2004).

The cognitive perception that the client can have in the moment of using the service could be explained in the work of Turner and Eve. Turner explores how presence can be maintained within a "synthetic" environment or set of objects. His work encompasses both phenomenological study of the embodied self and the individual's relationship with the surrounding environment(Eve, 2012).

Cognitive intentionality is a set out as the interplay between action and thought. Our perceptual senses are directed at the external world (the information they collected is about things and events in the world (Turner, 2007)). This perceptual sense is also closely connected to the way in which we move and the actions we perform. We would not be able to walk successfully across a city without adjusting to the constant perceptual inputs. Turner therefore suggests that this interplay is the note and is important in assessing presence.

Eve explains that AR offers a number of ways to cognitively involve the users with the AR environment, the users can move around the landscape and change the point of view, the user is standing in reality, there are not edges and no limits on where the user cannot go. The world is the workplace and almost anything can be inserted into it. It allows many opportunities not only to engage cognitively with the perception of the real world, but also the AR environment as well(Eve, 2012).

The two scenarios are given to prove the ability to draw two of the basic class features: point and line. Beside location these AR features representations can have orientation which can be added with the bearing of the device, in this case the orientation of an AR feature is not taking into account in the point scenario. The line scenario use point features as vertexes, which means that feature points will be used as part of the line feature and will provide guide to the line.

There is going to be two ways of representation the AR features according to the scenario, in the point scenario, the point features will be represented as column symbols and the line scenario the lines will be wall symbols. The height of the columns and the walls are decided by the client. The height of the features can represent an attribute or several attributes from geographical data, such as concentration, ratios, or quantity.

From the technical concepts, the research in the AR that has been done so far focuses mainly on the improvement of the display of the AR models, such as better algorithms to do the rendering of the AR models and the design of the devices to display the AR models. The work of Hoang and Thomas shows the possibility of modifying AR models in the AR environment but any 3D model can be put in the AR environment. This study works for the creation of the AR models from in situ data (Hoang & Thomas, 2009).

Chapter 3 Methodology

By using the findings and details in chapter 2, this chapter elaborates on the point and line features scenarios. It will present how the sketch procedure will use geo-data and transform into 3D objects for AR use. First a concept design for an Outdoor Sketch Application (OSA) is given taking into account the three tier architecture, which is a client server architecture where the user interface, the functional process and data are defined and developed as individual modules. With this, the conceptual design of the AR sketch is done (RQ1) and a case study can be realized. It means that data can be collected, stored, processed and transformed to create the 3D symbols. With the use of the android application Layar, it is possible to create such an AR environment. In order to create the AR models, the procedure uses the input created by the user, construct a 3D mesh and save the 3D mesh in a server to be displayed at the AR environment, which is explained in 3.1 (RQ2). In the next chapter, the precision of the procedure is tested by doing several measurements in the same location of 8 different spots, the vertical and horizontal position of the measurements are observed and tested with a t-test, with the criteria that the mean difference in vertical and horizontal coordinates towards an RTK GPS referenced point are equal to 0 (RQ3).

3.1 AR Sketch: Implementation

The first research question is tackled in the following way, some preliminary analysis in the possible tools, devices, software and hardware that are necessary in order to realize the sketching. The Layar environment allows the easy introduction of AR features but the features need to be created in the field, for this one step we need to create input, the data must be designed and processed in order to upload it to Layar server.

The procedure operates in the way that the user requires for a service which provides the necessary modification to the raw input and converts it in a 3D features ready to be displayed in AR environment. The procedure is showed in the next figure (Figure 4). The client only will collect the data to construct the feature he want to create and he will visualize it later on, in the meantime he will be idle while the service process the data.

The concept design tiers are the following:

- Client. The user of the application, the client sends the data to the service and receives from the service the outcome of the process.
- Service. The service is in charge to process the input that the client submits and the service is in charge of the management of the data, it's process, transformation and storage. The storage includes the publication of the data on the designated server for its publication.
- Data. It is the data generated by the client and by the service, it also displays the transformations in file types.

There are 6 steps in the conceptual design of the Outdoor Sketch App that involves the three tiers, the client, the service and the data. The concept design is made for the client understanding, the steps are the following (Figure 4):

- Step 1. Sketch. The client will sketch an object that he desires and perform the necessary measurements to complete the desired object that he/she wants to create, with the use of the ”GPS Essentials” application. Once the measurements are done, the client will send the data, features, to the service tier. The client must provide to the service the type of outcome he desires, point features or line features. In case of point features the client could specify which time of models he desires to put in the point symbols, such as trees or light poles. If the client desires line features, he must provide the height of the line symbols.
- Step 2. Data Process 1. Once the client sends the data to the service, the service will manage the data in separate objects for further processing. Depending in the number of measurements the greater the number of objects will be.
- Step 3. Data Process 2. Here the service will use the data and the height the client provided as a guide to create a 3D frame, which is a set of lines which will be used to create the 3D mesh .
- Step 4. Draw. The service will draw the 3D models by using the 3D mesh as a guide line, all of this is done in a software that allows 3D models modification, such as Google SketchUp.
- Step 5. Storage. The service will store the 3D models in a server, so the client can call the features from the server.
- Step 6. Visualization. The client will access data from the server, the 3D models allowing the visualization of them in the AR environment, in this case the Layar application, inside the mobile device.

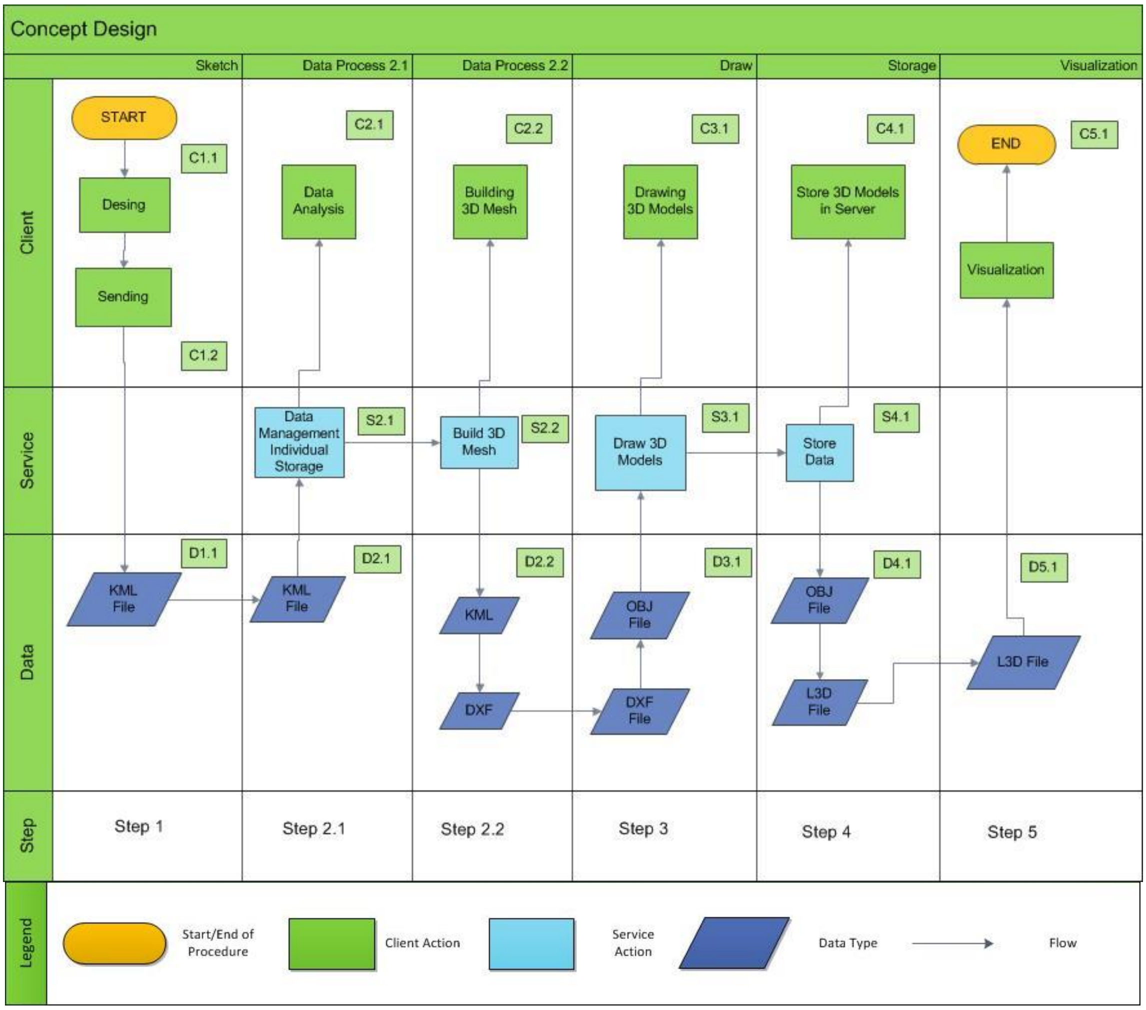


Figure 4. Conceptual design

The service will use the application according the following sketch implementation, which are the steps that the service do (Figure 5):

- Sketch. This step will consist in two phases, the preliminary design of the objects before taking the measurements and going to the field and get the necessary waypoints in order to create the guide for desired 3D models; the waypoints will be the vertexes of the 3D models. This step will use the GPS application for smartphones "GPS Essentials".
- Data process. This process consists in convert the waypoints, into lines, which it will lead to the creation of the 3D mesh, all of this is possible by using different kind of geo tools. The process is realized by ArcMap.
- Draw. From the 3D mesh, the final 3D model is designed. By using the frame as a guide, the 3D models are draw manually, in the case of point features; the base of each 3D mesh is used as an anchor for the models; with the line features the frame is used to draw a wall. The design of the models is done in Sketch Up Pro.
- Storage. Once the 3D models are finished, the entire model is stored in a server and a layer is created in the Layar website to visualize the models.
- Visualization. The client uses the Layar application to visualize the models, some data can be added to the layer of AR models.

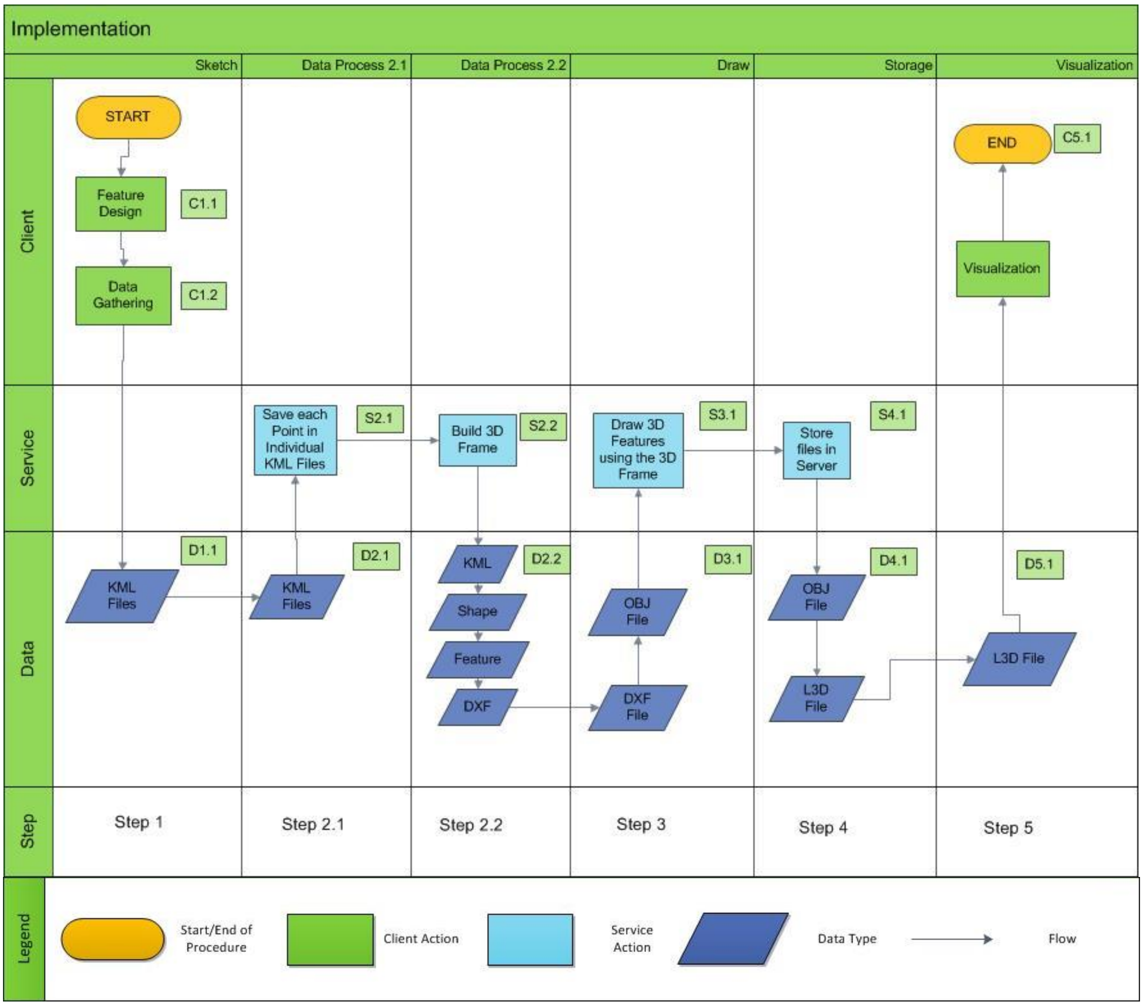


Figure 5. Sketching Implementation

The first step, Feature Design (C1.1), the user will come up with a design of his desire according to the surroundings, in our case the objects are based on points and lines , the client also provides to the service the desired height for the 3D model, next the user employ the mobile application "GPS Essentials" (appendix B) and complete the Data Gathering(C1.2) step, which is the record of the necessary waypoints to construct the desired 3D model, the application only records vertical and horizontal position. In the scenario for creating point objects, each recorded object is one waypoint, and in the scenario for creating line objects, each waypoint can represent vertexes and midpoint of the lines. All the data is stored in kml format (D1.1) in the memory card of the mobile device.

Later each point will be saved in separate KML files (S2.1, D2.1); these KML files are used to construct a 3D mesh according to number and placement of the waypoints. The KML file stores geographic modelling information in XML format; includes points, lines, and polygon; used to identify and label location.

The KML (D2.2.1) files are used to build a 3D mesh (S2.2) by doing the following steps, the KML files are converted in one or several shape files by using a script developed by Jason Prent (Annex C), later the files are converted in features for easy management, the features need to be in UTM projection in order to have distance units in meters, then the features are merged in one data set, the features are converted into a line which serves as a guide line for the 3D mesh. The guide line and point set are buffered; the buffer of the line is slightly smaller to generate more intersections with the points' buffer. Both buffers are converted into lines and merged into one feature, which is a set of lines from the buffers. Then we create the vertex points with the tool "Features to Point", these points represent the base of the 3D mesh; in order to add the height of the 3D mesh, from this last created feature, a copy of the database table is made, the height that the user specified in the Feature Design (C1.2) step is added and merged with the base points of the feature. This cloud of points are the 3D vertex points of the mesh, the mesh is constructed with the sight lines; but this tool create a lot of lines that can be reduced in number by doing a simple selection of features, this select is based in the minimal distance between the original waypoints.

Finally the 3D mesh is exported as a DXF file (D2.2.4), which is used for computer-aided design (CAD) vector images and is compatible with other programs since it's ASCII (text) based; the DXF file can open it in SketchUp Pro (or other software that can modify 3D models and allow exports in OBJ files) as an import file, this allow the easy modification and drawing of the 3D model. An OBJ file is a three dimensional object containing 3D coordinates, texture maps, and other object information; a standard 3D image format that can be exported and opened by several 3D editing programs.

In the Draw part, the 3D model is draw (S3.1) in a 3D software. The drawing differs according to the scenario; in figure 8 the concept design for the Drawing part is illustrated. The created 3D models in the previous step have to be clean and draw inside the software that allows the edition in 3D, such as SketchUp; as well the features need to be transformed in the OBJ format (D3.1).

In the point symbol scenario, the models of trees and light poles are added and located in the middle of the "columns" that were design in the 3D mesh.

The 3D mesh is cleaned by deleting the lines that link the columns, the columns represent the location where the client made the measurements of the waypoints (P2.1), the columns can be replaced with imported models that the user wants to sketch. The imported models are placed at the centre base of the columns (P3.1).The remains of the frame (the columns) are erased and finally the features are exported in OBJ formant (P4.1) (Figure 6).

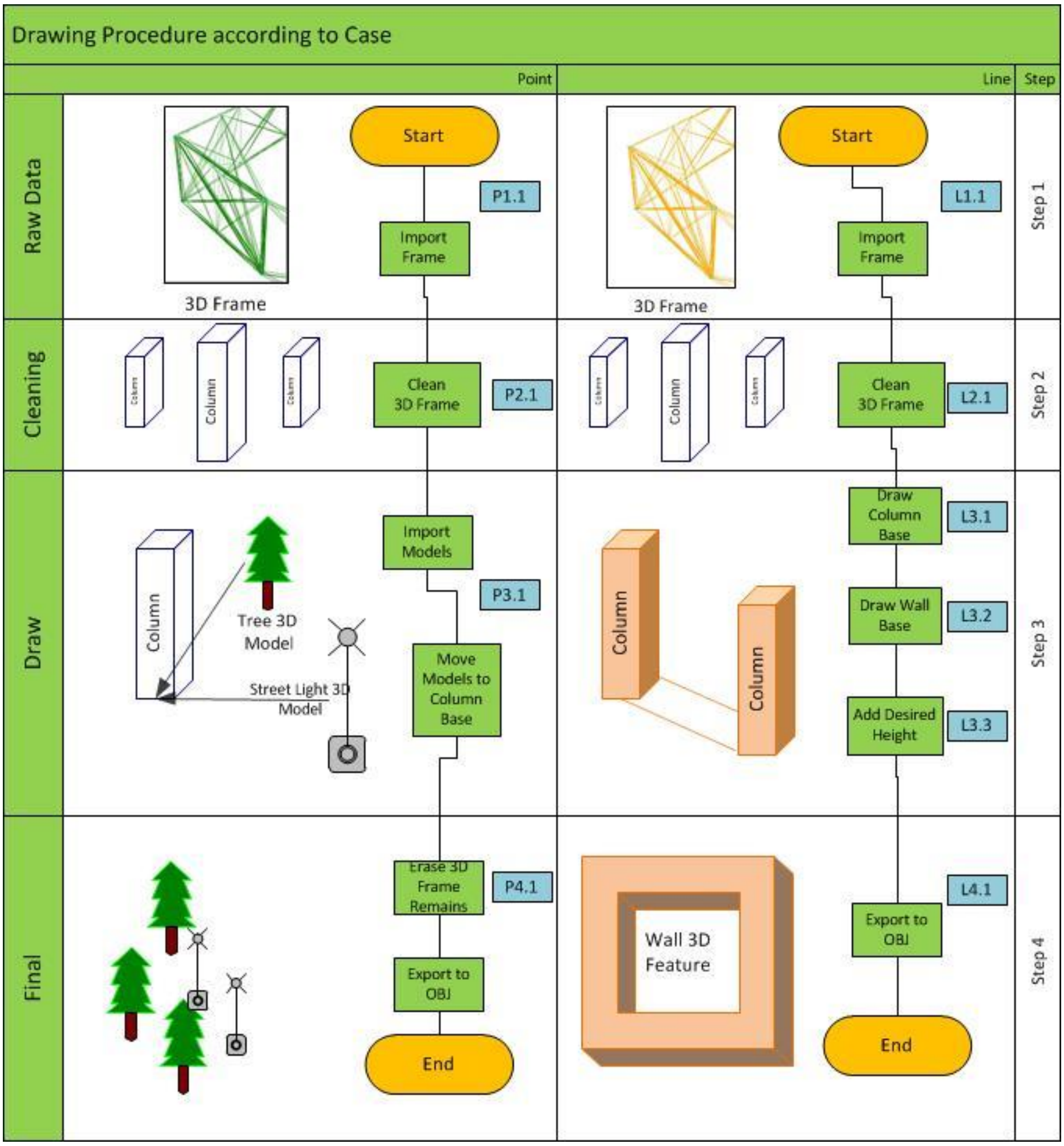


Figure 6. Sketching procedure for point and line feature based scenarios

For the line symbol scenario, each column represent a vertex of the line feature, which can represent a "wall", as in the point scenario the lines that link the columns are erased (L2.1). In the software, the base of the columns is drawn (L3.1) and lines are drawn as well to create the base of the "wall" (L3.2). The height is added, the base of the wall and the column are extruded until they reach the top of the 3D models (L3.3). Finally the result is exported in OBJ format (L4.1) (Figure 6).

In step 4, Storage, the OBJ file is converted in the format that the Layar application can read, for this the company Layar created a java script to change the format from OBJ to L3D (D4.1); this java script can store the textures and the location of the 3D models, the outcome is a L3D file with a JSON file. Both files are stored (S4.1/D4.1) in the server in where the Layar application call the 3D models. In order to call the 3D models from the server, it was necessary to write a XML file which contains the details of the AR features displayed, which include: coordinates, the URL direction of where the AR features are located in the server, scale, text and other details that can be added to the display of the features (Chapter 2.1.1/Appendix E).

Finally in the Visualization (C5.1), the Layar application (Appendix C) can call the L3D files with the respective info that are stored in the server (RQ2).

3.2 Sketching by AR: Test Procedure

The testing of the OSA (Outdoor Sketch App) has been done on the campus of Wageningen University, close to the main building (Forum Building), this location was selected because of its low urban density to avoid the obstruction of the GPS signal, the measurements where carried near to the building to observe how the OSA works near urban areas (figure 7).

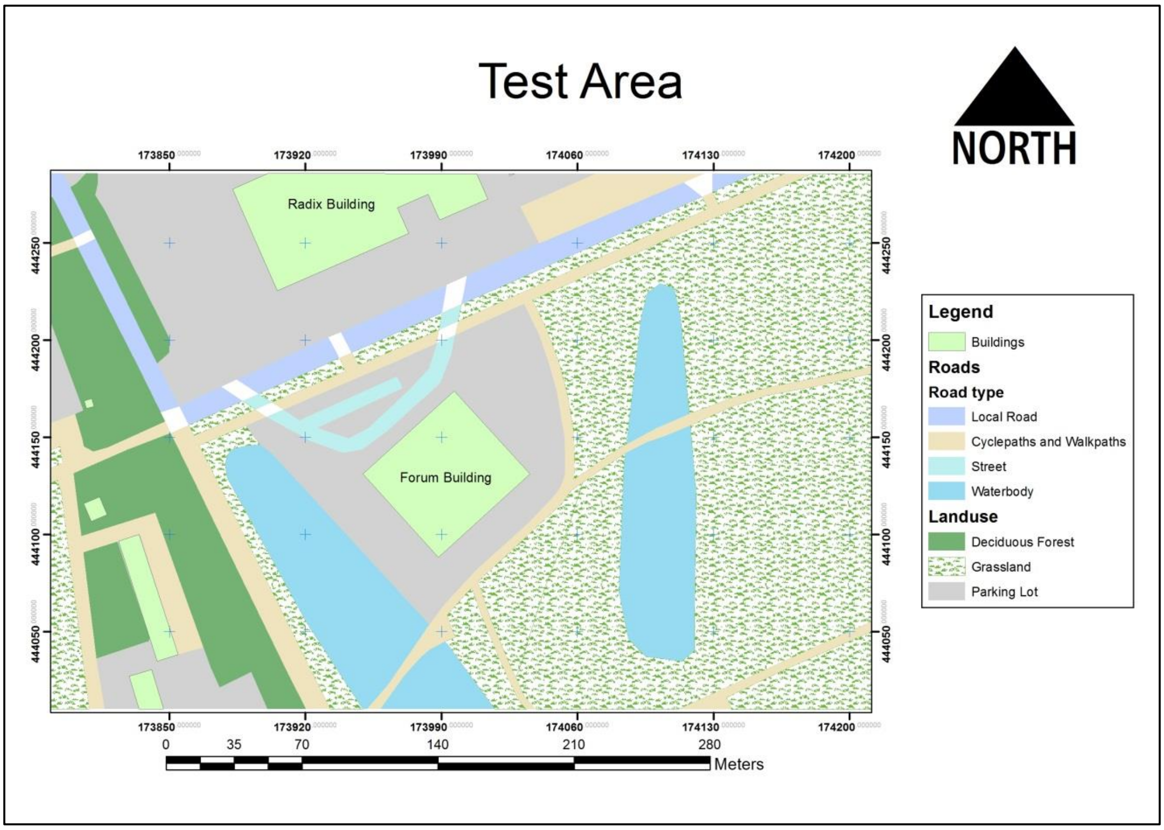


Figure 7. Area where the Outdoor Sketch App is tested

To check the vertical and horizontal coordinates of the generated AR features, a testing procedure is created to prove the accuracy of the procedure. This test is only carried out for the line feature scenario. The reason is that the line symbols are not seriously affected by the orientation as much as the Point symbols.

The test is divided into parts:

- Measured accuracy. Some points are designated to construct a line object; these points are taken several times at the same place, the points that from part of the line feature are geo referenced with a RTK GPS. The test is carried out 50 times and the coordinates are observed. The difference between the RTK GPS coordinates and all measured coordinates of the points are tested with a t- test (the t-test is used to determine whether the mean of a population significantly differs from a specific value, in this case, if the mean is equal to 0, the test is carried in in R) to observe if there is a significant difference of the measurements with the RTK GPS points coordinates. From each measurement, we take into account to the distance towards the RTK GPS points by calculating the difference in the X and Y coordinate. With the difference in X and Y, the distance from the measurement to the RTK GPS point is calculated with the geometric distance formula.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

- Statistical analysis. The distance from the measurements to the RTK GPS are taken into account and graphed in a box plot to see its distribution, as well a linear regression is carried out to look for the RMSE (Root mean square error) to see the fit of the model.
- Visual assessment. The points and the RTK GPS points that were taken in the position test are converted in 3D models by using the sketching procedure described in the methodology, the final AR models will be composed by several columns, where the RTK points will have a higher height that the others to observe the difference between them. In the Layar application we visualize the difference in the distance of the AR measurements columns towards each of the AR RTK GPS columns, the measurement columns will be classified according to the distance to the RTK point. This classification is done during the Draw step (S3.1), where the distance from the measurements columns to the RTK GPS point is evaluated and it is going to be classified in the following way:
    - 0.00 to 2.50 meters.
    - 2.50 to 5.00 meters.
    - 5.00 to 7.50 meters.
    - 7.50 to 10.00 meters.
    - 10.00 to more meters.
- Sketched accuracy. Sketching is per definition not accurate, because it always expresses intended locations and volumes. To understand the impact of the measured and visual assessed accuracy a sketch reference data set has been created, in where the RTK GPS points are put on a paper map and people are asked to sketch a rectangle as small as possible that contain the RTK GPS point. For this test, the size of the point is made bigger in order to be more easy to sketch. The test has an scale of 1:1,000, where 1 cm equals 10 meters.
- Sketched Features Comparison. The paper sketched features the AR sketched features are compared by doing the calculation in the distance from the measurements towards the RTK GPS points and the calculation of the distance from the vertices of the sketched rectangles towards the RTK GPS points. By assuming that the minimal scale is 1:1,000, the procedure can be reproduced for smaller scales like, 1:50,000 or 1:10,000, these scales are mostly used for cadastral and urban maintenance.

Chapter 4 Application

The use of the developed OSA (Outdoor Sketch App) is illustrated by performing an example in the campus of Wageningen University.

The OSA input is created by the client (the user), the user will come up with a design of the features he wants to sketch. The user will record the necessary waypoints that represent all the features that he wants to sketch with the "GPS Essentials" applications with the smartphone by doing the following steps:

1. The user will stand in the location the desired object he wants to sketch and start up GPS Essentials by pressing the icon (Figure 8).

Figure 8. GPS Essentials application start up

2. The user will record the points in GPS Essentials by pressing the plus symbol (Figure 9).

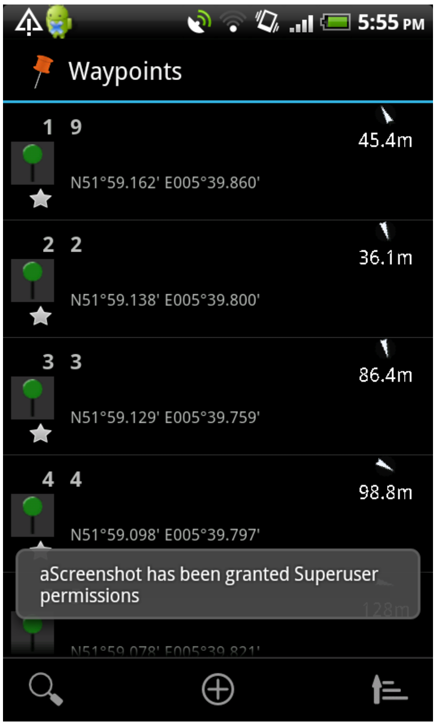


Figure 9. Points recording in GPS Essentials

3. Repeat step 1 and 3 until all points are recorded and check the objects that are going to be sketched (Figure 10).

Figure 10. Points recording in GPS Essentials app

4. Import the objects as a KML file and store it in the removable memory of the smartphone, the files could be downloaded by the service or send to the service for processing (Figure 11).

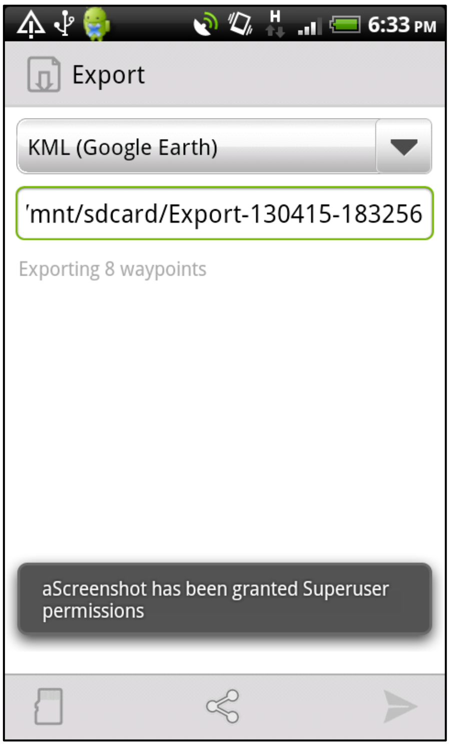


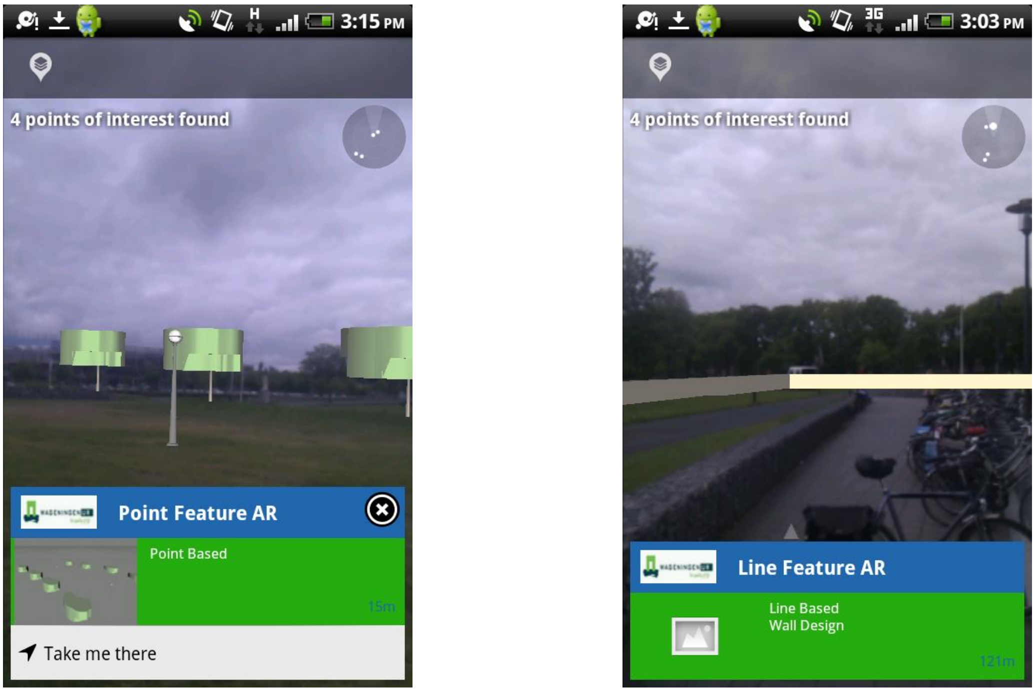
Figure 11. Import objects in a KML file

5. The user waits for the outcome from the service.
6. Once the service notifies the user that the processing is done, the user can start the Layar application and visualize the outcome (Figure 12).

Figure 12. Layar application start up

When the user finished the recording of the necessary points to sketch the features, he needs to save the list of points in kml format in the smartphone and send the file to the Service to be processed. For this as well the user needs to specify to the Service the type of features he wants to represent, in this case, points (for AR columns) or lines (AR walls). In case the points are going to be columns, the user can request to the service to substitute the columns with other 3D models like trees, light poles or other models.

When the service finishes with the processing of the features, the service will provide to the user with the name of the layer created in Layar, so the user can have access to the it in the Layar application at the smartphone. Finally the user can visualize the AR features (Figure 13).



a) b)

Figure 13. Possible AR outcome from sketched: a)3D points models, b)3D lines models

Chapter 5 Results

5.1 Sketching Procedure (RQ1, RQ2)

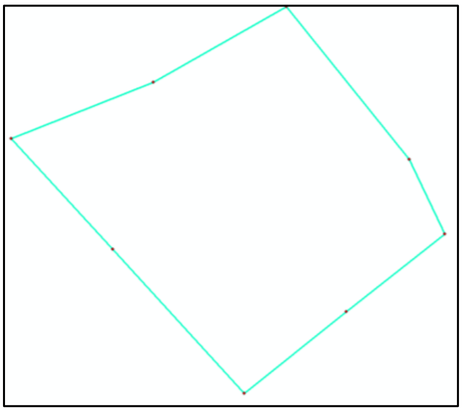
The client can record in-situ any position he desires (Figure 14), and the client send the waypoints to the service are imported to a geo data software , in this case into the ArcMap, to create the 3D frame to later on create the 3D object of the feature.

Figure 14. Record of points

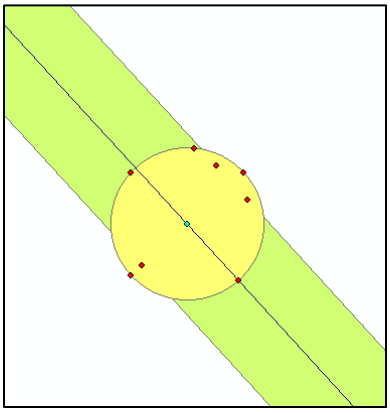
With the proceedings explain in appendix D, which consist in the conversion of the points in a 3D mesh, this procedure was developed for both scenarios due the fact that it is simple to modify the mesh in the 3D software environment for each of the scenarios , the process is summarized in the following steps:

1. We create a feature to join all the points (figure 15a),
2. The created lines and the measured points are buffered (figure 15b). Depending on the scenario the buffer distance is half a meter for point features, in order to be visible in the 3D software for drawing the feature. In the case of the line features scenario the buffer can be changed, if the user wants to represent thicker line features.
3. Next points are created from the intersections between the buffers of the points and the line (figure 15b), these points are duplicated and height is added. The height is by default one meter and a half but it can be changed according to the desires of the client.
4. The points are merged and by using a tool to create line features that represent sight lines from one of more observer points to features in a target class, the 3D mesh is created. The tool creates lines from one point to each of the other points,

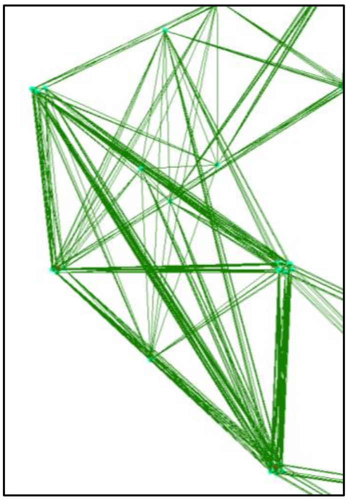
taking in count the height of the points, giving the look and the impression of a 3D object.



a)



b)



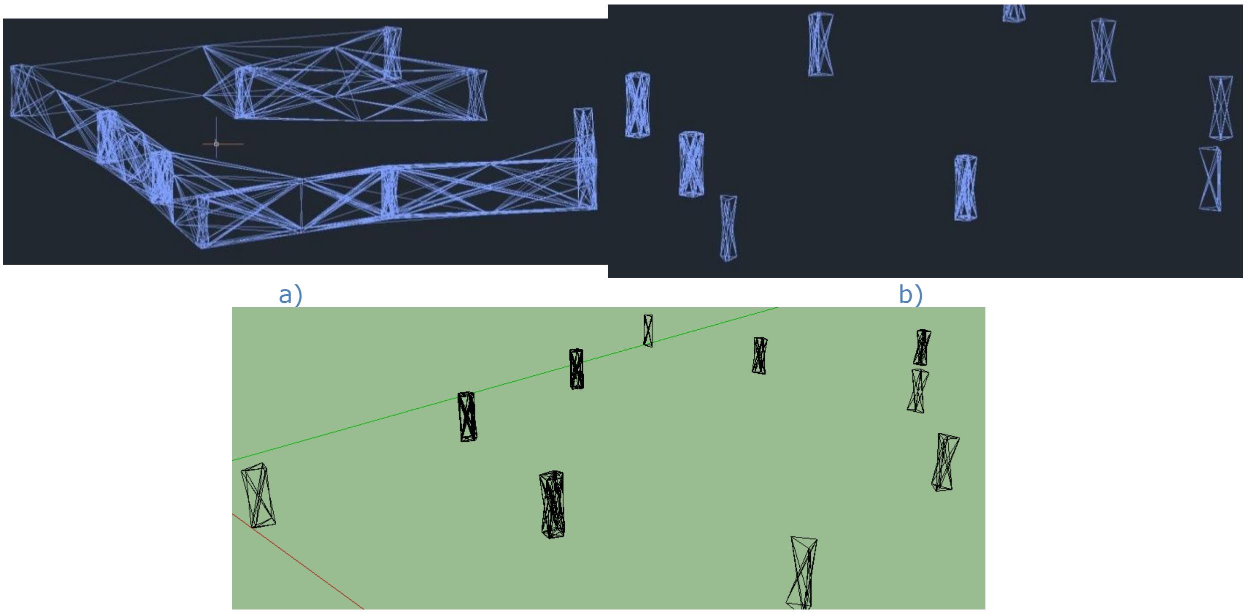
c)

Figure 15. Data Process (S2.2), creation of 3D mesh from points
a) Feature base line b) Intersection points
c) 3D frame builded from intersections points with height

5. Once the 3D mesh is finished, it is exported in DXF for drawing. In this step of the procedure is what makes the difference between both scenarios. In the 3D software the mesh is modified according to the scenario (point or line) by erasing the extra lines and extrude the base of the mesh to build the 3D feature.

5.1.1 Point Features scenario

In the 3D software, in this case Google SketchUp version 8.0.16846, the 3D frame is modified, where lines from the mesh are erased just to leave the frame for the columns (figure 16a), and have a clean representation of 3D columns (Figure 16b). The frame needs to be clean because there are lines between each point of the model . When the frame is cleated and the columns only remain, the columns represent the locations the client send to the service. By using the base of these columns as a guide line, 3D columns are drawn,

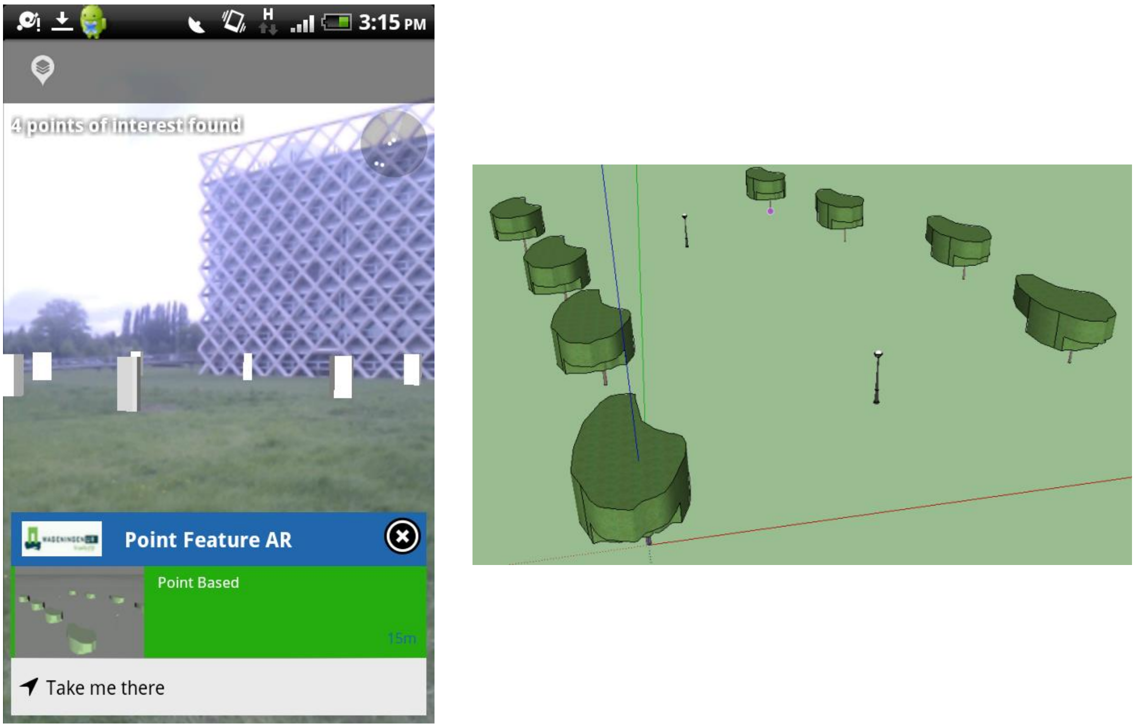


a) b)

c)

Figure 16 Drawing point features
a)3D mesh of Point Features b)Clean 3D mesh
c)Draw the 3D surface on mesh

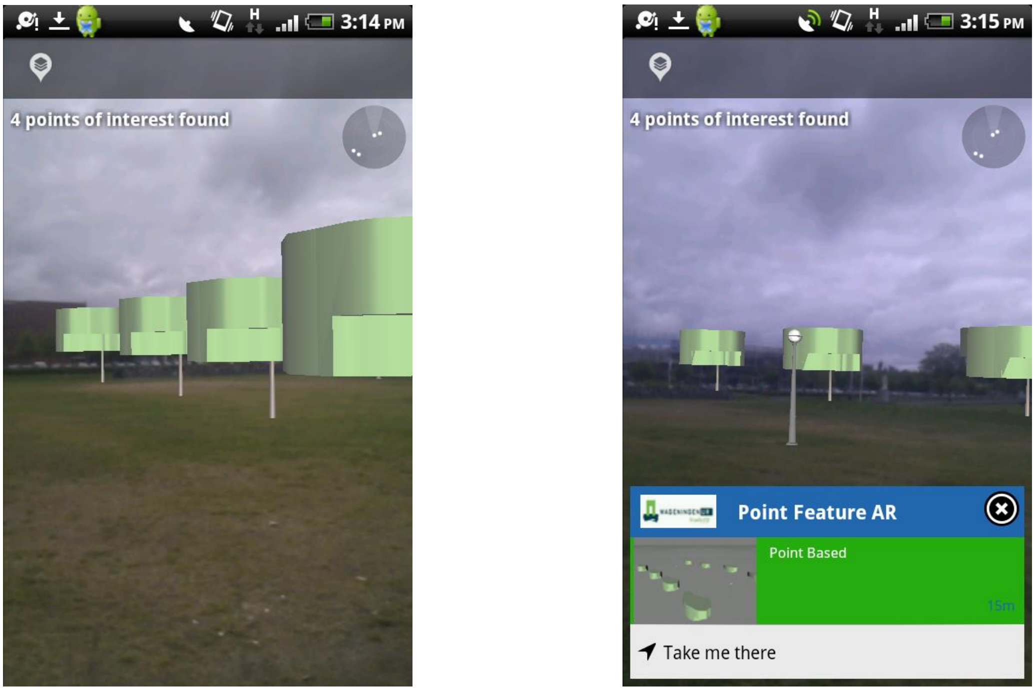
The finished 3D features (S4.1, Figure 5) are uploaded to the server and the AR features are shown in the mobile device (Figure 17a). In this example each 3D feature (like the columns) can be replaced with different 3D models (custom 3D models, trees, cars, light poles), taking in count that these are put in the middle of the column. These models can be suggested by the client, depending in the desires of the client. In this example trees and light poles are put in place (Figure 17b).



a) b)

Figure 17. a)AR point features
b)Imported models on point features locations

With the models in place, the 3D features are uploaded to the server as well and they are displayed in the AR environment (Figure 18a, 18b).

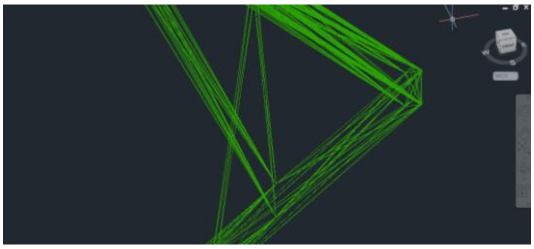


a) b)

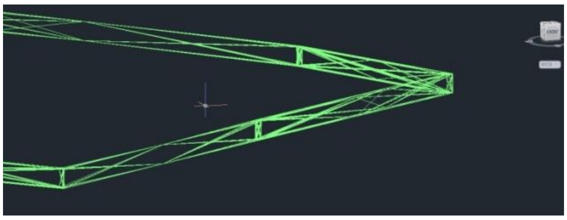
Figure 18. Point Features in AR.
a) Trees in detail b) Light pole in detail

5.1.2. Line Features scenario

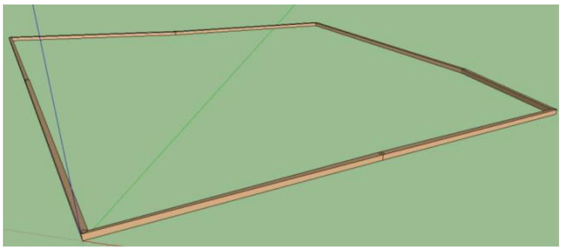
In the 3D software, the line mesh must be clean as well of the extra lines where created in the construction of the 3D mesh (Figure 19a), as in the point features, the columns remain with the addition of the lines that connect columns which are successive to each other (Figure 19b). This means that the 3D frame will have the shape of a wall (Figure 19c).



a)



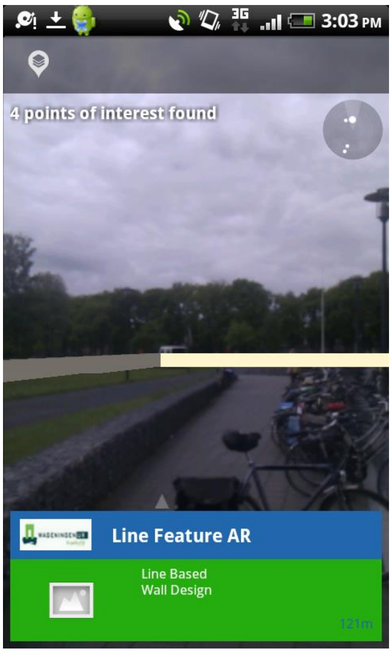
b)



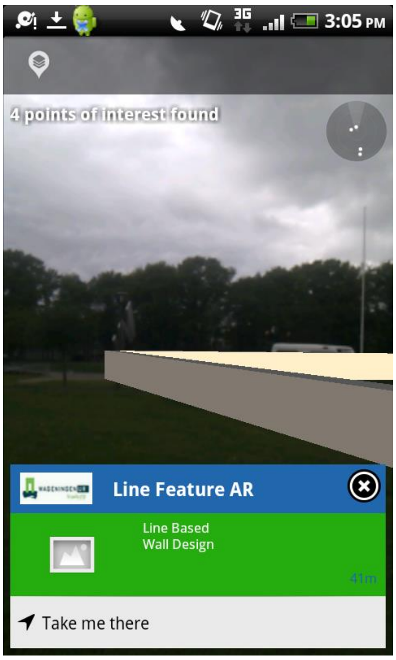
c)

Figure 19. Wall creation.
a) Cleaning of feature. b) 3D wall frame.
c) 3D wall

Later the 3D model is uploaded in the server for its visualization in the AR environment (Figure 20a, 20b)



a)

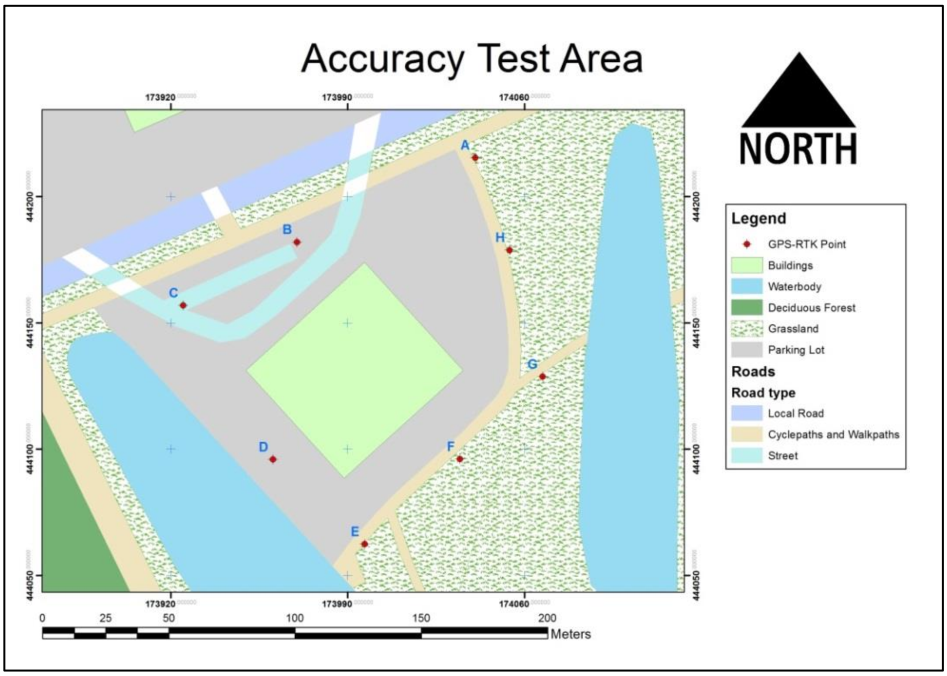


b)

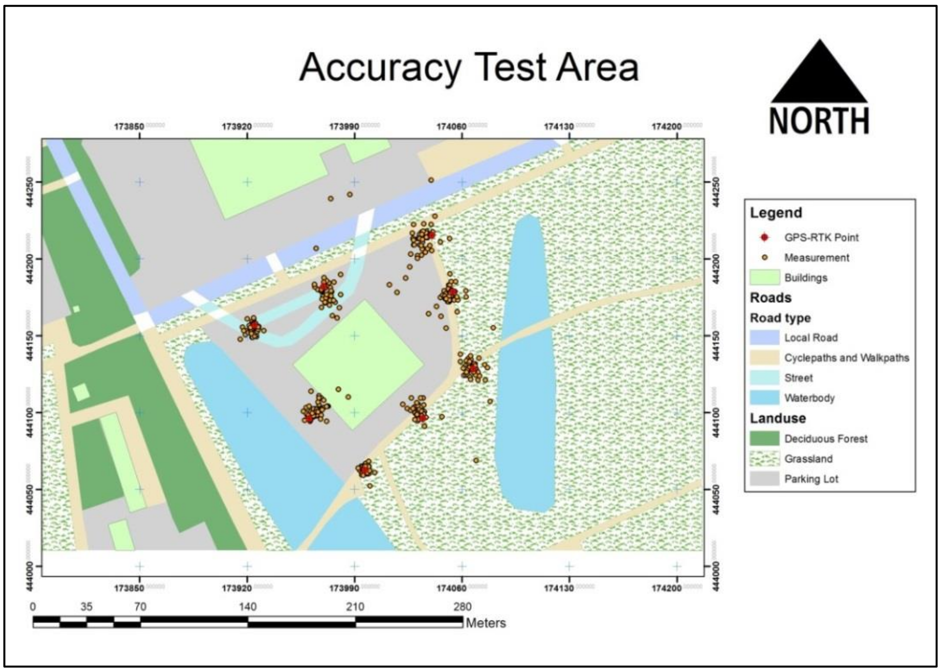
Figure 20. Line features in AR environment

Chapter 6 Accuracy test

This subchapter is divided in three parts, the statistical test, the visual inspection and the sketch. The position test was carried in the same place where the line features was design. In figure 21a is the map of the test area with the location of the GPS RTK points, all measurements are on the map are shown in figure 21b. In red dots represent the GPS RTK points where all the measurements were carried out.



a)



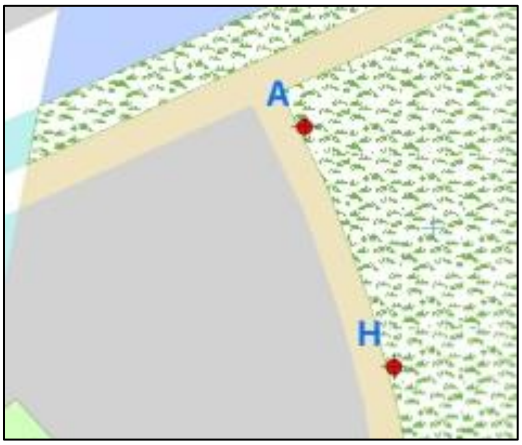
b)

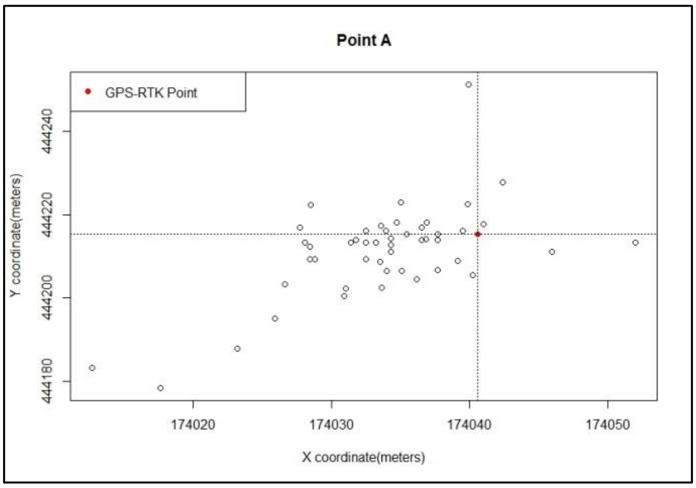
Figure 21. Test Area Wageningen University campus (Forum Building).
a) GPS RTK Points in the test area, b) Measurements in the test area

6.1 Statistical test

Point A

Point A is the located in the far north from the set of GPS RTK points where the 50 measurements from the mobile device where made (figure 22a, 22b).





a) b)

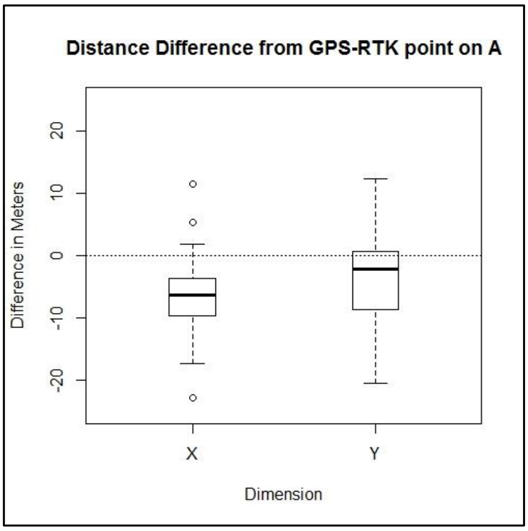
Figure 22. Point A
a) Point A location, b) Measurements on point A

In the t-test is carried out with 95% of confidence interval, the null hypothesis is that the difference in X and the difference in Y is 0, the outcome the test is in table 1. The significance values for the difference in X and Y are lower than 0.05 (0.00 for X and 0.015 for Y), which means it fails to prove the null hypothesis, and the difference towards the RTK GPS point is not equal to 0.

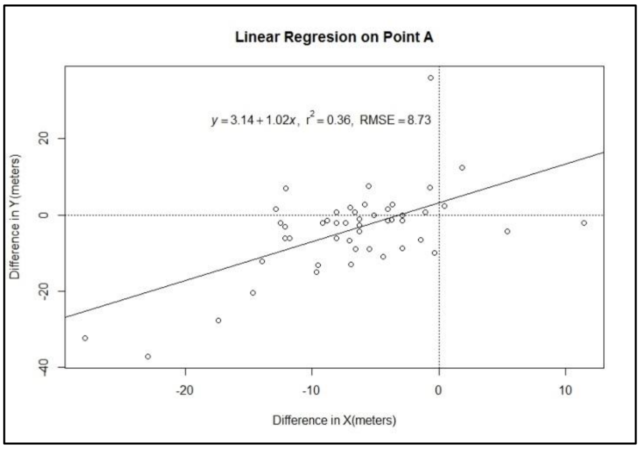
Table 1. t-test from point A

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
diff_rtkx	-7.566	49	.000	-6.921936	-8.760456	-5.083415
diff_rtky	-2.515	49	.015	-3.915881	-7.045147	-0.786616



a)



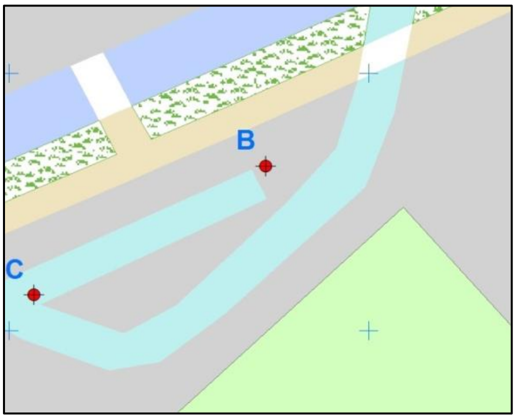
b)

Figure 23. a) Boxplot of the difference in X and Y coordinates on Point A.
b) Linear Regression model of X explaining Y on Point A

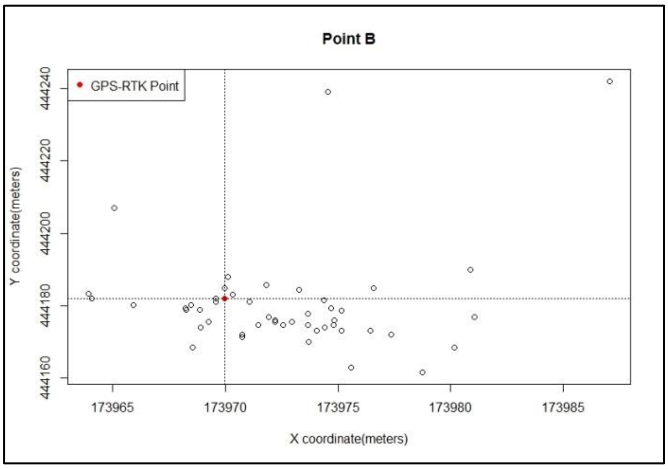
Figure 23a shows the boxplot of the difference in X and Y coordinates for all the measurements in point A, showing that the distribution of the difference in X and Y with negative means. The linear regression, where the difference of X explains the difference in Y, shows a R^2 of 0.36 with an RMSE of 8.73, which means that only 36 % of the data fit the model (figure 23b). This shows that the difference in X do not entirely explain the values in the difference in Y and the measurements follow a pattern, in which the measurements cluster at the west of point A.

Point B

Point B is located in the top centre of the RTK GPS points, figure 24b shows the measurements made on point B.



a)



b)

Figure 24. Point B
a) Point B location, b) Measurements on point B

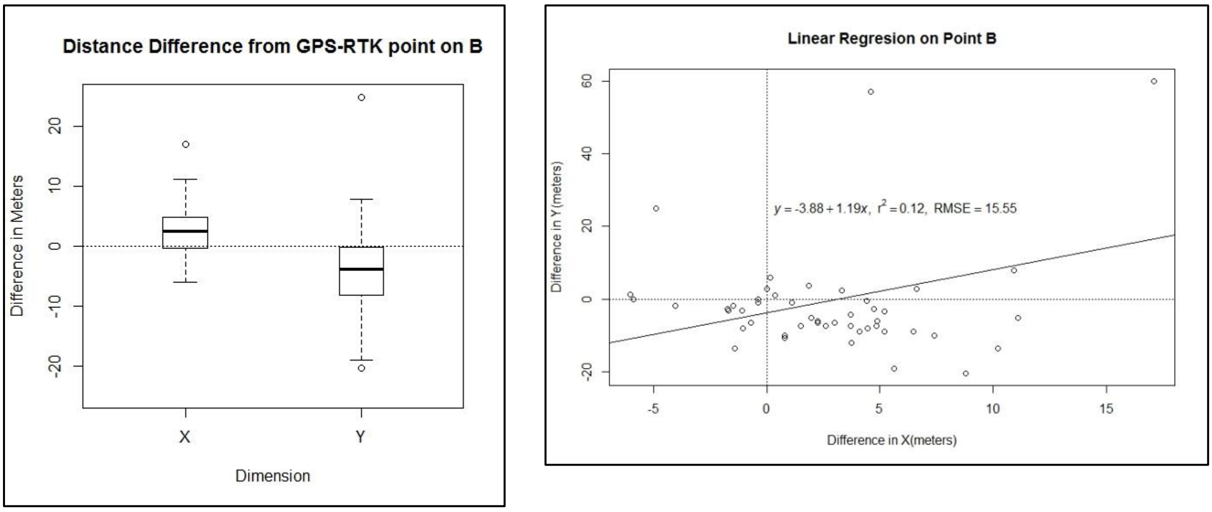
In the t-test is carried out at 95% of confidence interval, the null hypothesis is that the difference in X and the difference in Y is equal to 0. Table 2 shows that the difference in X fail to prove the null hypothesis (Sig. equal to 0.00), whereas the difference in Y proves the null hypothesis due the fact that the significance is larger than 0.05,

Table 2. t-test from point B

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
diff_rtkx	4.178	49	.000	2.896432	1.503167	4.289696
diff_rtky	-.182	49	.856	-0.430816	-5.192006	4.330374

Figure 25a shows the boxplot of the difference in X and Y coordinates for all the measurements in point B, showing that the mean in X is positive and negative in the Y coordinate. The linear regression, where the difference of X explains the difference in Y, shows a R^2 of 0.12 with an RMSE of 15.55, meaning that only covering only 12% of the data (Figure 25b). The values of the difference in X do not explain the values of the difference in Y as in the previous point, as in the previous point, the measurements are clustered, this time at the southeast of Point B, where the building is located.

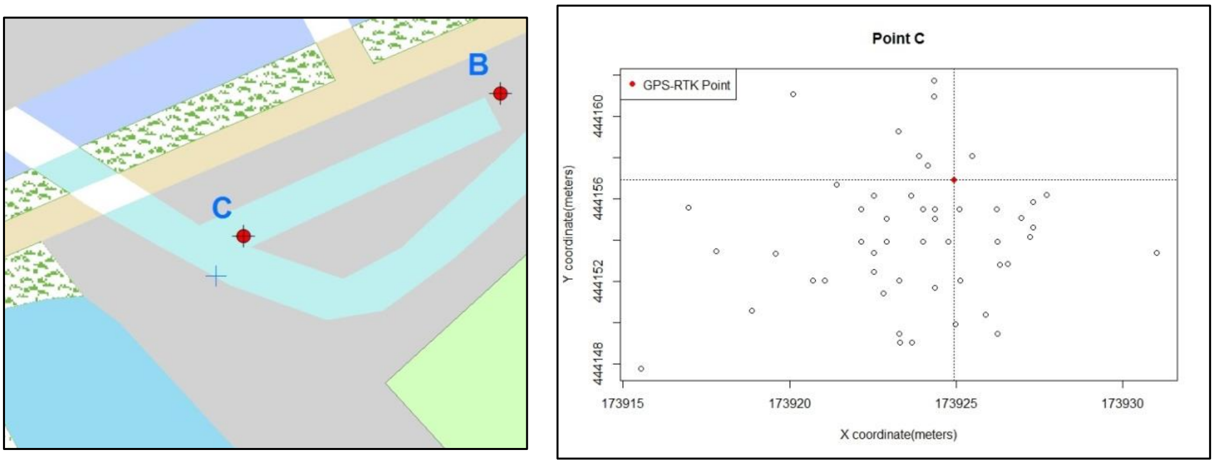


a) b)

Figure 25. a) Boxplot of the difference in X and Y coordinates on Point B
b)Linear Regression model of X explaining Y on Point B

Point C

Point C is the far west point from the set of GPS RTK points; figure 26b shows the measurements done with the smartphone in point C.



a) b)

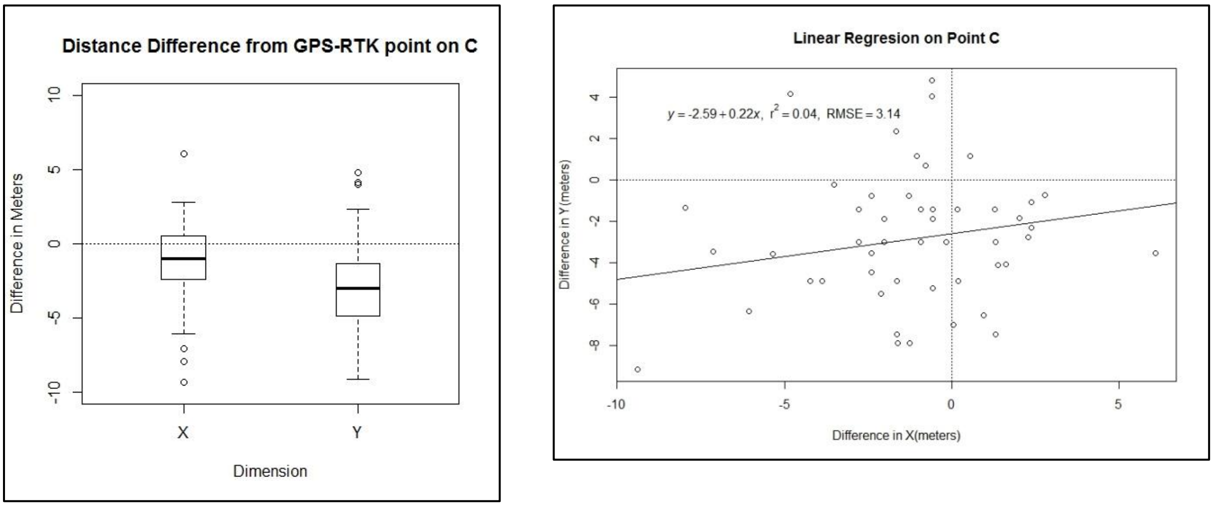
Figure 26. Point C
a) Point C location, b) Measurements on point C

The null hypothesis that the difference in X and the difference in Y is 0, the test is carried with 95% of confidence interval. The significance values for both, X and Y difference, are below 0.05 which means they fail to prove the null hypothesis, so the difference in X in Y is not equal to 0.

Table 3. t-test from point C

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
diff_rtkx	-3.187	49	.003	-1.392392	-2.270414	-0.514369
diff_rtky	-6.318	49	.000	-2.899635	-3.821976	-1.977295



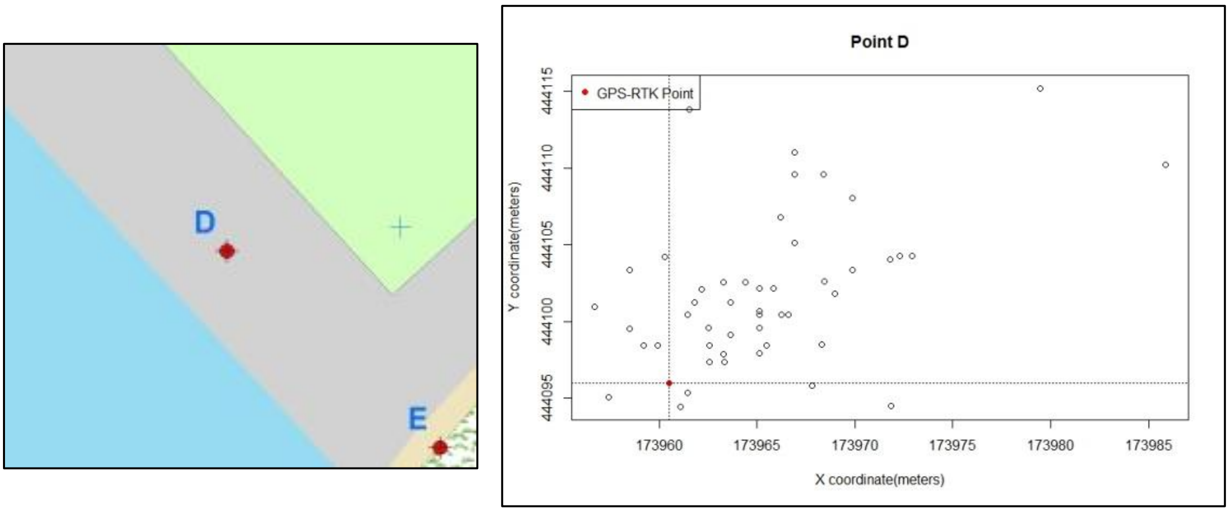
a) b)

Figure 27. a) Boxplot of the difference in X and Y coordinates on Point C.
b) Linear Regression model of X explaining Y on Point C

Figure 27a shows the boxplot of the difference in X and Y coordinates for all the measurements in point C, show that the mean difference have negative values. The linear regression, where the difference of X explains the difference in Y, has a R^2 of 0.04 and a RMSE of 3.14, this means the models has a small error but almost nothing of the data fit the model (figure 27b). The regression shows that the model do not apply, the difference in X values do not explain the difference in Y values. At this point, the measurements do not follow a pattern as in the previous point, the points are more disperse around point C.

Point D

Point D is located in the middle right of the set of RTK GPS points, figure 28b shows the measurements made with the smartphone on point D.



a) b)

Figure 28. Point D
a) Point A location, b) Measurements on point D

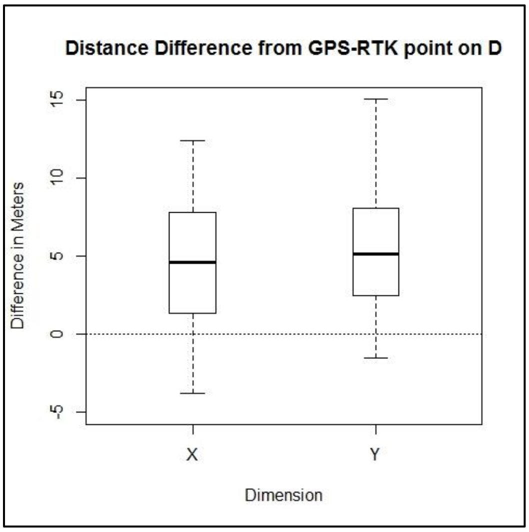
Table 4 shows the t-test at 95% of confidence interval of the difference in X and Y, the null hypothesis is that the difference in X and Y is equal to 0. The significance for both coordinates is lower than 0.05, which means it fails to prove the null hypothesis, so the difference in X and Y coordinates is not equal to 0.

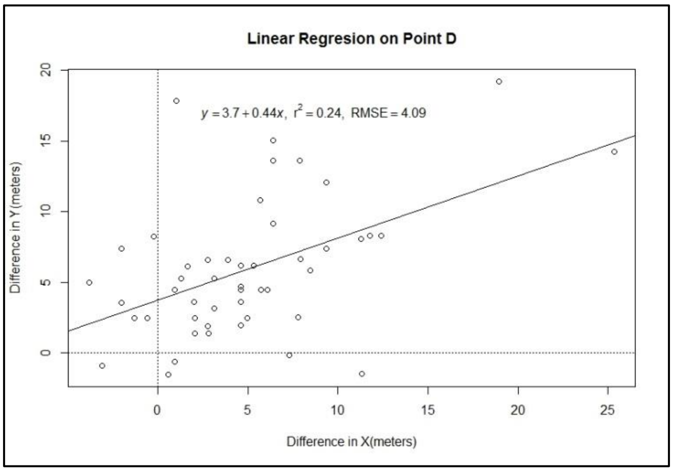
Table 4. t-test from point D

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
diff_rtkx	6.470	49	.000	4.888271	3.369925	6.406618
diff_rtky	8.697	49	.000	5.849282	4.497703	7.200860

In figure 29a the boxplot of the difference is showed, the means in the difference in X and Y are positive. The linear regression model, where the difference of X explains the difference in Y, has a R^2 of 0.24 and a RMSE of 4.09. Which means the 24% of data fit the model and the RMSE is not a high value (figure 29b). The regression shows that the difference in X do not explain the values in the difference in Y, only 24% of the data fit that model, also it is visible that the measurements follow a pattern, they are allocated at the northeast of the point, where the building is located.



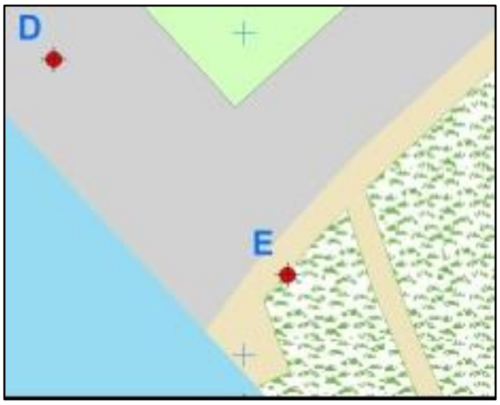


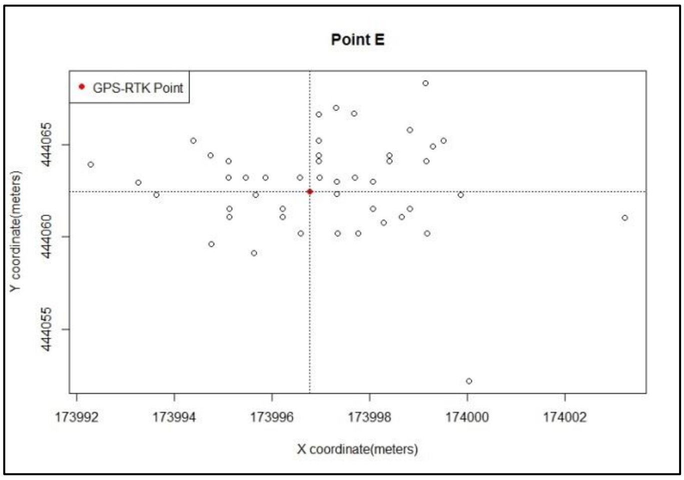
a) b)

Figure 29. a) Boxplot of the difference in X and Y coordinates on Point D
b) Linear Regression model on X explaining Y on Point D

Point E

Point E is the bottom right point if the set of RTK GPS points, the figure 30b shows the measurements made in point E.





a) b)

Figure 30. Point E
a) Point E location, b) Measurements on point E

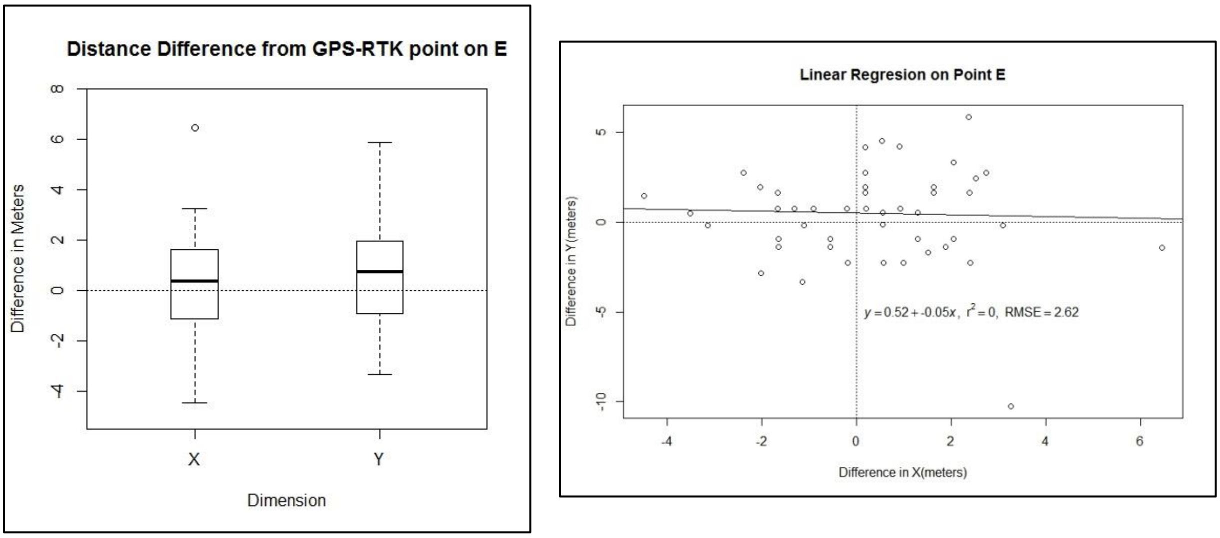
In table 5 shows the outcome of the t-test, as before the test is carried with 95% of confidence interval, the null hypothesis is that the difference in x and Y is equal to 0. The significance values are larger than 0, 0.223 for X and 0.187 for Y, so the null hypothesis is accepted which mean the values of the difference in X and Y is equal to 0.

Table 5. t-test from point E

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
diff_rtkx	1.233	49	.223	0.348109	-.219217	0.9154377
diff_rtky	1.337	49	.187	0.500925	-.251986	1.253838

In figure 31a the boxplot of the difference in X and Y in point E is shown, where the means are close to 0 and figure 24b shows the linear regression model for the difference in X explaining the difference in Y where R^2 is 0 and the RMSE is 2.62, this means that the data do not follows the linear regression model but it has a low value of RMSE (figure 31b). In the regression, the values in the difference in X do not explain the values of the difference in Y, the measurements are disperse and follow a pattern along the Y axis. However the error in both differences is the smallest of all the points.

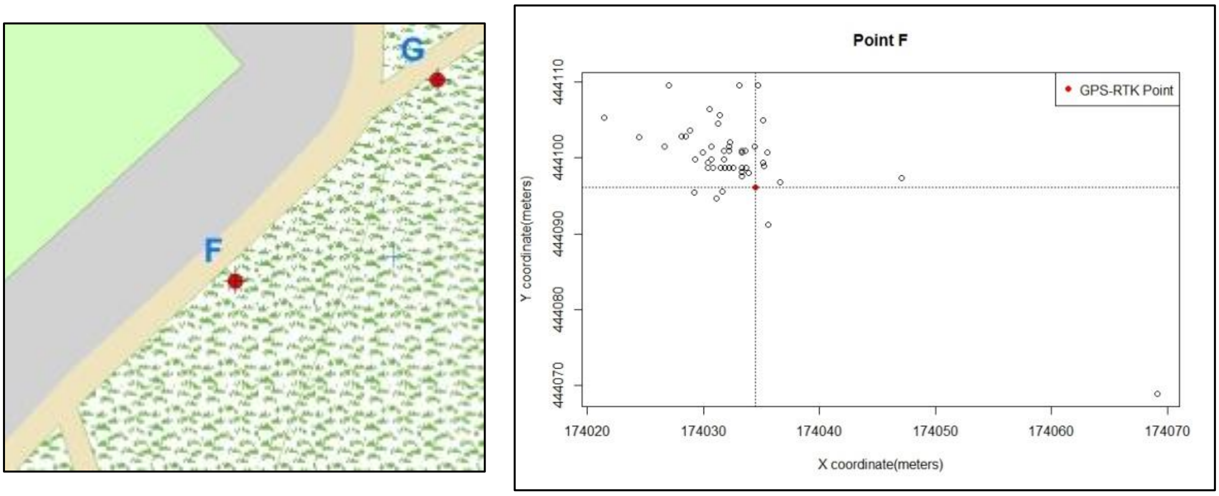


a) b)

Figure 31. a) Boxplot of the difference in X and Y coordinates on Point E
b) Linear regression on point E of X explaining Y

Point F

Point F is located in the bottom centre of the set of RTK GPS points, figure 32b shows the measurements carried on point F, one of the measurements became an outlier but was include in the testing.



a) b)

Figure 32. Point F
a) Point F location, b) Measurements on point F

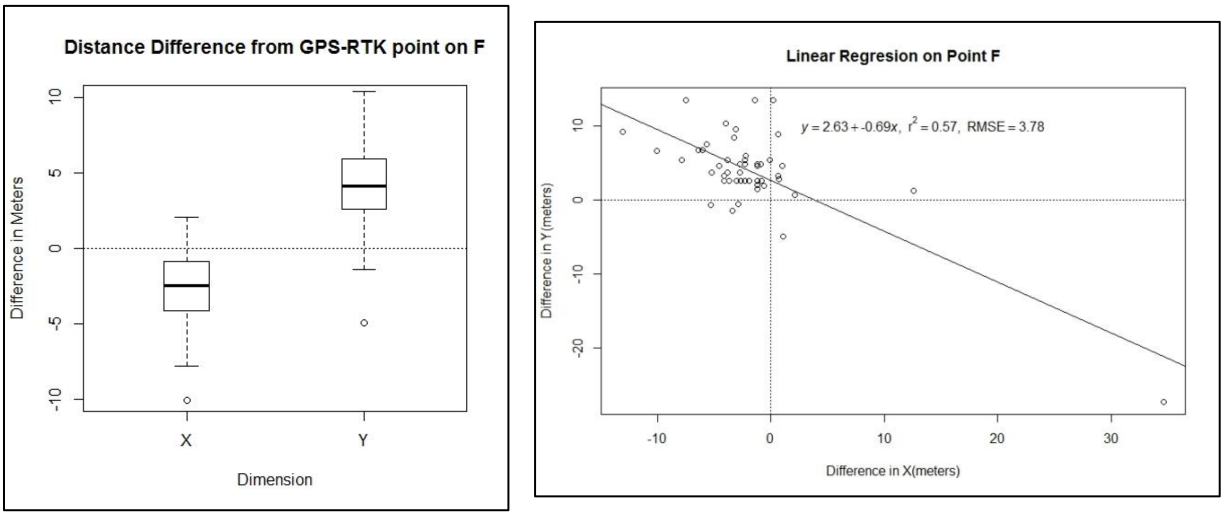
In table 6 the outcome of the t-test is shown, the test was carried with 95% of confidence interval with a null hypothesis that the difference in X and Y is equal to 0. The significance values are below 0.05 (0.046 for X and 0.00 in Y), which means it fails to prove the null hypothesis, which means the difference in X and Y is not equal to 0.

Table 6. t-test from Point F

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
diff_rtkx	-2.051	49	.046	-1.849381	-3.661187	-0.037576
diff_rtky	4.755	49	.000	3.901678	2.252752	5.550603

In figure 33a, the boxplot of the difference in the coordinates shows that the mean in X is negative and in Y is positive, figure 26b displays the linear repression, where the difference of X explains the difference in Y, it gives a R^2 of 0.57 and a RMSE of 3.78, which means that 57% of the data follows the models and the RMSE value is not that high in comparison of the rest points (figure 33b). At this point, the regression shows that half of the values of the difference in X explain the values difference in Y. The measurements follow a pattern, they are allocated at the northwest of point F.

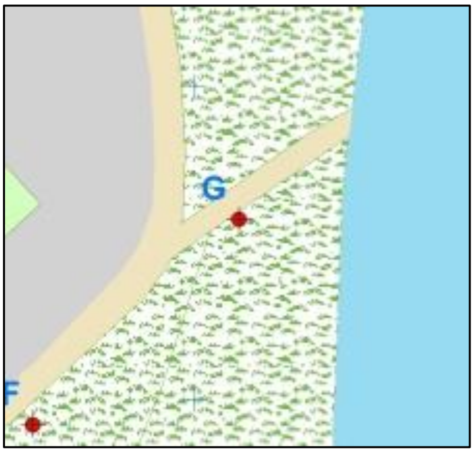


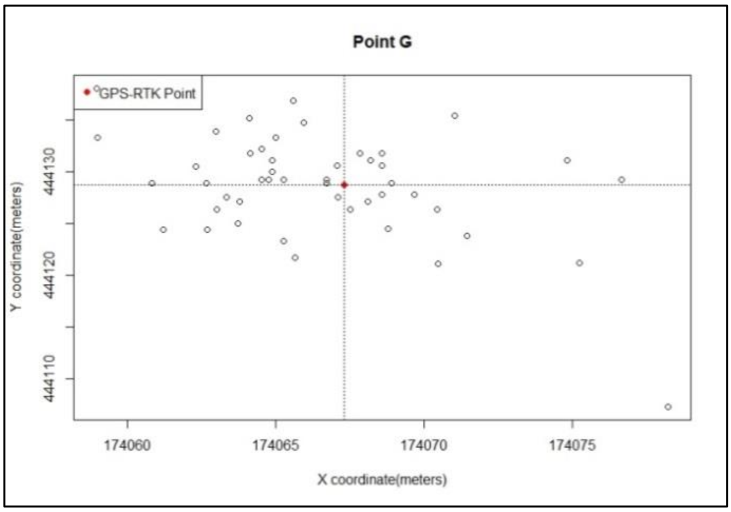
a) b)

Figure 33. a) Boxplot of the difference in X and Y coordinates on Point F
b) Linear regression model of X explaining Y in point F

Point G

Point G is located in bottom right of the set of RTK GPS points, figure 34b shows the measurements at the point.





a) b)

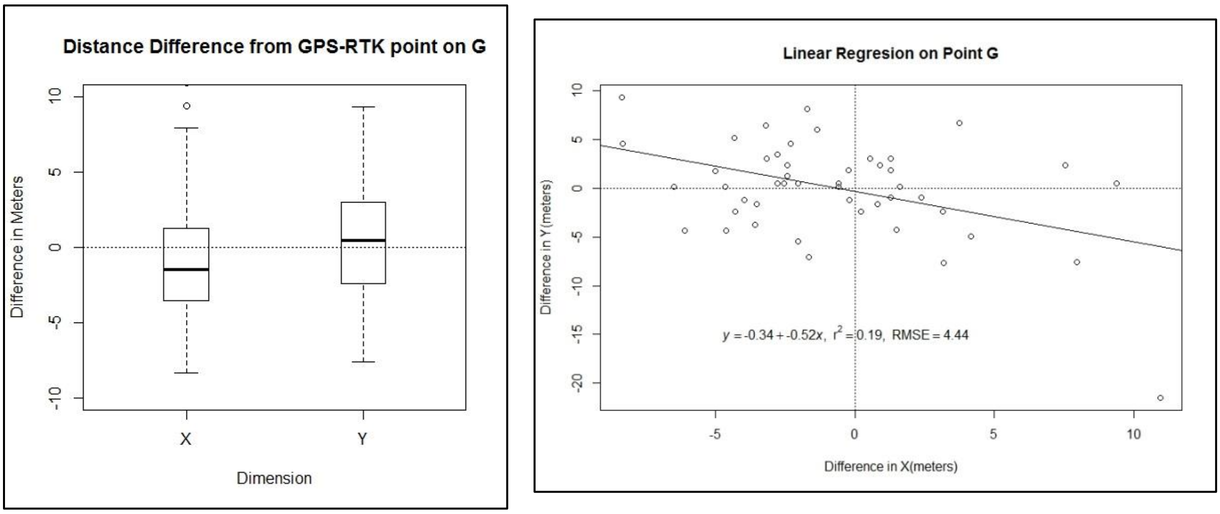
Figure 34. Point G
a) Point G location, b) Measurements on point G

Table 7 shows the outcome to the t-test on point G, the test is done with 95% of confidence interval and with the null hypothesis that the difference in X and Y is equal to 0. The significance values are larger than 0.05 (0.228 in the X coordinate and 0.969 in the Y coordinate), this means that the test accepts the null hypothesis and the mean difference is equal to 0.

Table 7. t-test from point G

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
diff_rtkx	-1.220	49	.228	-0.713034	-1.887930	0.461862
diff_rtky	.039	49	.969	0.027544	-1.385112	1.440200



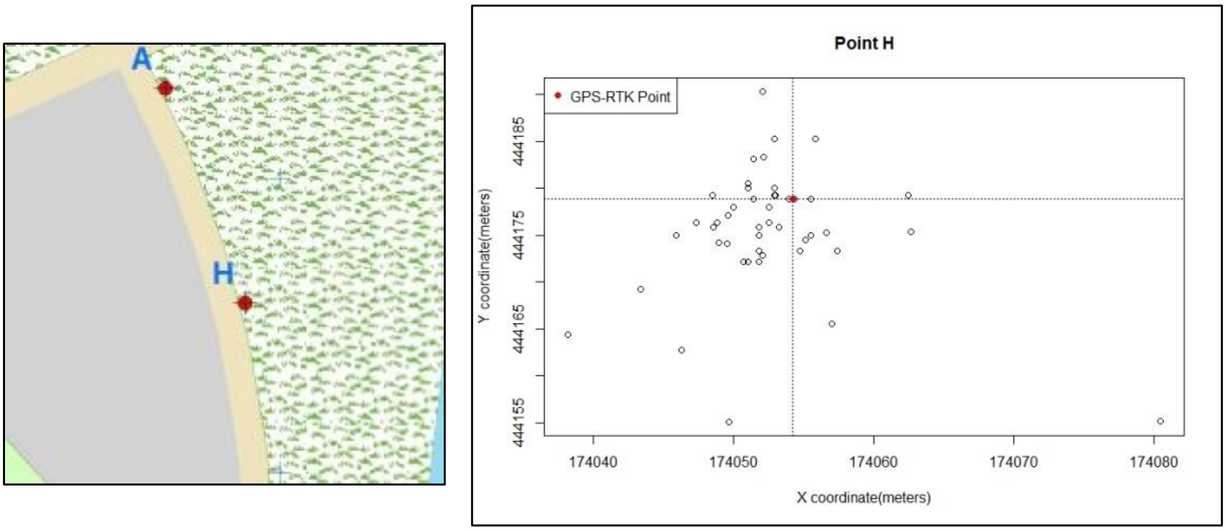
a) b)

Figure 35. a) Boxplot of the difference in X and Y coordinates on point G
b)Linear Regression on point G where X explains Y

Figure 35a shows the boxplot of the difference in X and Y coordinates in point G, the mean in X coordinate is negative whereas the mean Y coordinate is positive. The linear regression model, where the difference of X explains the difference in Y, it shows a R^2 equals to 0.19 and a RMSE of 4.44, which means that only 19% of the data follow the model and the value of RMSE is not as high as the rest of the points (figure 35b). As the previous points, the values of the difference in X do not entirely explain the values in the difference in Y. The measurements are disperse around point G.

Point H

Point H is the last point which is located in the middle right of the RTK GPS points, figure 36b shows the measurements done at the point.



a) b)

Figure 36. Point H
a) Point H location, b) Measurements on point H

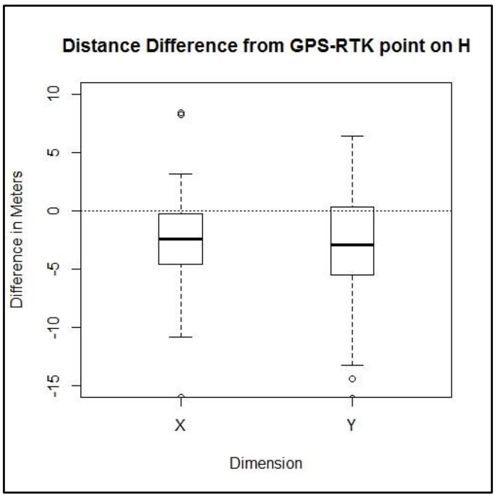
Table 8. t-test from point H.

One-Sample Test

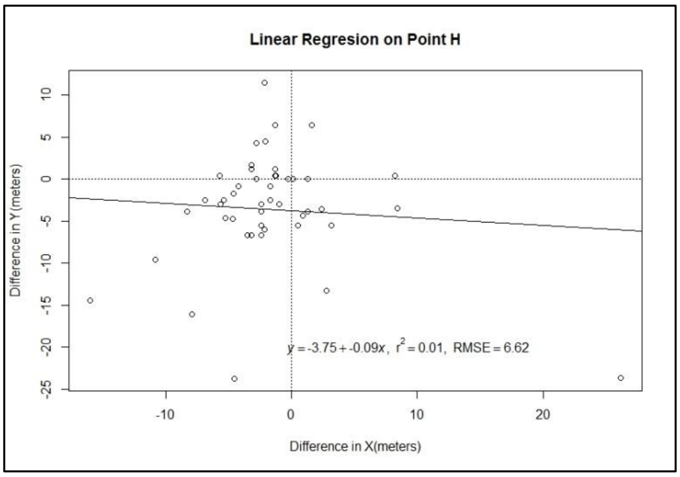
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
diff_rtkx	-2.267	49	.028	-1.849103	-3.487912	-0.210295
diff_rtky	-3.780	49	.000	-3.584705	-5.490382	-1.679029

Table 8 shows the outcome of the t-test, the t-test is carried out with 95% confidence interval with the null hypothesis that the difference in X and Y are equal to 0. The significance values are below 0.05 (0.028 in X and 0.00 in Y) which means that the test fails to prove the null hypothesis, that is that the difference in X and Y is not equal to 0.

The boxplot of the difference in X and Y is shown in figure 37a, where the means in the difference in both coordinates is negative. The linear regression model on point H (Figure 37b) where difference in X explains the value of the difference in Y have a R^2 of 0.01 and a RMSE of 6.62, which means that the data do not fit the model and the error is average in comparison of the other points. The values of the difference in X do not explain the values in the difference in Y and the measurements are clustered at the west side of point H were the building is allocated.



a)



b)

Figure 37. a) Boxplot of the difference in X and Y coordinates on Point H
b) Linear Regression on point H where X explains Y

Figure 38 shows the boxplot of the difference in the X coordinate, where it shows that the mean difference in points E and C are the lowest, whereas point A and D show the bigger difference of them all.

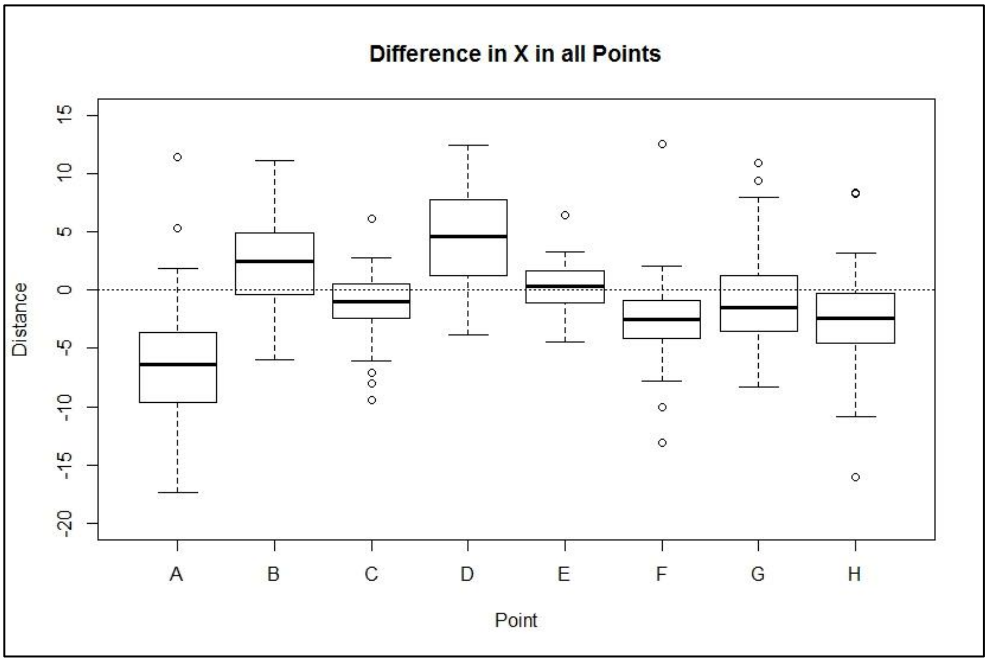


Figure 38. Boxplot of the difference in X coordinates in all points

In figure 39 shows the boxplot the difference in Y coordinates, where the mean difference in point E and G are the lowest, whereas point B and D show the biggest difference of them all.

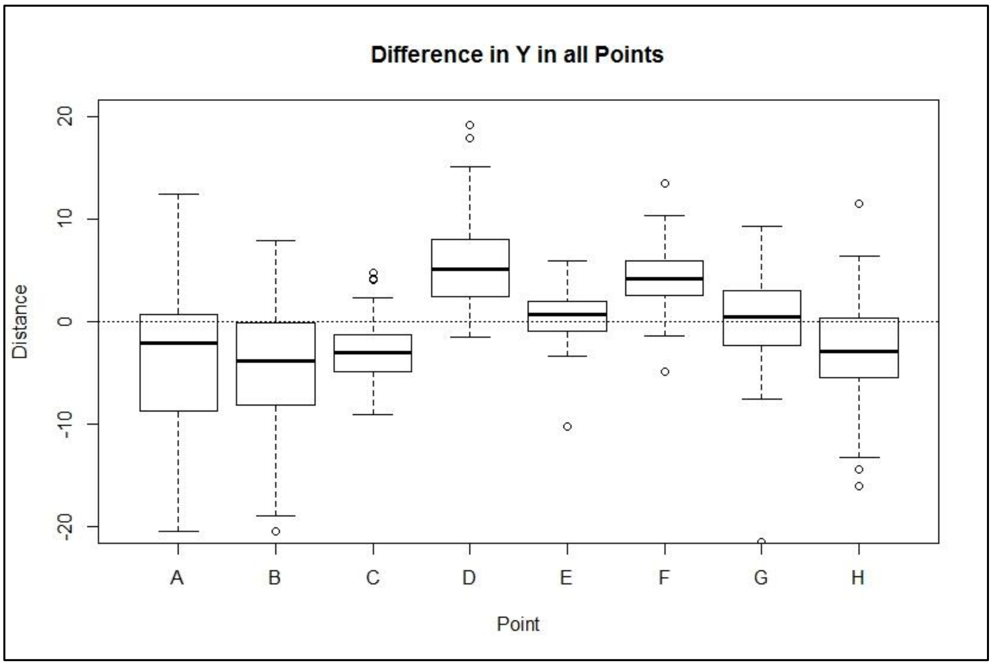


Figure 39. Boxplot of the difference in Y coordinates in all points

Table 9. Summary in difference in X and Y coordinates towards the RTK GPS points

Point	Mean Difference in X (in meters)	Mean Difference in Y (in meters)	Measurements Mean Distance to RTK GPS point (meters)
A	-6.922	-3.916	11.761
B	2.896	-0.431	11.089
C	-1.392	-2.899	4.744
D	4.888	5.849	8.612
E	0.348	0.501	2.799
F	-1.849	3.902	7.113
G	0.713	0.027	5.182
H	-1.849	-3.585	7.123
Mean	-0.396	-0.552	7.303

Table 9 shows the summary of the mean difference in the coordinates in X and Y and the mean distance from the measurements to the RTK GPS points, from the table is visible that point E and G have the lowest differences in X and Y plus the lowest distance from the measurements towards the RTK points. Point A and D have the biggest means in X and Y. The possible explanations of this will be discussed in the visualization inspection, in chapter 6.2.

Table 10 shows the summary in the R^2 values and RMSE from the linear regression in all the points. It shows that point F has the more higher values that fit the model and point E has no single value that follows model but the value of RMSE in point is the lowest of them. Point B has the biggest error RMSE and is the second largest mean distance to the RTK GPS point. The point A has the biggest mean distance to the RTK GPS point, 11.76 meters, and point E has the smallest mean distance with 2.79 meters. The mean R^2 is 0.19, the mean RMSE is 6.12 and the mean distance of the measurements to the RTK GPS points is 7.30 meters.

Table 10. Summary of R^2 and RMSE

Point	R^2	RMSE	Measurements Mean Distance to RTK GPS point (meters)
A	0.36	8.73	11.76
B	0.12	15.55	11.08
C	0.04	3.14	4.74
D	0.24	4.09	8.61
E	0.00	2.62	2.79
F	0.57	3.78	7.11
G	0.19	4.44	5.18
H	0.01	6.62	7.12
Mean	0.19	6.12	7.30

In Figure 40 the boxplot shows the distances from the measurements to the RTK GPS points, the boxplot shows that most of the measurements are located in the distance between 2.5 and 7.5 meters. Also this boxplot gives the ranges for make more easy the visual inspection, these ranges are:

- 0.00 to 2.50 meters
- 2.50 to 5.00 meters
- 5.00 to 7.50 meters
- 7.50 to 10.00 meters
- 10.00 to more meters

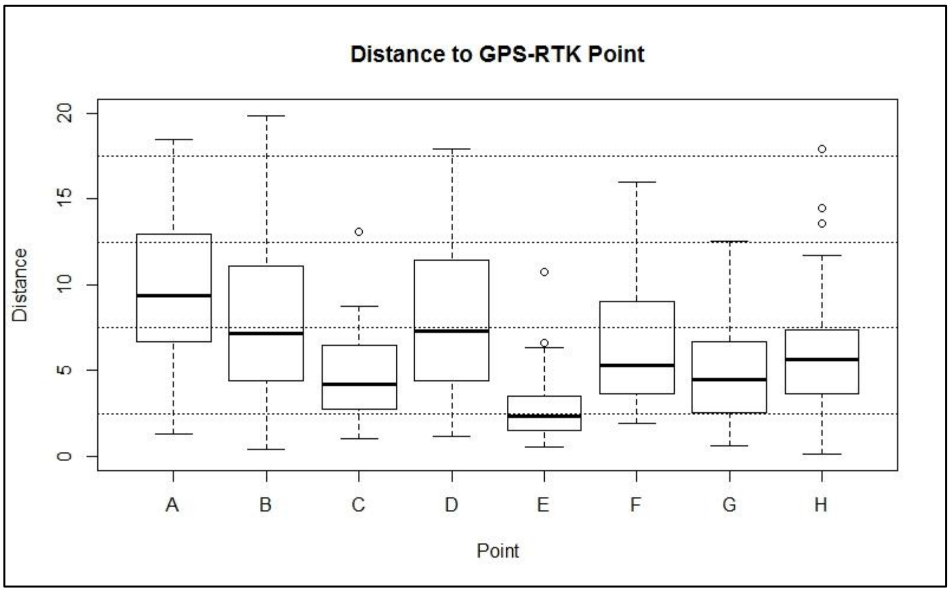


Figure 40. Boxplot of the distance from the measurements to the RTK GPS points

6.2 Visual Inspection

Using the methodology described in chapter 3, the measured sketch points were drawn as 3D point symbols (columns) and the RTK GPS measured points as well. The point features are exported to the AR environment to observe how close the measurements to the RTK GPS point are. For this the RTK GPS points are designed to be higher than the measured sketch points and to visually observe the horizontal displacement of the observations to the RTK GPS points, the columns are classified as follows:

- RTK GPS points are displayed in red
- 0.00 to 2.50 meters. The columns located in this range are in dark green
- 2.50 to 5.00 meters. The columns located in this range are in green
- 5.00 to 7.50 meters. The columns located in this range are in yellow
- 7.50 to 10.00 meters. The columns located in this range are in orange
- 10.00 to more meters. The columns located in this range are in grey

Next, observations are made with the camera to assess the location of the features and observe the displacement of the features in the AR environment. The photographs were taken of the RTK GPS point location and the location of the AR views at the point, as well with the angle from the picture was taken. The Field of view of the user is represented by the lines with an arc line.

The figures in this sections show a photograph of the camera view of the smartphone display in which the RTK GPS measured point feature is represented by a red dot in the picture labelled as a). The photograph in the top right labelled as b), shows again the camera view of the OSA application on the smartphone. It displays the 3D point model (column) on the RTK measurement location and the measured sketched points. The colour of the column refers to the distance class from the measurements towards the RTK GPS points. The last item, labelled as c), shows a map of the rest area with the location and view angle of the sketching person, the location of the RTK GPS measured point feature and the sketched points. The meanings of the colours are the same as in b) (figure 41).

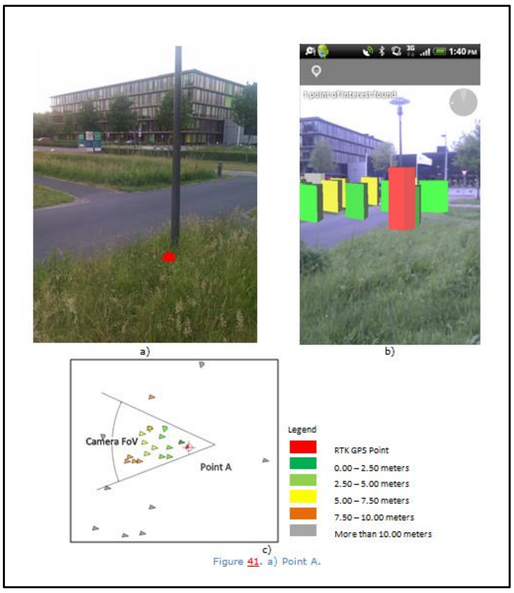
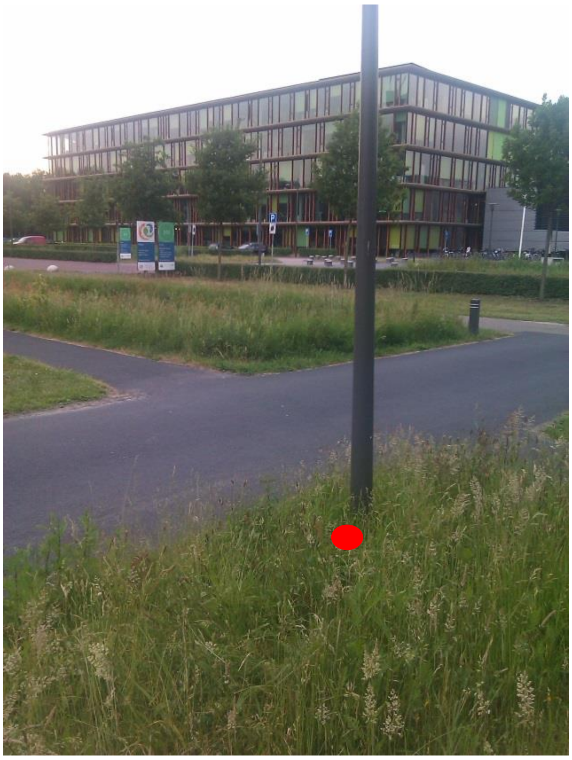


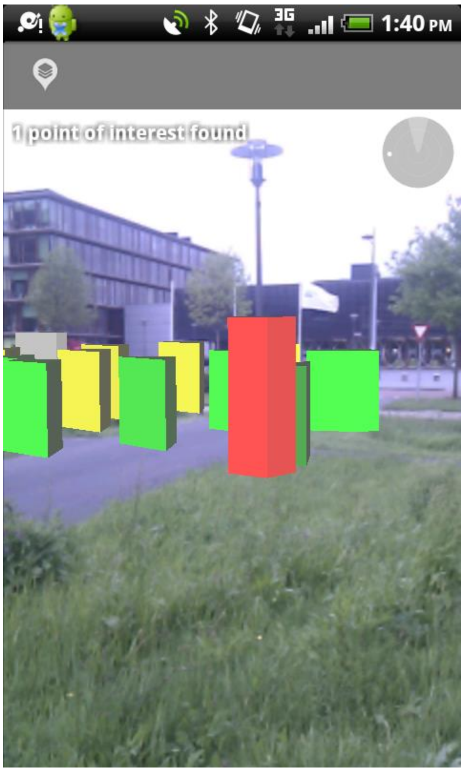
Figure 41. Format of visual inspection

Point A

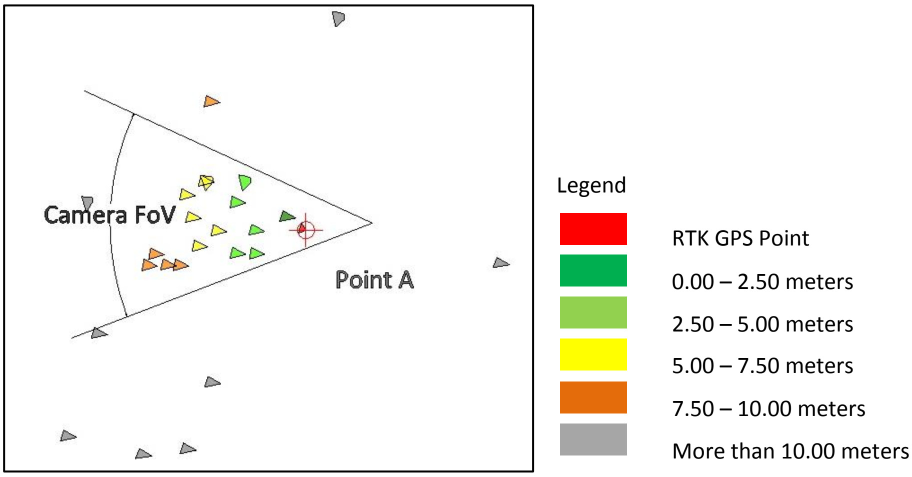
The RTK GPS point is located near the base of the light pole (figure 42a). When the AR models are displayed, the column that represents the RTK GPS point is located almost in the same position as the measured RTK GPS point (figure 42b). Figure 42c shows that the picture was taken from the east of the point, showing the field of view from the user.



a)



b)



c)

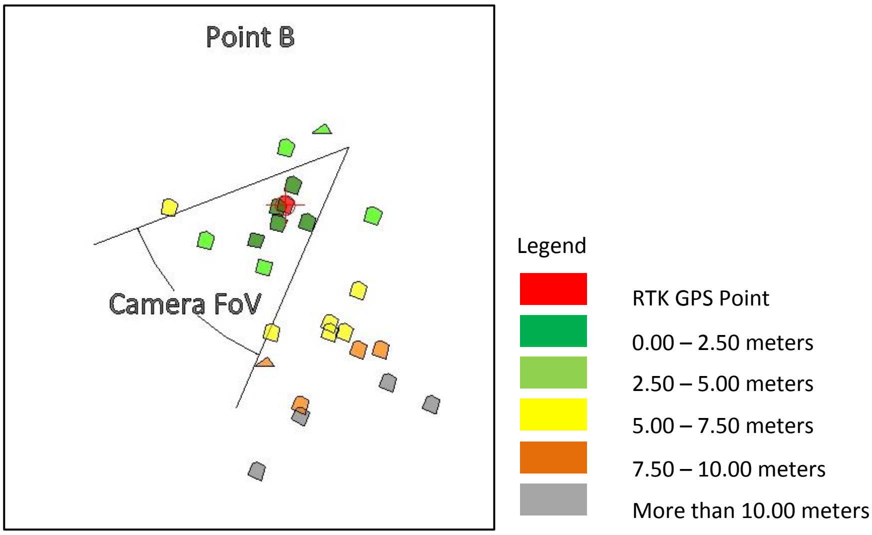
Figure 42. a) Point A.
b) Augmented measurements and RTK GPS point.
c) Camera field of view in Point A

Point B

Point B is located at the base of the pole (figure 43a), it is observed that the AR features corresponding to the point is misplaced, giving the ilusion that the AR feature is located higher that the point itself (figure 43b). The picture was taken from the north-east of the point (figure 43c).

a)

b)



c)

Figure 43. a) Point B.
b) Augmented measurements and RTK GPS point.
c) Camera field of view in Point B

Point C

Point C is located in the border of the sidewalk; figure 39b is observed that the AR feature of the RTK GPS point is away from the original RTK GPS point. The picture was taken from the south (Figure 44 a, b, c).

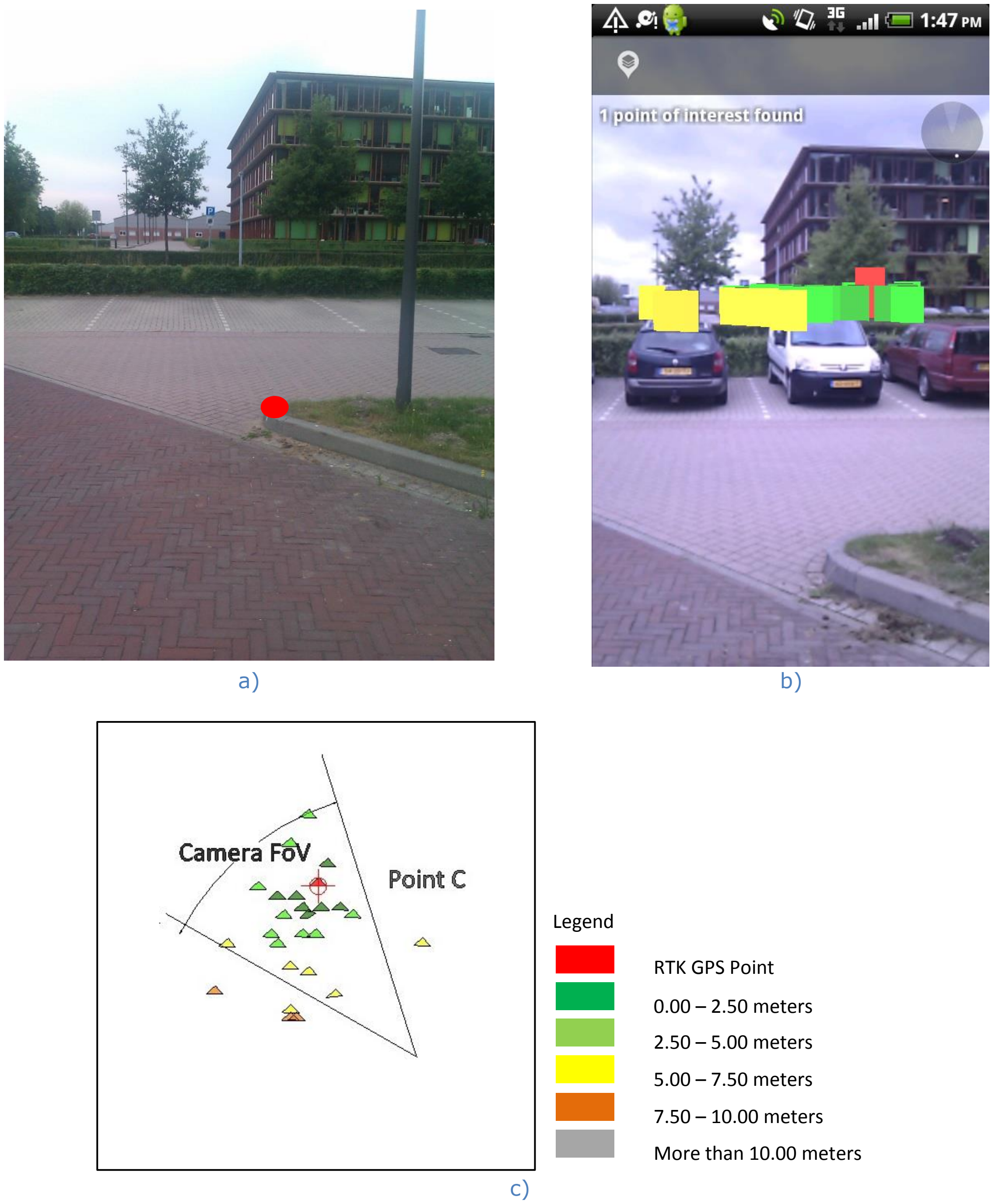
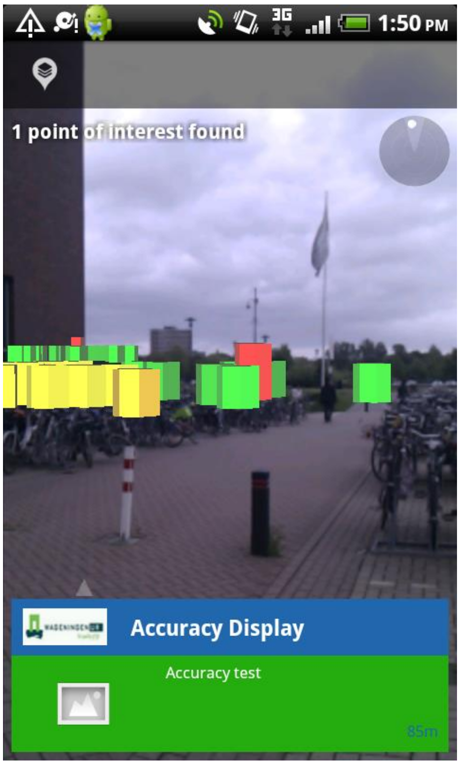


Figure 44. a) Point C.
b) Augmented measurements and RTK GPS point.
c) Camera field of view in Point C

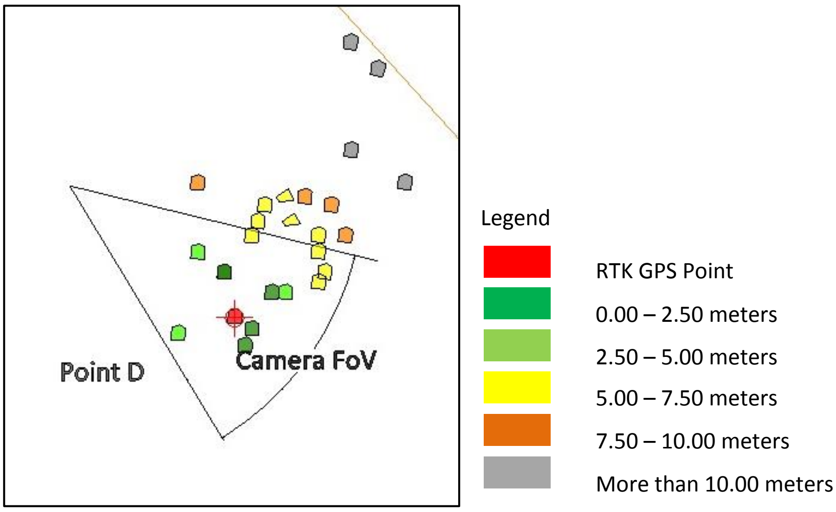
Point D

Point D is as well located in the base of the pole, it is observed that the AR features are misplaced and with additional height. The picture was taken from the northwest of the point (Figure 45 a, b, c).

a)



b)

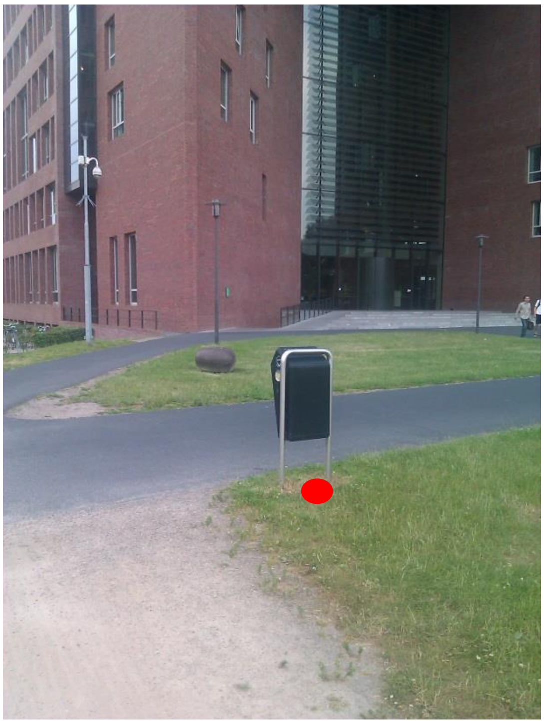


c)

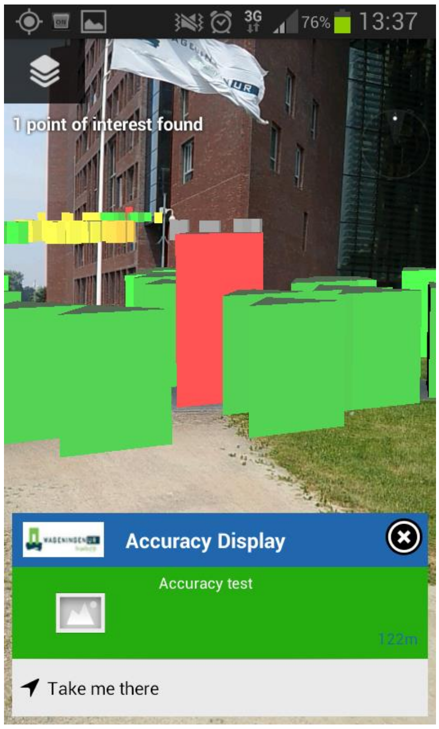
Figure 45. a) Point D.
b) Augmented measurements and RTK GPS point.
c) Camera field of view in Point D

Point E

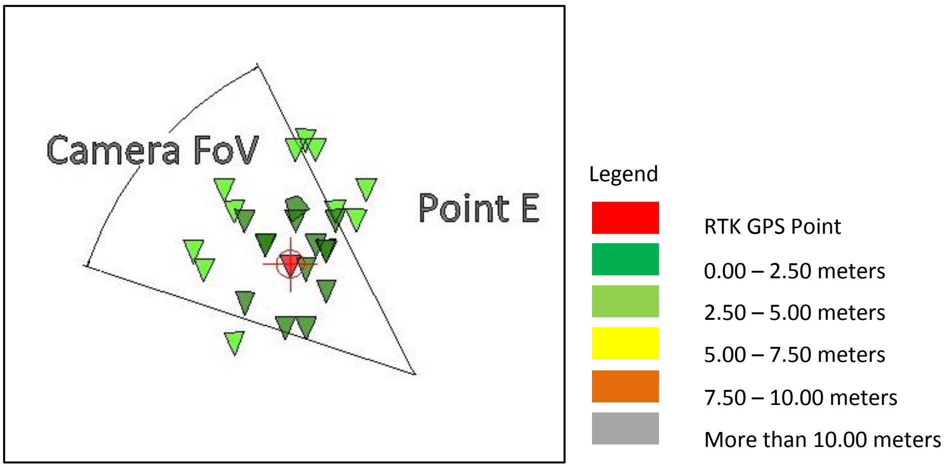
Point E is located by the trash can, it is observed that the AR features are located in top of the point. The picture is taken from the southeast (figure 46 a, b, c).



a)



b)



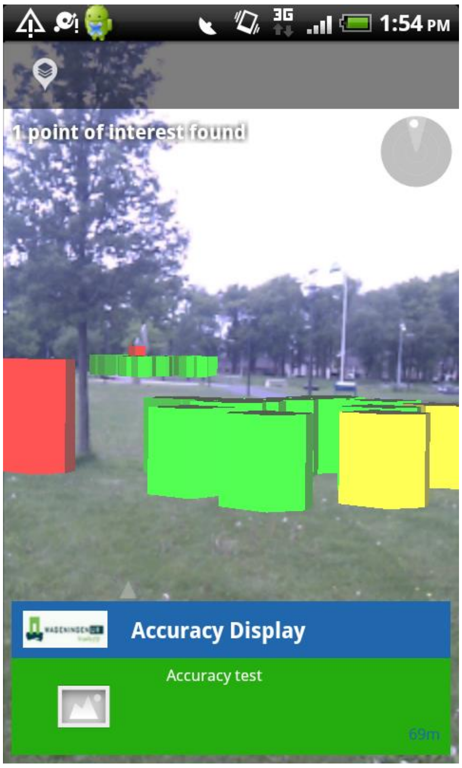
c)

Figure 46. a) Point E.
b) Augmented measurements and RTK GPS point.
c) Camera field of view in Point E

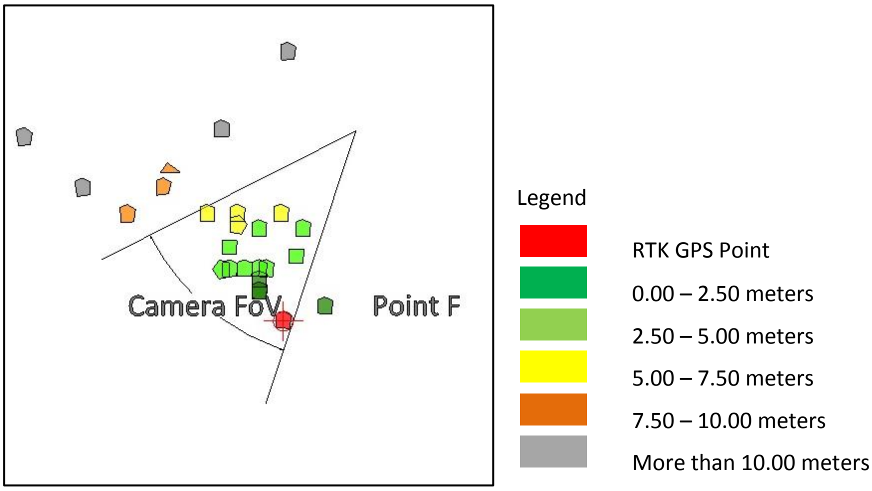
Point F

Point F is located between the light pole and the tree, the AR features are moved to the south. The picture is taken from the northeast of the point (figure 47 a, b, c).

a)



b)

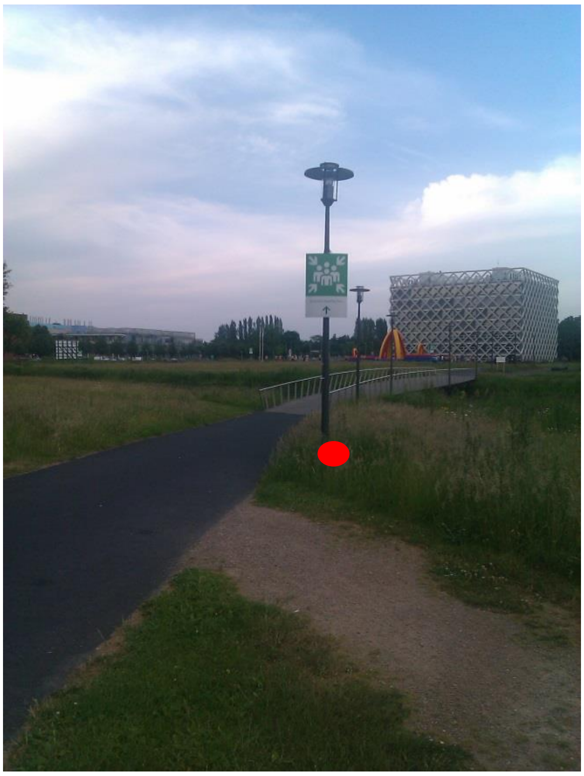


c)

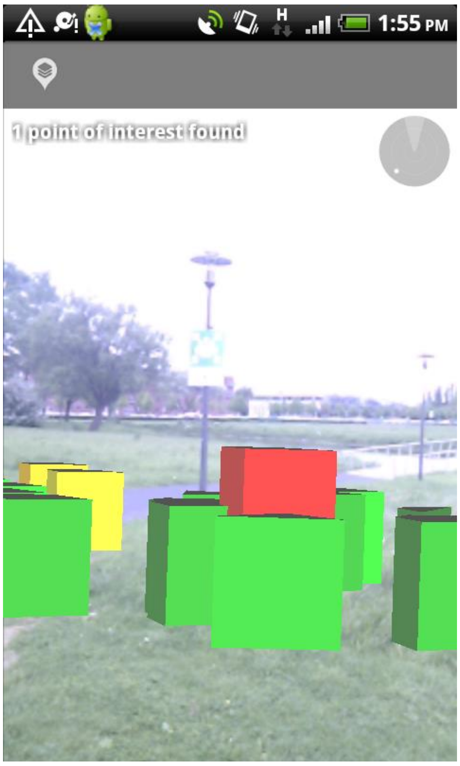
Figure 47. a) Point F.
b) Augmented measurements and RTK GPS point.
c) Camera field of view in Point F

Point G

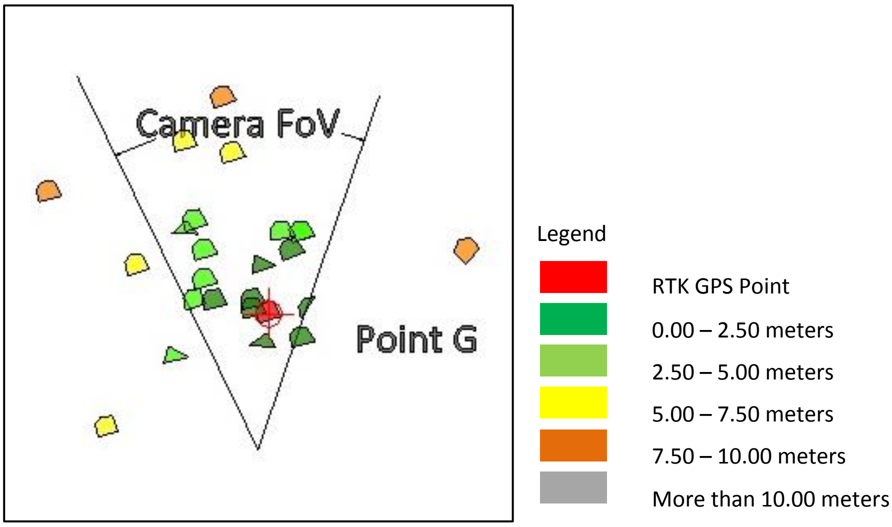
Point G is located in the base of the light pole, the AR features are located near to the RTK GPS point. The picture is taken from the south of the point (figure 48 a, b, c).



a)



b)

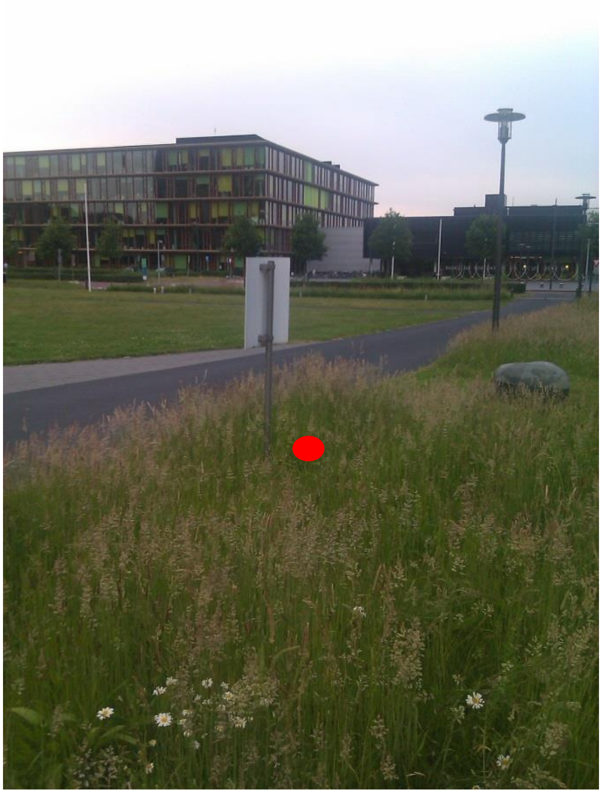


c)

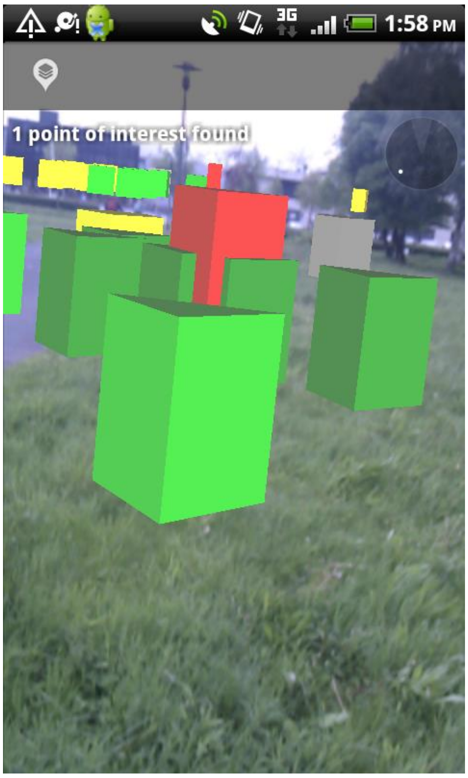
Figure 48. a) Point G.
b) Augmented measurements and RTK GPS point.
c) Camera field of view in Point G

Point H

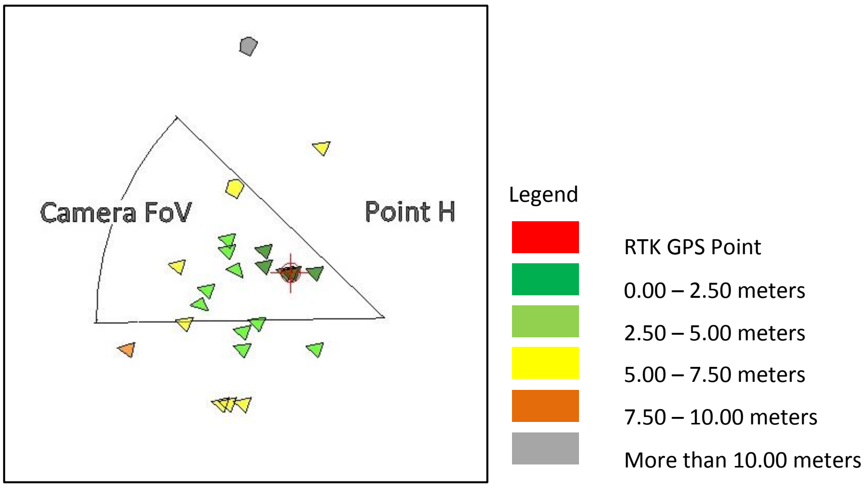
Point H is located in the base of the sign, the AR features are observed that are moved to the east. The picture was taken from the east of the point (Figure 49 a, b, c).



a)



b)



c)

Figure 49. a) Point H.
b) Augmented measurements and RTK GPS point.
c) Camera field of view in Point C

The visual inspections shows that the AR symbols are positioned close to the real location, it is visible that the measurements are located closer than the statistical analysis suggest. Point A and B have the biggest mean distance from the RTK GPS points, in the inspection, point B and D are the closest to the building in the centre, this could explain why the statistical test show that they have more error but in the visual inspection is possible to observe that measurements are clustered between the building and the RTK GPS point, this pattern repeats in point F. Points C, E and G have the less distance error and the measurements are clustered around the RTK GPS point, these points are in the corners of the buildings, they are more in the open so the GPS signal is stronger. Point A is surrounded by vegetation in its north east part, this has an impact in the GPS signal (Figure 50).

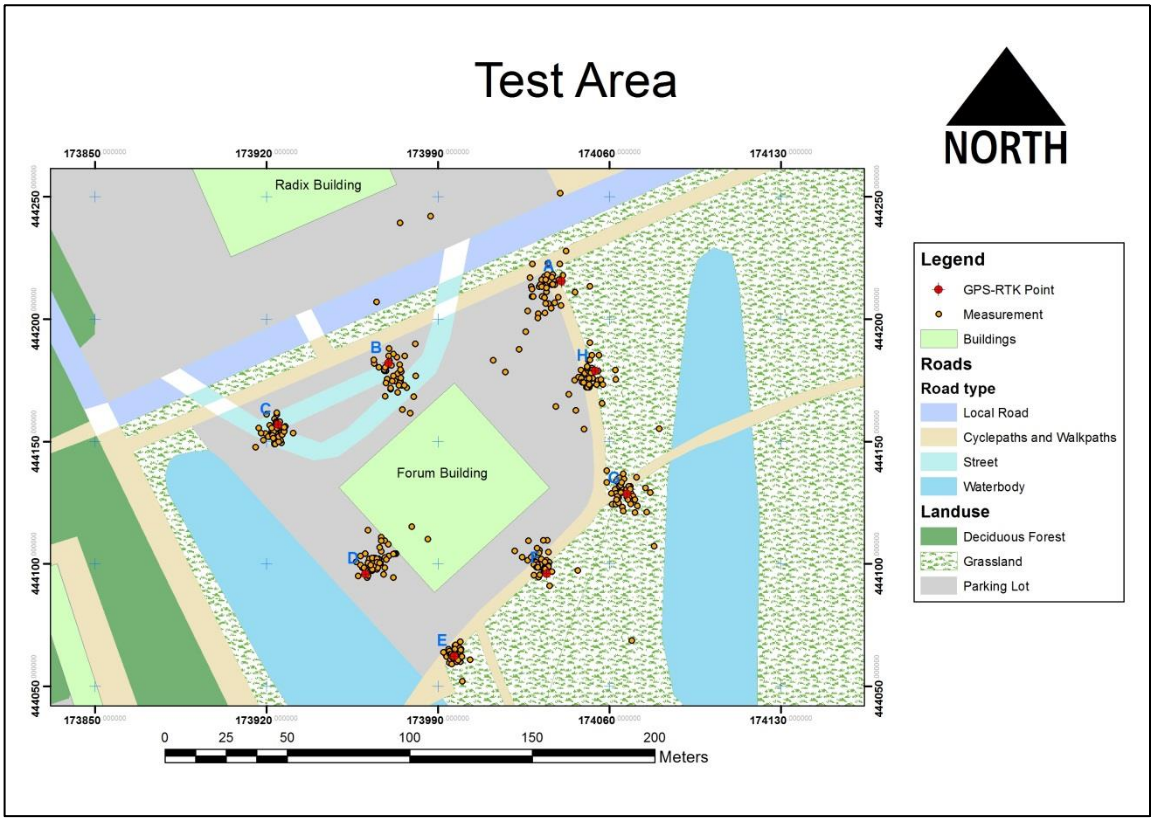


Figure 50. Measurements in RTK GPS points

Chapter 7 Conclusion, Discussion & Recommendations

The objective of the research is to "Develop an outdoors sketch procedure by mobile devices to create three-dimensional features to be used as Augmented Reality", all the steps in the methodology demonstrate that simple input can be transformed in AR models, this chapter presents the outcomes of the research project.

7.1 Conclusion

As mentioned before, the objective is to "Develop an outdoors sketch procedure", which is accomplished, the input points are converted in AR models and displayed in the AR environment, allowing the user to have a visual interaction with the AR models in the Layar application. It was possible to create point features and line feature with this procedure in the form of AR columns and AR walls to allow a fine and roughly representation.

Question 1. How can 3D features be created directly from/in the real world?

By using other mobile applications, is possible to record and "sketch " the necessary points to build AR models, in this case is the waypoints that are recorded by the android application (GPS Essentials). It is been shown that is possible to record the basic object which is the point, the points can represent line features where points represent the vertex points and it is possible to build a polygon feature from the points as well. All of this input is processed to create a set of 3D models or one single 3D model depending of the scenario (point scenario or line scenario), also these 3D models are created in the specific format to be uploaded to the AR environment, in this case in the transformation in format goes from KML file, to SHP file, Feature file, DXF file, OBJ file and to L3D format in order to display the features in the AR environment.

Question 2. How to visualize these features by Augmented Reality?

For visualization of the sketched 3D features, the Layar application was chosen due to its easy install procedure and manipulation in the mobile devices. Also the application can display in the AR environment the desired sketched features, even with all the format changes the 3D models do not show alterations in design, the features maintain their composition, the location of the AR models is affected directly by the GPS signal of the mobile device, however this locations is close to the initial in situ sketch.

Question 3. How to guard positional accuracy of these 3D AR features?

The test looks to prove the accuracy of the method, the t-test on the difference in X and Y towards the RTK GPS points shows that only two of the eight test points have no differences in the X and Y coordinates, which means that the 25% of all measurements show no statistical difference towards the RTK GPS points, the points were E and G, which are points located in corners where the area is free of objects that can disrupt the GPS signal. The rest of the points have high differences in coordinates X and Y, but the points are located near to buildings or trees which interfere with the GPS signal. The AR models in the visual inspection show that the models are close to the RTK GPS points, even with low accuracy in the other six points, a low number the measurements could be located in the range of 0 and 2.5 meters away from the RTK GPS points. The visual inspection also shows that in point E almost all measurements are inside the range from 0 to 5.00 meters.

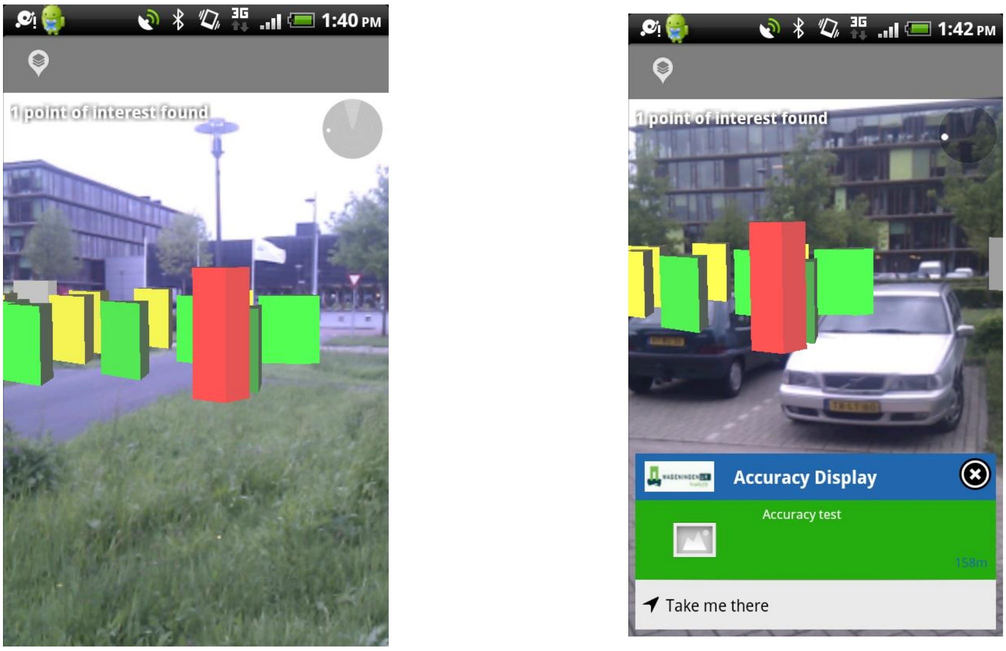
7.2 Discussion

The methodology that was used can be change in different aspects but it retains the same concept which is the recording of the input which is the points that are the base basic feature that can be sketched. From the methodology the applications and programs can be changed, but the need to do the same actions as the ones that were selected for the process of sketching the features. With them the client should be possible to "sketch", record and send the input to the service, the service should be able to use process the data in order to create a 3D mesh, but it is compulsory that this 3D model must be in OBJ file in order to be uploaded to the server. The AR application also can be changed, but the Layar application for the mobile phones is one of the few applications that allow geolocation of AR models in the AR environment.

When the user is sketching the points on the OSA (GPS Essentials application) there is a chance that the recorded points are not located at the desired position that the user wants, because the GPS and the compass from the mobile devices tend to be sensitive and depends in the location and accuracy of the sensor, the GPS information can be affected by magnetic disturbances (mobile device compass) or be unavailable in urban environments (Arth & Schmalstieg, 2011).

During the creation of the 3D mesh, it's necessary to take into account that this mesh is only a guide line for the 3D model that is going to be drawn in the 3D software, the parameters implemented during the building of the 3D frame could be changed, it depends of the service desire. Also when creating the 3DL file, the 3D models need to be georeferenced with the coordinates in decimal degrees of the 3D model in the point or edge located in the far south of the model or set of 3D models.

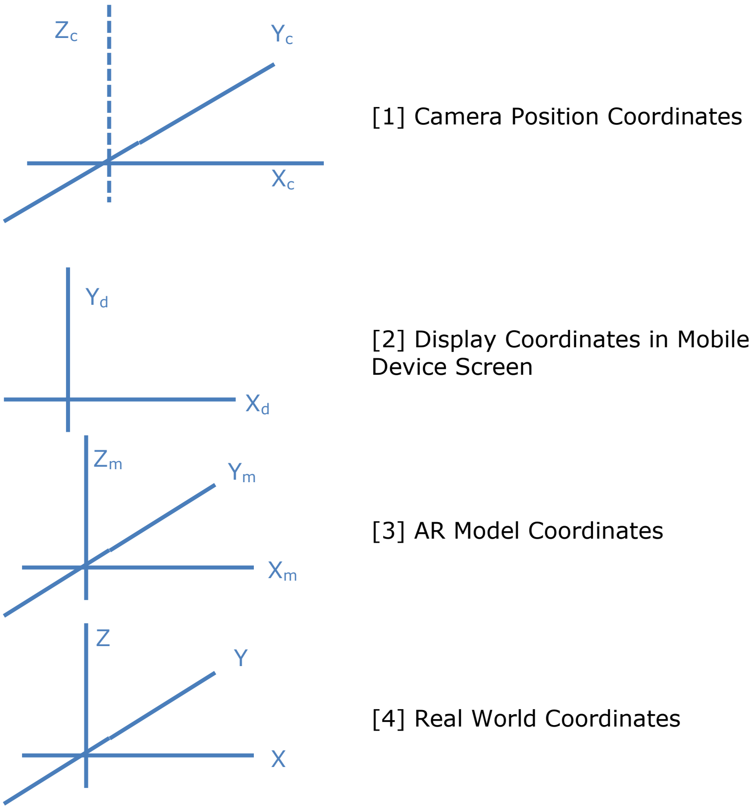
The Layar application might not be perfect in displaying the AR features; some aspects in their representations need to take into account, like the number of features displayed, with a big number of AR features the applications could not load properly. If the setup of the layer in the Layar website (Appendix E) is not well done or the wrong storage of the AR models in the server, the AR models will not load. Also when representing AR features, with the constant moving of the mobile device, the client needs to refresh time to time to adjust the coordinates of the client position. Figure 51 shows this kind of issue; the Layar application shows the layer without update when the client moves around, in figure 51a point A is displayed but if the client moves to the direction of point B and doesn't refresh the AR models, the models of point A are still displayed instead of the ones of point B as is shown in figure 51b.



a) b)

Figure 51. a) AR features on Point A ; b) point A AR features on point B

This kind of issue can be explained, this is caused by the constant change in reference systems (change in X, Y, Z coordinates), during the recording of the input and during the displaying of AR models on the mobile phone screen. The referenced systems that need to take into account are shown below (figure 52):



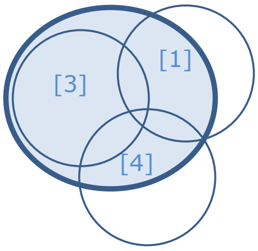


Figure 52. Reference systems change

Yang explains that the position and perspective of the 3D models are called out by the identified pattern and are displayed on the monitor through the geometric transformations among the AR features, camera coordinate and the real world (figure 53) (Yang, Chao, Huang, Lu, & Chen, 2013).

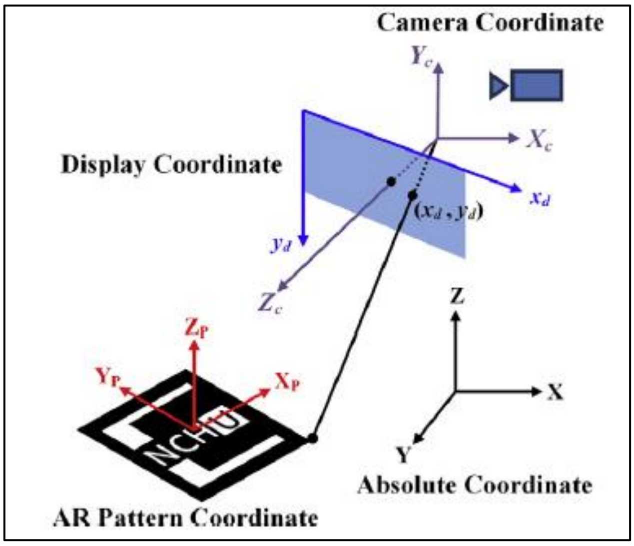


Figure 53. Geometrical relationship between AR patterns coordinates vs. camera coordinate and real-world coordinate(Yang et al., 2013)

This means that in the display canvas, the user is observing these different reference systems without realizing that this transformations cause the error in the coordinates in the display of the AR features in the mobile device. The camera in the mobile device has its own coordinates, the display of the mobile device and the AR features, the three of them have to be integrated into the coordinates in the real world and all of them depend on the GPS coordinates of the mobile device. Assuming that the accuracy of the AR features totally depends in the GPS in the mobile device.

The statistical t-test shows that the difference in the coordinates of the AR features and the RTK GPS points is totally different in 6 of the 8 points, only 2 of the point show that the difference is 0; this is all possible because of the surroundings of the RTK GPS points. By observing figure 14, points B and D are close to the building in the centre, point C is located in a parking lot which means that electromagnetic signals disturb the GPS reception (Arth & Schmalstieg, 2011) and point A, F and H are close to vegetation. Meanwhile point E and G are more in an open area, where the GPS reception is better.

A prototype developed for architectural applications, which uses Urban Sketcher a Mixed Reality (MR) tool, allows users to directly alter the perceived reality by sketching on canvases in a video see-through augmented representation of the urban scene. The systems consist in (Sareika & Schmalstieg, 2007):

- Sketching interface. The envisioned sketching should follow the similar conventions of 2D painting programs, but the digital paint should be applied directly on 3D surfaces in the video augmented scene. The painting is in 2.5D which means working in 3D space while one dimension is locked static.
- Canvas Billboards. The user can paint on the canvas with either a 2D or 3D input device. Canvases can be filled with arbitrary user-created content relying on a variety of paintings and sketching tools similar to the ones known from 2D painting applications.

The Urban Sketcher Interface is divided into painting area and a control interface, the most frequently used functions area directly available when working in the painting area, the control interface is arranged in sections of commonly used command groups, available as a tabbed dialog.

The procedure and methodology have the potential to sketch objects and use them to represent basic features that can modify and improve the urban environment. From the Visual inspection in chapter 5.2.2, is possible to observe that even with the neglect of the statistical test in the 6 of the points is possible, but not precise, to represent the AR features in the desired position. To prove this, a small test is implemented to prove the acceptable inaccuracy of the AR features that are displayed in the mobile device and show the nature in sketching a basic feature.

7.2.1 Sketch Mini Test

To prove how sketching works, a test is carried out where in the maps 1 centimetre represents 10 meters, 20 persons were asked to sketch or draw a square around each point, the square must contain a point and should be small as possible (figure 54).

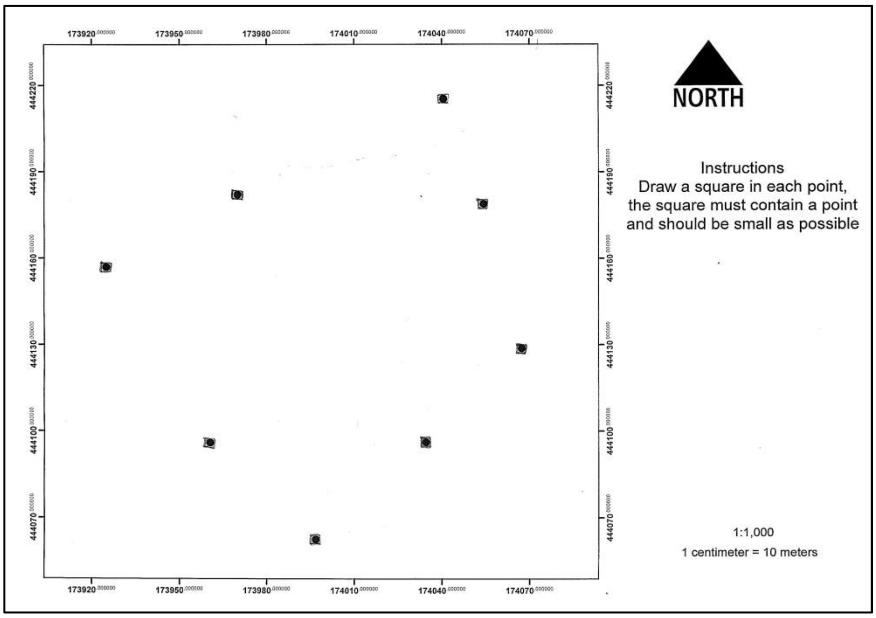
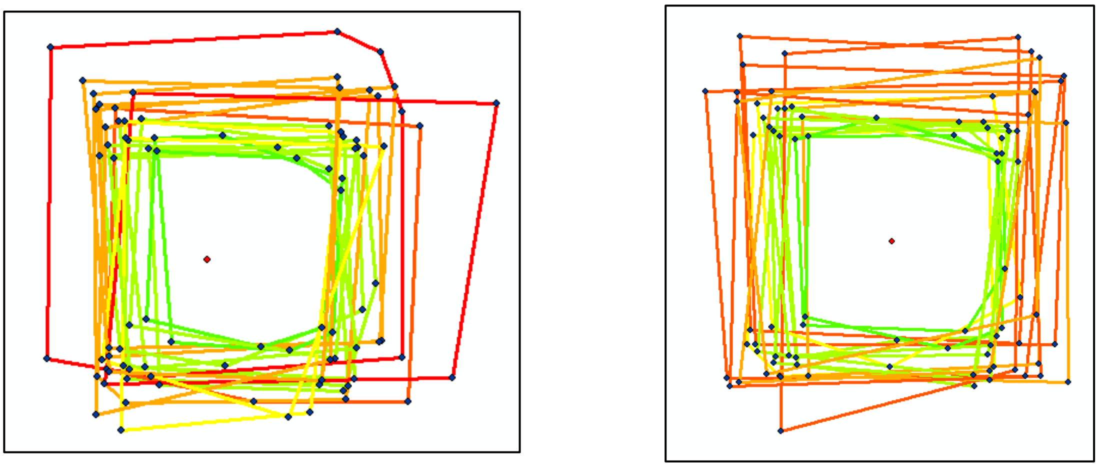


Figure 54. Test setup
scale 1:1,000, where 0.25cm accuracy means 2.5 meters in the real world

The test were scanned and digitalized to observe the difference in the area that was sketched by the people, in figure 55a and 55b show two of the examples in the test.



a) b)

Figure 55. Examples of the sketch test

In table 11 shows the statistics that were carried out in the digitalized areas. The mean distance to the RTK GPS points is the 2.337 meters with a standard deviation of 0.631 meters.

Table 11. Sketch statistics

Statistic	Value (meters)
Mean	2.337
Standard Deviation	0.631
Sum	1976.940
Min	0.821
Max	4.760

With this test it is possible to observe that sketching varies in the X and Y direction in a significant matter, even for sketching a small square in a small point (5mm diameter). This show the inaccuracy of sketching in a small scale, in the sketching outdoors application 3D models are constructed from 2D features that were taken from the real world, sketching by definition is a quick way of graphically demonstrating an image, idea or principle.

7.3 Recommendations

The procedure to sketch in situ and create the AR models by the OSA can be optimised in different ways, the recording of the "sketch" features entirely depends on the accuracy of the mobile device, which varies from each model of device (smartphone brand or tablet). The OSA as well works with the manual intervention at the service part of the procedure, where the service needs to draw the 3D mesh from the output of the procedure in ArcMap, this part could be automatized by a script or group of scripts.

The Layar application is the main tool of the procedure; it is the only one application on the market that allows the creation of georeferenced AR models instead of AR models that need markers for reference. Because of this, it would be ideal to create a AR application that allows the creation of the input and the design of the 3D models for the AR environment. In the Layar application, one of the new features that can be exploited is the new 3D animation feature, in this some 3D dynamic models could be uploaded and georeferenced to recreate an event or simulate a specific action.

It is visible that the OSA could have a good performance in open areas, but the ideal should be that the application could have that good performance in tight urban environments. This could be fixed by increasing the power from the GPS receiver from the mobile device by upgrading the calculations of the GPS signal. This as well is limited by the model and brand of the mobile device.

The OSA focuses on the X and Y coordinates, further work can be applied to create a way to implement the use of the 3D coordinate system, X, Y and Z. This could improve the visualization of the AR models and open different perspectives allowing not only point and line features but also polygon features. With such improvement better sketches can be done for/by the urban planners and architects. However a usability test must be done to make sure that such an OSA has an additional value.

The OSA was only used to sketch new objects; the modification of existing objects in the real world is not tried. Examples of such usage are to sketch modifications in buildings or urban environments and for sketching demolitions or diggings in the real world. The OSA development has focused on simple sketches, such as wall and point objects. Further developing can be done for displaying more complex sketches.

AR can be used to monitor energy usage in residential areas, with AR models that auto update with a determinate time span. AR technology still has a lot of potential in the planning of urban environment.

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Appendix

Appendix A. Smartphone specifications

Table 12. Smartphone specifications

General	2G Network	GSM_1 850/900/1800/1900
	3G Network	$HSDPA_2$ 900/2100
	SIM	Mini-SIM
	Announced	2010, February
Body	Dimensions	119 x 60 x 11.9 mm
	Weight	135 gr.
Display	Type	AMOLED3 or SLCD capacitive touchscreen, 16M colours
	Size	480 x 800 pixels, (~252 ppi pixel density)
	Multitouch	Yes
Memory	Card slot	Micro SD, up to 32 GB
	Internal	576 MB RAM, 512 MB ROM
Data	$GPRS_4$	Class 10 (4+1/3+2 slots), 32-48 kbps
	$EDGE_5$	Class 10, 236.8 kbps
	Speed	HSDPA, 7.2Mbps; $HSUPA_6$, 2Mbps
	WLAN	Wi-Fi 802.11 b/g
Camera	Primary	5 MP, 2592 x 1944 pixels
	Video	WVGA (800 x 480 pixels)
Features	OS	Android OS v2.2
	Chipset	Qualcomm QSD8250 Snapdragon
	CPU	1 GHz Scorpion
	Sensors	Accelerometer, proximity, compass

1. Global System for Mobile
2. High Speed Downlink Packet Access
3. Active Matric Organic Light Emitting Diode
4. General Packet Radio Service
5. Enhanced Data rates for GSM Evolution
6. High Speed Uplink Packet Access

Source: http://www.gsmarena.com/htc_desire-3077.php

Appendix B. GPS Essentials

By: Mictale.com

Description

Android application which is available in Google Play currently is in version 3.0.10 which was released on November 2nd 2012 and has the following features:

- Dashboard. Shows navigation values such as: accuracy, altitude, speed, battery, bearing, climb, course, date, declination, distance, ETA(Estimated time of arrival), latitude, longitude, max speed, min speed, actual speed, true speed, sunrise, sun set, moonset, moonrise, moon phase, target, time, turn (figure 56a).
- Compass. Show the orientation of the earth's magnetic field, show an arbitrary angle and the current target. Also a marine orienteering compass.
- Track. Record tracks and view them on map. Export KML files and import to Google Maps, Google Earth and others (figure 56b).
- Routes. Manage routes and view them on map. Import KML files from Google Maps, Google Earth, and other. Create turn-by-turn instructions between waypoints (figure 56c).
- Camera. A camera HUD (heads-up display) view to show your waypoints, take pictures and share them.
- Map. A map to show your waypoints. Convert mail addresses of your contacts to waypoint so that they can be used within the app. Supports Google Maps, MapQuest, OpenStreetMap and others.
- Waypoints. A list of all your waypoints with export and import (KML and GPX format).
- Satellites. A sky view of the current positions that shows satellites in view.
- Features. Supported positions formats: UTM, MGRS, OSBG, degree-minute-second, degree-minute-fractions, decimal. Supports over230 datums.

Permissions

Hardware controls

Take pictures and videos. Allow the app to take pictures and videos with the camera. This permission allows the app to use the camera at any time without your confirmation.

Location

Precise location (GPS and network-based). Allow the app to get your precise location using the GPS or network location sources such as cell towers and Wi-Fi. These location services must be turned on and available to your device for the app to use them. Apps may use this to determine the exact location of the device; this may consume additional battery power

Approximate location (network-based). Allow the application to get the device location. This location is derived by location services using network location sources such as cell towers and Wi-Fi. These location services must be turned on and available to your device for the application to use them.

Network Communication

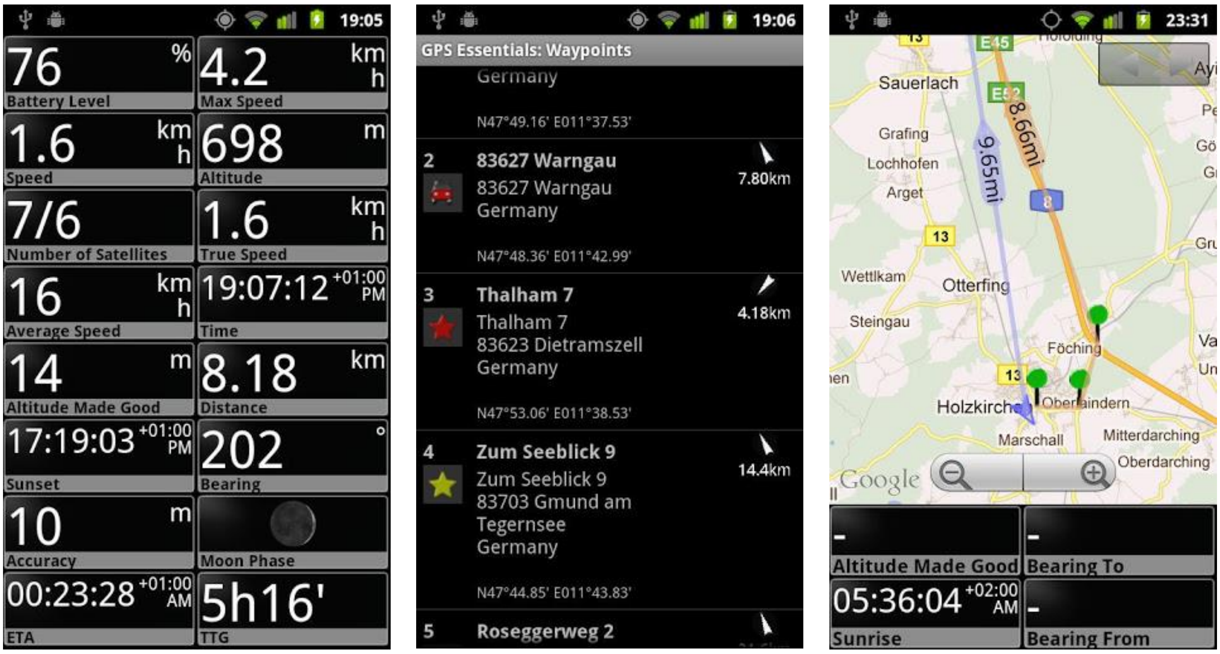
Full network access. Allows the application to create network sockets and use custom network protocols. The bowser and other applications provide means to send data to the internet; this permission is not required to send data to the internet.

Phone calls

Read phone status and identity. Allows the application to access the phone features of the device. This permission allows the application to determine the phone number and device IDs, whether a call is active, and the remote number connected by a call.

Storage

Modify or delete the contents of your USB storage modify or delete the contents of your SD card. Allows the app the write to the USB storage. Allows the app to write to the SD card.



a) b) c)

Figure 56. GPS Essentials application

Appendix C. Layar Application

Description

Print comes to life with Layar. With over 29 million downloads, Layar is the number 1 AR and interactive print app. Scan magazines, newspapers, posters, products and other items that have been enhanced with Layar – just look for the Layar logo. Then watch as extra digital content appears, allowing you to interact with print in a whole new way.

- See magazines come alive with videos right on the page (figure 57 a, b).
- Purchase items directly off the page with mobile shopping links.
- Connect with links to web content and share items on social media.
- Scan QR codes to view thousands of Geo-Layers for location based content like ATMs, restaurants, historical locations and more.
- Additional language support for Dutch, French, German, Japanese and Spanish.

Permissions

Hardware controls

Take pictures and videos. Allow the app to take pictures and videos with the camera. This permission allows the app to use the camera at any time without your confirmation.

a) b)

Figure 57. Layar application

Location

Precise location (GPS and network-based). Allow the app to get your precise location using the GPS or network location sources such as cell towers and Wi-Fi. These location services must be turned on and available to your device for the app to use them. Apps may use this to determine the exact location of the device; this may consume additional battery power

Approximate location (network-based). Allow the application to get the device location. This location is derived by location services using network location sources such as cell towers and Wi-Fi. These location services must be turned on and available to your device for the application to use them.

Network Communication

Full network access. Allows the application to create network sockets and use custom network protocols. The bowser and other applications provide means to send data to the internet; this permission is not required to send data to the internet.

Phone calls

Read phone status and identity. Allows the application to access the phone features of the device. This permission allows the application to determine the phone number and device IDs, whether a call is active, and the remote number connected by a call.

Storage

Modify or delete the contents of your USB storage modify or delete the contents of your SD card. Allows the app the write to the USB storage. Allows the app to write to the SD card.

Appendix D. KML to SHP

Converting KML files to shape files in ArcGIS with the KML to SHP tool

Author: Jason Parent (jason.parent@uconn.edu)
Date: May 3, 2008
Modified by: Robert McCann
Modified on: June 6, 2008
Modified by: Charles Morton
Modified on: August 24, 2009

The purpose of the Convert KML to SHP tool is to convert Google Earth kml files to shape files. The output shape file will contain feature names, descriptions, and Google Earth folder as attributes. The coordinate system of the output shape file is in geographic coordinates (WGS84). The kml file may contain any number of points, lines, and polygons. The script will create a shape file for the feature type of interest. If the kml file contains more than one type of feature, you will need to run the script once for each feature type that is to be converted to a shape file.
When digitizing in Google Earth, it is recommended that you store all features intended for a given shape file in a single folder. You can do this by using the following procedure:

- Create a folder in the goggle Table of Contents by 1) right-clicking on My Places, 2) click Add, and 3) click Folder.
- Add features to the folder by clicking on the folder so that it is highlighted. Then proceed to create polygons, lines, or points.
- When finished creating features, save the entire folder as a kml file by 1) right-clicking on the folder, 2) select "Save As", and 3) change type to kml. Individual features may also be saved as kml files.

About the script…
The KML to SHP tool is a python (version 2.4) script that has been set up to work from within the ArcToolbox of ArcGIS version 9.2 or later. The script will not work with ArcGIS 9.1 since it does not use an equivalent version of python. The script is designed to read kml files generated by Google Earth version 4.2 (Nov 13 2007) or later and may not read kml files generated by earlier versions. The script cannot convert kml files generated in Google Maps. Before you can run the script in ArcGIS, you will need to load the script's toolbox into ArcToolbox.

Loading the KML_to_SHP toolbox into ArcToolbox:
The download from the ESRI ArcScripts site contains the file KML_to_SHP.tbx – this file is the toolbox which you will need to load into ArcToolbox (unless you are using ArcGIS v9.2). If you are using ArcGIS 9.2, you will need to load the KML_to_SHP_9_2.tbx toolbox. The kml_to_shp.py is the script file which must always be kept in the same location as the .tbx file so that the toolbox can find the script.
To load the toolbox into ArcToolbox:

1) Start ArcMap and open ArcToolbox.
2) In ArcToolbox, right-click on ArcToolbox
3) Click on Add Toolbox, navigate to the KML_to_SHP.tbx (or KML_to_SHP_9_2.tbx), and click Open
4) Click the plus symbol to the left of the Convert KML to SHP toolbox to expand it. The toolbox will contain the Convert KML to SHP script.
5) Double-click on the script to run it.

The Convert KML to SHP tool contains documentation on how to use it. To view the documentation, double-click on the script to open the dialog window. The help column to the right will provide general information about the tool as well as specific information for each parameter when you click in the parameter input box. For further information, click on at the top of the Help column. This will open up an html page containing further documentation for the tool.

Troubleshooting…

- The script does not read older kml formats. If the script has a problem reading a kml file, you should try recreating the file in Google Earth v4.2 or later. To do this, load your kml file into Google Earth and resave the file. Try running the new kml file in the script.
- The script cannot read compressed kml files (files with .kmz extensions). To convert to a kml file, open the kmz file in Google Earth and save as a kml file.
- The script cannot convert kml files generated in Google Maps even after resaving in Google Earth. These kml files do not contain actual data; they only contain a link to the data on Google's server. To convert a Google Map kml file to a shape file, it would need to be re-digitized in Google Earth and then saved to a new kml file. The resulting kml file can then be converted to a shape file.
- If you receive the error "ArcGIS Data Management Toolbox not found. Script cannot execute", then you will need to modify the script to give it the location of the Data management toolbox. Refer to the PowerPoint file called "Specifying toolbox location.ppt" for an illustration of how to do this.
- If you are using ArcGIS 9.2, make sure you are using the KML_to_SHP_9_2.tbx.

Appendix D. Procedure in ArcMap

Figure 58 shows the procedure to create a 3D mesh from the point data set in KML format, the procedure consists in creating a set of points from the buffer of the points and a line that unites them. The points are duplicated and added height, the 3D mesh is constructed with the creation of sight lines from each point to the rest of the points.

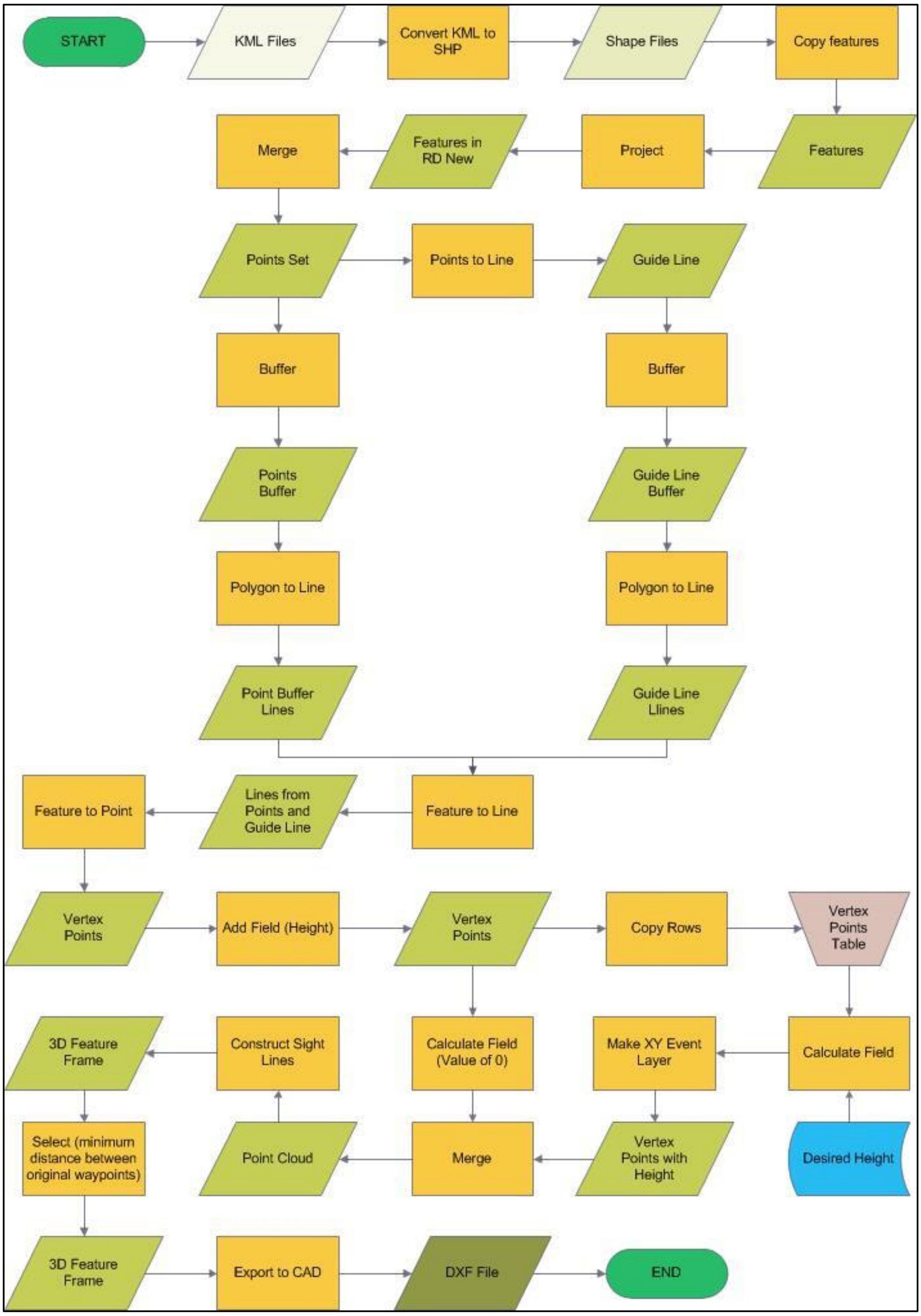


Figure 58. Procedure to create a 3D mesh.

Appendix E. Create a Layar Layer

In order to create layers in Layar, it is necessary to create an account in the Layar website and make the following steps:

- Log in with the Layar account (https://layar.com/accounts/login). This Layar account should be verified and with developer role enabled
- Click on "My layers" button shown next to the user name on top right part of the page (figure 59).

Figure 59. Main title

- Get access to the publishing site environment and "layers" tab is show by default (figure 60).

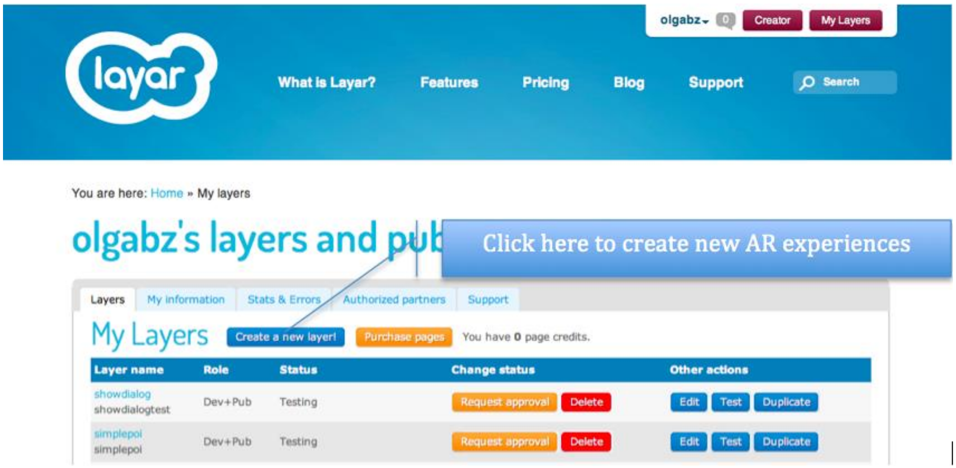


Figure 60. Layers manager

- Click on "Create a layer" button to open the layer creation form (figure 61)

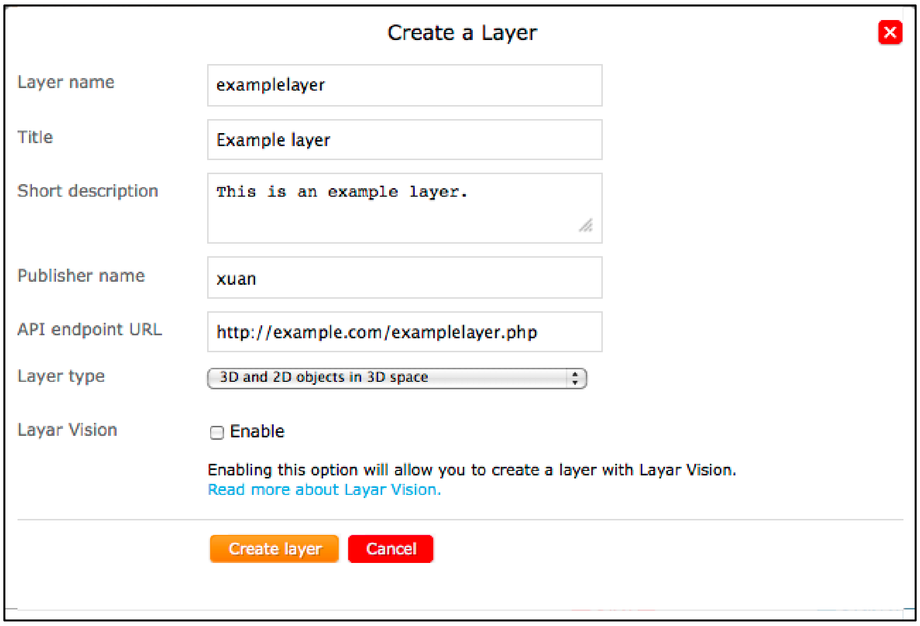


Figure 61. Layer creation

This form is used to define and create a layer on the publishing site. All these fields are mandatory. Except that the layer name could not be renamed, other fields can be modified in layer editing afterword.

- After filling in the information, click on "create layer" button. Layer is created and the layer editing page is show (figure 62).

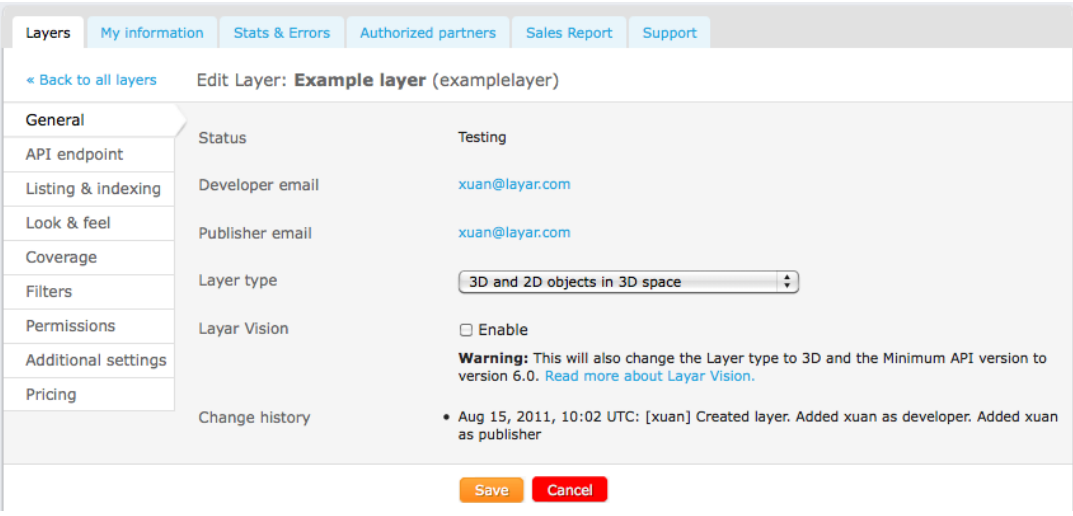


Figure 62. Layer options

Edit a Layer

Some several mandatory fields that are needed in layer creation. This section customize the layer, to edit it click on "Edit" button for this layer to open the layer editing page. There are 8 tabs, to modify the layer:

- General. The basic information about this layer, such as layer status.
- API Endpoint. Mainly the POI URL for developer's web service that provides hotspots response.
- Listing & Indexing. Mainly layer listing on the phone.
- Look & Feel. Manage the appearance of the Camera view on the phone.

- Coverage. Define layer country region and set up bounding box for local layers.
- Filters. Set up filter settings for a layer.
- Permissions. Assign different publisher and add viewers to a layer.
- Reference Images. Upload and manage reference images to Layar server. This tab is not visible, if “Layar Vision” is not enabled.

Appendix F. XML files for Features and Accuracy Assessment.

XML File for Application

In order to insert 3D objects in the AR environment it is necessary to prepare the following line code for each set of 3D objects that are created.


```
<!--Point Feature -->
<poi>
       <dimension>3</dimension>
       <alt>0</alt>
       <transform>
              <rel/>
              <angle>0</angle>
              <scale>1</scale>
              </transform>
       <object>
              <baseURL>http://www.geo-
informatie.nl/Miscellaneous/victor/Pts/</baseURL>
              <full>Pts_A.l3d</full>
              <reduced/>
              <icon/>
              <size>23</size>
              </object>
       <relativeAlt>0</relativeAlt>
       <attribution/>
       <distance/>
       <id>01</id>
       <imageURL>http://www.geo-
informatie.nl/Miscellaneous/victor/Pts/A_pts.jpg</imageURL>
       <lat>51.985905</lat>
       <lon>5.666252</lon>
       <line2>Point Based</line2>
       <line3/>
       <line4/>
       <title>Point Feature AR</title>
       <type>2</type>
       <doNotIndex>0</doNotIndex>
       <inFocus/>
       <showSmallBiw>1</showSmallBiw>
       <showBiwOnClick>1</showBiwOnClick>
</poi>
<poi>
       <dimension>3</dimension>
       <alt>0</alt>
       <transform>
              <rel/>
              <angle>0</angle>
              <scale>1</scale>
              </transform>
       <object>
              <baseURL>http://www.geo-
informatie.nl/Miscellaneous/victor/Pts/</baseURL>
              <full>Pts_A2.l3d</full>
              <reduced/>
              <icon/>
              <size>23</size>
              </object>
       <relativeAlt>0</relativeAlt>
       <attribution/>
       <distance/>
       <id>02</id>
       <imageURL>http://www.goe-
informatie.nl/Miscellaneous/victor/Pts/A_pts2.jpg</imageURL>
       <lat>51.986076</lat>
```

```
		<lon>5.666945</lon>
		<line2>Point Based</line2>
		<line3/>
		<line4/>
		<title>Point Feature AR</title>
		<type>2</type>
		<doNotIndex>0</doNotIndex>
		<inFocus/>
		<showSmallBiw>1</showSmallBiw>
		<showBiwOnClick>1</showBiwOnClick>
	</poi>
```

The code contains the specifications of coordinates, root directory in the server, colour, text that pop up in the feature and images that could represent the AR feature in the Layar application.

XML File for Accuracy Assessment

The following code lines are the setting for the accuracy part, which is similar but it requires less information

```
<!-- Accuracy -->
<poi>
	<dimension>3</dimension>
	<alt>0</alt>
	<transform>
		<rel/>
		<angle>0</angle>
		<scale>1</scale>
		</transform>
	<object>
		<baseURL>http://www.geo-informatie.nl/Miscellaneous/victor/</baseURL>
		<full>accuracy.l3d</full>
		<reduce/>
		<icon/>
		<size>23</size>
		</object>
	<relativeAlt>0</relativeAlt>
	<attribution/>
	<distance/>
	<id>01</id>
	<imageURL>htttp;//www.geo-
informatie.nl/Miscellaneous/victor/accuracy.jpg</imageURL>
	<lat>51.984634</lat>
	<lon>5.663693</lon>
	<line2>Accuracy test</line2>
	<line3/>
	<line4/>
	<title>Accuracy Display</title>
	<type>2</type>
	<doNotIndex>0</doNotIndex>
	<inFocus/>
	<showSmallBiw>1</showSmallBiw>
	<showBiwOnClick>1</showBiwOnClick>
</poi>
</pois>
```

Appendix G. R code for Position Test

For the statistical calculation in R, for each RTK GPS point, the measurements were calculated by point of measurement, for each point the following code was constructed.

```
A<-test[which(test$NAME=='A'),]

# Plot points at A
plot(A$POINT_X,A$POINT_Y, main="Point A",xlab="X coordinate(meters)", ylab="Y
coordinate(meters)")
points(RTK[1,]$x,RTK[1,]$y,col="Red", pch=16)
abline(h=RTK[1,]$y,v=RTK[1,]$x,lty=3)
legend("topleft",inset=0.0, c("GPS-RTK Point"),pch=16,col="Red")


## Statistical values and Distance calculation, mean, std deviation, distance

A$diff_rtkx<-A$POINT_X-RTK[1,]$x
A$diff_rtky<-A$POINT_Y-RTK[1,]$y
A$dist<-sqrt((A$diff_rtkx*A$diff_rtkx)+(A$diff_rtky*A$diff_rtky))

boxplot(A$diff_rtkx,A$diff_rtky, main="Distance Difference from GPS-RTK point on
A", names=c("X","Y"),xlab=c("Dimension"), ylab="Difference in Meters")
abline(h=0,lty=3)

#Plot difference
plot(A$diff_rtkx,A$diff_rtky,main="Difference towards GPS-RTK Point in A",xlab=
"Difference in X(meters)",ylab="Difference in Y(meters)",col="Red")
abline(h=0,v=0,lty=3)


# T-test
Atestx<-t.test(A$diff_rtkx,paired=F,conf.level=0.99)
Atesty<-t.test(A$diff_rtky,paired=F,conf.level=0.99)
Atestx
Atesty


# RMSE
fitA<-lm(A$diff_rtky~A$diff_rtkx, data=A)
rmseA<-round(sqrt(mean(resid(fitA)^2)),2)
coefsA<- coef(fitA)
b0A<-round(coefsA[1],2)
b1A<-round(coefsA[2],2)
r2A<-round(summary(fitA)$r.squared,2)

eqnA<-bquote(italic(y) == .(b0A) + .(b1A)*italic(x) * "," ~~
              r^2 == .(r2A) * "," ~~ RMSE == .(rmseA))

plot(A$diff_rtky~A$diff_rtkx, data=A,main="Linear Model on Point A",xlab=
"Difference in X(meters)",ylab="Difference in Y(meters)")
abline(h=0,v=0,lty=3)
abline(fitA)
text(0,25,eqnA,pos=2)
```

For the global calculation of the measurements the following code was put in R.

```
#Boxplot of distances

boxplot(A$dist,B$dist,C$dist,D$dist,E$dist,F1$dist,G$dist,H$dist, main="Distance to
GPS-RTK Point", xlab="Point", ylab="Distance",
names=c("A","B","C","D","E","F","G","H"))
abline(h=c(5,15,25,35,45,55),lty=3)

#Detail
boxplot(A$dist,B$dist,C$dist,D$dist,E$dist,F1$dist,G$dist,H$dist, main="Distance to
GPS-RTK Point", xlab="Point", ylab="Distance",
names=c("A","B","C","D","E","F","G","H"), ylim=c(0,20))
abline(h=c(2.5,7.5,12.5,17.5),lty=3)

Adm<-mean(A$dist); Bdm<-mean(B$dist); Cdm<-mean(C$dist); Ddm<-mean(D$dist); Edm<-
mean(E$dist)
Fdm<-mean(F1$dist);Gdm<-mean(G$dist);Hdm<-mean(H$dist)

Tdistmean<-mean(Adm,Bdm,Cdm,Ddm,Edm,Fdm,Gdm,Hdm)

mean(rmseA,rmseB,rmseC,rmseD,rmseE,rmseF1,rmseG,rmseH)
```

Appendix H. DVD Contents

This thesis was delivered with a DVD labelled, “Sketching in Situ: Sketching Reality Features with Mobile Devices”, GRS2013-16

This table shows the contents of the DVD:

- Report (Word, PDF)
- Presentation
- Figures used
- Data
  - 3D mesh
  - OBJ files
  - 3DL files
  - Accuracy test
- 2D Sketch test
- Literature