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Project management and communicational challenges in renovation projects with point cloud data utilization

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TABLE OF CONTENTS

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1 Abstract

The field of renovations is constantly growing when viewed from the monetary value point of view. According to estimations made by experts, the field is facing a need for a substantial growth in resources or efficiency. One of the potential methods for increasing the efficiency in renovation projects is the growing use of point cloud data technology.

Point cloud data is a dense group of three-dimensional (3D) measurements, which can be used for example to establish a three-dimensional model of an existing building. The most significant advantage of using point cloud data, is the three-dimensional nature and the accuracy of the measurements. Current methods for 3D-modeling an existing building rely on unreliable old construction drawings and arduous physical measuring. The use of point cloud data simplifies the process of 3D-modeling of an existing building. In addition, the overall quality of the model increases due to precise 3D measurements.

As my master's thesis, I researched the topic from a theoretical point of view and with interviews. In the theoretical part of the research I covered the different forms of information used in modeling existing structures and their qualities. At the same time, I zoomed in on the terminology of point cloud data. The current terminology is used in conflicting manners. This emphasizes the role of language and communication when new technologies are introduced to projects. With the research, I formed several new definitions for point cloud data related terminology to improve the communication between experts.

I also examined the effects of Finnish Common BIM Requirements 2012 in to the initial data and methods used to model existing buildings. The current requirements are five years old and are outdated due to the quick development of different utilization methods and technical aspects of point cloud data. The rise of new technologies, such as photogrammetry, demand more attention when composing updated guidelines for the process and methods of 3D-modeling existing buildings.

The interviews were carried out to gather user experience related to the subjects covered in the theoretical part of the research. Based on the interviews carried out in my master's thesis, the utilization of point cloud data technology greatly affects the project management within renovation projects.

The proposed paper will focus on the above communicational challenges and changes in project managent. Technology is often examined only from a technical point of. This however neglects the humane aspects completely. For example, the use of point cloud data in a project require changes in the way we make calls for tenders and contracts. New technology also impact how, when and with whom we are supposed to communicate within the project. With the help of the proposed paper, renovation designers can also understand what changes the utilization of point cloud data as a technology bring to interaction inside the project.

The argument of the proposed paper, is that understanding point cloud data as a technology is not enough to utilize it efficiently. One must also understand the cultural effects.

2 The operational environment of the field of renovation

The operational environment of the field of renovations is wide and from the economical point of view substantially important. It is important to understand the fundamental differences of the field compared to the field of new construction.

The field of renovations in Finland has been growing steadily, from the monetary value point of view, since the early 1990's (Risulahti 2016). According to the estimations, the growth of the monetary value and the rising demand on the field will continue its current trend (Hyyppä 2012).

A potential mean of responding to the rising demand is the digitalization of design methods. Digitalization is said to be the biggest single phenomena to reshape the society currently. The magnitude of the reshaping effects is estimated to be equivalent to the invention of steam power and electricity. (Pohjola 2015).

In the field of construction, digitalization started with computed aided design (CAD) methods, then continued with three-dimensional modeling (3D-modeling) and further evolved to creating building information models (BIM) (Freese et. al. 2007). The next trend could be the utilization of point cloud data.

3 Forms of initial data for renovation design

Renovation design requires a properly compiled baseline to examine the effects of existing structures to the design process. To compile a proper baseline, the project needs various forms of different initial data. The information can be categorized to measurements and qualitative information.

In this paper, I assess the following forms of information:

- Old construction drawings
- Physical measuring
- Photography
- Tacheometer measuring
- Laser scanning (LIDAR)
- Photogrammetry

Old construction drawings are a common form of initial information used in renovation design. They can be used for measures or the collection of qualitative information. When using the measures of an old drawing, one must acknowledge the uncertainty of the documents. Many of the changes made during and after the initial construction are undocumented (Risulahti 2016). However, one can collect vast amounts of qualitative information from the drawing, such as what's inside the surface. Many of the relevant structures are hidden but with proper drawings it's possible to predict what kind of structures are hidden. Although the only way to get reliable information about hidden structures, is to make openings to the surface structures.

The traditional methods for generating measurements is physical surveying on the field. This method is arduous work and the accuracy is rather low. At the same time, due to hazardous surveying locations, building surveyors might have limited accessibility. (Arayici 2007).

Photography is a widely-used method for collecting up to date qualitative information about the appearance of the subject. It's almost impossible to estimate measurements from photographs, but it's possible to identify rough defects found in for example old construction drawings.

Tacheometer is a device used for measuring. The device measures the horizontal and vertical angle and the distance to the measured subject and with the assistance of a computer formulates a coordinate for the measured point (Laurila 2012). The greatest advantage of measuring with a tacheometer is the accuracy of a few millimiters. The disadvantage on the other hand is the weak coverage of the subject.

Laser scanning (light detection and ranging, LIDAR) is measuring method used to survey a subject with a great accuracy and coverage. LIDARs can be airborne or terrestrial, the latter being used more frequently in building surveying. LIDAR surveys all the visible surfaces and generates point cloud data in the desired resolution. (Laurila 2012).

The field of photogrammetry examines the image based 3D measuring. It is related to computational image interpretation. With computational analysis, the photogrammetric algorithms form a geometrical relation between the image and the subject of the image. (Bethel et. al. 2001; Luhmann et. al. 2006).

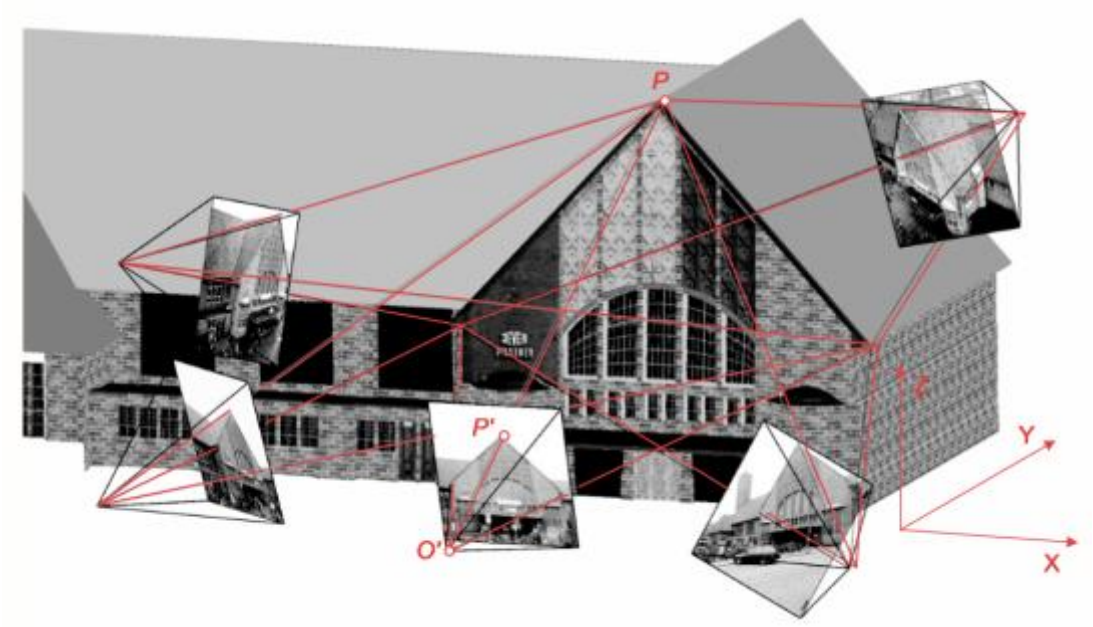

Figure 1. Photogrammetric algorithms form a geometrical relation between image and the subject. (figure: Luhmann et. al. 2006)

Photogrammetric processes generate point cloud data but the accuracy is slightly weaker than the data generated through laser scanning. Recently the amount of remotely controlled multicopters has grown and this may have resulted in rising popularity of photogrammetric applications.

4 Point cloud data and related terminology

The terminology of point cloud data related subjects is used with conflicting meanings. That's why I consider it fundamentally important to define the related the terms so that they can be used in consistent ways.

The reason, why I use the term 'point cloud data' is because 'point cloud' is related to the form of presentation of the data. Therefore, I've defined point cloud data as dense three-dimensional point data about the geometry of the subject that can be produced and presented in various ways. (Savisaari 2017)

As I mentioned, point cloud data can be produced in various ways. The methods that I cover in this paper is laser scanning and photogrammetry. As I explained in chapter 3, point cloud data produced with laser scanning is more accurate than data produced with photogrammetry.

The data can be also presented in various ways. Currently designers mostly use point cloud presentation, which means that the data is presented as separate points that can be visually interpreted as a subject. However, the same data can also be presented as a textured mesh or text. All these ways of presentation have different strengths and preferred methods for utilizing them.

Point cloud data has a certain point density, which refers to the word 'cloud'. The data is dense enough to be called a cloud in case the subject is visually recognizable based on the data. The denser the data, the bigger the size of the file. High density values may result in files that are hard to handle and therefore it is important to consider the needed density with a case-by-case principle.

Figure 2. The visual effect of modifying the point density of point cloud data that's presented as a point cloud. (Figure: A-Insinöörit Suunnittelu Oy 2017).

Currently point cloud data is mostly used as initial data for renovation design and modeling existing structures. However, the data can be used also as is. Especially data presented as a mesh can be used for visualization. The third option is to combine these too ways of utilizing the data and partly using the data as is and partly data that has been modeled based on the point cloud data.

5 Inventory modeling

Inventory modeling is a relatively new concept used for modeling existing structures. The use of the term isn't established yet and currently it has several different meanings due to varying and conflicting definitions. I have defined the term as modeling existing structures based on measurements with building information modeling policies. (Savisaari 2017).

It is important to enclose BIM specifications to the inventory model, since the information about the used forms of initial data is crucial in evaluating the reliability of the inventory model (Rajala 2009).

When dealing with inventory modeling it's also important to evaluate the initial data critically, because the data used affects the usability of the whole model. The modeling should

preferably be executed based on “measurements, inventories and investigations performed on site” (Common BIM Requirements 2012, part 2).

The previous forms a clear principle for the hierarchy of used initial information, since it favors data gathered from the true conditions of the existing structures. Also, it’s important to notice, that even data gathered on-site may be outdated, if it’s not new enough.

Currently inventorymodeling is discussed a lot and many designers are interested in the method. Many of the designers feel that inventorymodel are unreliable. At the same time, inventorymodeling is considered to be a potential mean for raising the quality of design in renovation projects. (Lassila 2016).

The biggest challenge of inventory modeling is that the practice isn’t established in the field of renovation design. The Finnish Common BIM Requirements 2012 aim to address this issue and standardize the methods used in inventory modeling.

6 Finnish Common BIM Requirements 2012

Finnish Common BIM requirements 2012 is a collection of documents that are used as a tool for standardization of BIM. It also offers several instructions and guidelines. The methods for inventory modeling and modeling existing structures in general are defined in series 2 of the collection.

In my opinion, the requirements and guidelines are a way to categorize different parts of inventory modeling into different levels of quality, in order to clarify the fundamental preferences of inventory modeling. Even though my research focuses on point cloud data and its utilization, the guidelines also cover the use of other forms of initial data, in order to demonstrate the differences.

The Common BIM requirements set requirements and guidelines for:

- Initial data
  - Measurements
  - Surveys, analyses and inventories
- Modeling
  - Site model, site elements
  - Accuracy and the level of detail (LOD) of the inventorymodel

All details regarding the initial data and modeling have the same guideline that further details and specifications of the content of the project should always be defined on a project basis (Common BIM Requirements 2012 series 2). The different levels of definitions introduced in the requirements functions as a template to be modified to fit the project.

Measurements are divided into 3 levels of quality. The level defines the required accuracy of the data and also the method and device used to obtain the data (Common BIM Requirements 2012 series 2):

- Level 1 – Laser measuring and old construction drawings
  - Accuracy: no requirements
  - Data can’t be used to make a reliable inventory model.
- Level 2 – Tacheometer surveying

- Accuracy: error margin max. 5mm
- Data is suitable for making inventory models of geometrically simple subjects.

- Level 3: Laser scanning
  - Accuracy: error margin max. 10 mm, point density 5mm
  - Data is suitable for making detailed inventory models.
  - For an exceptionally detailed subject, the point density can be reduced.

Similar levels of quality are also introduced for surveys, analyses and inventories:

- Level 1 - Room tags and general building element types
- Level 2 – Room inventory and building element types
- Level 3 – Historical and research information of the building

The definitions of different quality levels for different forms of initial data are a good way to characterize the wideness of the data used. However, the current level definitions are somewhat conflicting and need additional development. For example, the levels of measurements completely neglect the existence of photogrammetry. This stems from the fact, that when the requirements were written, photogrammetry didn't have any proper applications to be used in the field of renovation design.

7 Communicational challenges caused by new technology

The first big issue in the communication regarding point cloud data related subjects is the conflicting use of terminology. According to my previous researches, currently same terms are used with different meanings and in my opinion, this makes the development of the field a lot slower (Savisaari 2017). The standardization of terminology aims to form a "fixed set of interpretations" in order to make communication among experts more effective (Johnson & Sager 1980).

Terminological units, such as the term point cloud data, are different from ordinary words due to the assumption, that they're simultaneously units of knowledge, language and communication. This means the unit "should cover the concept, the term and the situation components". (Cabré 2003).

This makes the use of new terms vulnerable to misunderstandings because a term contains multidimensional information. It should be in every experts interest to pursue the unification and standardization of the use of terminology in order to help developing the field.

In addition to terminological problems, the field is also developing so fast, that all the experts are not familiar with all the technical aspects of new technologies. For example, according to my previous research, photogrammetry as a form of initial data for architectural renovation design was known weakly. Also, the utilization of point cloud data presented in a mesh or text format was unusual. (Savisaari 2017).

When technical aspects of a new technology are unfamiliar, it's simply impossible to use the related terminology in a way that also addresses the unfamiliar technical aspects. And this in turn results in potential misinterpretation in professional communication among experts.

Therefore, in this paper I suggest that specialists working in the field of architectural renovation design ought to pursue keeping up to the technological advancements in their field in order to maintain effective communication between peers.

Not only is the communication among specialist complicated at the moment, but successful communication is also crucial to achieving a successful project. Communication is raised into a truly important role in a renovation or reconstruction project, that uses point cloud data or is inventory modeled, due to the Common BIM requirements 2012. Most of the things to be defined in a project are “to be defined with more detail on a project to project basis” (Common BIM Requirements 2012 series 2). This guideline steers the culture in a direction where different parties of a project need to understand all the communicational specialties the new technology introduces to the projects different phases.

Currently the field does not have proper instructions on when and what to communicate between which parties in the project. In my opinion, with proper instructions and guidelines many of the problems regarding point cloud data and inventory modeling can be avoided. The current system relies solely on communication in a project but does not address the communicational problems regarding unstandardized terminology and technically challenging aspects of new technology.

In the next chapter I will address the major communicational specialties I have discovered in my previous research. By acknowledging these specialties, it is possible to avoid fundamental communicational problems in renovation projects.

8 Calls for tenders and work distribution in projects

Technological development shake the traditional culture of calling for tenders and making contracts in renovation projects. Also the work distribution and number of parties in the projects may change. This ought to be paid attention to. The following is based on a series of interviews conducted as a part of my previous research. (Savisaari 2017).

For projects that utilize point cloud data and inventory modeling it is crucial to understand how to compose a suitable call for tenders for the project. The client is often responsible for composing the call for tender. However, the client often is not a specialist in the field of services the call is intended for and it’s important that the client has a capable consultant, for example the architectural designer, at service. The call may concern for example producing initial data for design (laser scanning, photogrammetry) or inventory modeling services.

When composing a call for tenders for producing point cloud data it’s crucial to understand the terminology of the field for reasons explained in chapter 7. In order to receive valid and comparable tenders that match the wanted ‘product’, the call must define the desirable product properly. For example, the client should be able to define the desirable:

- Method of production (laser scanning or photogrammetry)
- Point density
- File format
- Method of presentation (point cloud, mesh, text)
- Optional data segmentation policies
- Georeferencing methods

When the subject of the call for tenders is inventory modeling, it’s important to include the definition for the initial data used to model the existing structures. To do this, the client must

know what the objective of the inventory model in the project is and at the same time understand what are the limitations of different forms of initial data. It is impossible to get an inventory model that is more accurate than the initial data used to produce the model. Definition of inventory modeling should include:

- The software used for the modeling
- The extent of modeling, i.e. what to model
- Accuracy of modeling (different values for corner points, surfaces and irregular structures)
- Information to be included in the elements (BIM)

It's important to define the software used for the inventory modeling in case the firm that produces the inventory model is not the same one that is responsible for the architectural design of the project. The inventory model should be in the native file format of the design software the architectural designers use.

It's possible to separate the task of inventory modeling from the task of architectural design. This increases the amount of parties in the project and the communicational risks grow greater. However, in some cases this might be a beneficial solution. Currently some architectural designers think that inventory modeling ought to be separated from design and some think it's a natural part of design. The separation of the two functions may be of the clients' interest, since it offers new options for calling tenders. Nonetheless, to benefit from this option, the client must be well acquainted with the characteristics of point cloud data and inventory modeling.

9 Conclusions

Point cloud data is a modern technology that may revolutionalize the field of renovation. In my earlier research I have defined the term 'point cloud data' as dense three-dimensional point data about the geometry of the subject that can be produced and presented in various ways.

Point cloud data can be used to produce highly defined inventory models. In my previous researches I have defined the term 'inventory modeling' as modeling existing structures based on measurements with building information modeling policies

The technological advancements in the field allow great changes that may raise the efficiency of the design process. However, simply understanding the technique is not enough to utilize it effectively. Point cloud data and inventory modeling introduce various changes in project management and communicational challenges as discussed in this paper.

This paper introduces few of the communicational specialties that offer a potential method to avoiding many of the communicational problems that have originated from the new technologies.

To fully utilize the potential of point cloud data technologies, one must understand how it affects projects management and communication within a project.

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