Education of Open Infra BIM based Automation and Robotics

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Abstract –

This paper presents the learning outcomes of the Open InfraBIM and Construction Automation workshop in OuluZone motorsport Center, Finland, during October 2019. Totally of 45 students from the University of Oulu, the Oulu University of Applied Sciences, and the Oulu Vocational College were challenged to build the Speedway track by using the latest tools, such as real-time cloud service, work machines with automated 3D control systems, and drones. Furthermore, an autonomous excavator was demonstrated to the participants during the workshop. The students were divided into six groups. Each group had six different interesting tasks of a typical construction site guided by teachers and technology company experts. The idea was to practice real construction site work and problem solving. The feedback from the students, teachers and technology company experts were positive. The practical learning has found to be an excellent way to educate open infraBIM based automation and robotics.

Keywords –

Automation; Education; Infra Built Environmental Information Model (infraBIM); Robotics

1 Introduction

During last decade, Building Information Modelling (BIM) digitalized the entire construction sector from designing to the implementation and site logistic. Infra BIM is an acronym for Infra Built Environment Information Model, which includes the infrastructure information model and related structures and environment information [1]. According to Costin et al. [2] literature review, many publications have been published since 2002 to 2017 where BIM has studied various infrastructures related to the transport sector, such as bridges, roads, and mass transit. BIM has found to have unlimited potential for improving infrastructure, but there is still challenges interoperation and data exchange.

In Finland, a lot of trial project works have been done to obtain general guidelines and requirements for infrastructure construction since 2010. Building SMART Finland has been published Common infraBIM requirements (YIV2015, now second edition YIV2019), together with the infraBIM Classification and information transferring format [3] that are recommended to use in projects. Instead in Norway, the use of BIM become mandatory in large public infrastructure projects in 2016 [4]. The German Ministry of Transport and Digital Infrastructure (BMVI) aims at establishing the mandatory usage of BIM from 2020 for all building projects in its range of authority. For this reason, many pilot projects have been made [5]. In Sweden, government has assigned in 2012 to the Transport Admiration the task to the implement of BIM throughout of the construction industry. [6] These types of infraBIM piloting, guidelines and exploitations experiences have also been reported in other countries, such as in Spain ROAD-BIM EU-project [7]. As the benefits of BIM in the infrastructure pilots, demonstrations and projects have been found to be significant, it is important to be aware of the need for infraBIM training and education both for professionals and for construction students.

Currently, BIM education in higher education or technical training institutions has been reported providing globally in 17 countries, most in Architecture Engineering Construction (AEC) sector. In the report of NATSPEC 2019 [8], Infrastructure education has been provided only in Finland and Switzerland. History in Finnish infraBIM education was that technology companies involved in the infraBIM projects started to train employees in specific training content. Since 2014 YIV2015 become one of the lecture topics in courses organized for example in Metropolia University of Applied Science, Tampere University of Applied Science and University of Oulu. Since 2015, machine operators have also been trained model-based workflow i.e. infraBIM. Specific infraBIM coordinators training courses, including lectures, learning tasks, e-learning and development task, has been given in university of applied science level with a collaboration of construction industry started in 2020. [9] Tallinn University of Applied Sciences, Estonia, BIM for Infrastructure course has been developed more for active learning using Moodle for sharing, assessments, and the forum of questions and answers. Students learn by watching, listening, reading and doing step-by-step materials. During the course a number of different software design, construction and visualization tools are utilized in teaching. [10] HSR University of Applied Science Rapperwill, Switzerland, offers the BIM basic education three-day course. The content of the lectures is e.g. Industry Foundation Classes (IFC) and openBIM, and virtual project room (Common Data Environment, CDE) [11] Politecnico di Torino, Italy, has presented their experiences to train professionals to be qualified as infraBIM Managers expert both in the building process and in the parametric digital modelling. During the lectures, individual internship, and the project work students learned that the procedures and processes can be work properly no matter the BIM platform or tool used, the importance of teamwork and the importance of openBIM by presenting previous projects. [12]

In this paper, we present the findings and lessons learning from the practical workshop in Ouluzone 2019. The goal of the workshop was to challenge students to learn open infraBIM and automation by building Speedway track. For example, real-time cloud service, 3D measuring machines, and drones were used as modern tools.

2 Development of the Open infra BIM Workshop

OuluZone workshops were kept in OuluZone, which is a motorsport center owned by the city of Oulu, Finland. OuluZone is located in a place called Arkala, which is around 35 km northeast from the city center of Oulu. One goal of OuluZone is to enlarge its activities and develop it as research, development, and education centre. Currently many research activities have already going on related to drones, robotics, and autonomous excavators. In addition, different workshops have be done for infrastructure technology professionals. The collaboration education week is so called OuluZone – Open Infra BIM and Automation workshop. In the years 2017 [13], 2018 [14], and 2019 workshops were concentrated on educating open infra BIM automation and robotics for students. The objective of the workshop is to provide the latest knowhow, challenges and the future needs in the open infraBIM based automation and robotics to the students. The other goals were to develop teaching and collaboration between organizations. The learning outcomes of OuluZone workshop have been to understand the conceptional and practical knowledge relating to infraBIM technologies, workflows and protocols in the infrastructure construction sites. Each year the teachers met several times to plan the content of the workshop. Depending on the year, the OuluZone workshop week has been contained 2-3 lecture days from teachers and technology company partners, 2-3 practical days in the OuluZone motor center, and finally 0,5-1 feedback day. In the year 2019, the program for the OuluZone workshop week is presented in Table 1.

Table 1. The program of the OuluZone – Open Infra BIM and Automation workshop week 44, 2019 (28.10.-1.11.2019).

Day	Content	Example of the topics
1.	Lectures by teachers and technology company experts	Common InfraBIM Requirements 2019, Infra information modelling, foundations of cloud service system, and automation construction site. Questionnaire
2.	Lectures by teachers and technology company experts	Typical work tasks in construction site such as foreman and designer. Occupational safety, MVR-form
3.	Practical training	Tasks in Ouluzone motor center: training
4.	Practical training	Tasks in Ouluzone motor center: problems solving. Construction site audit. Autonomous excavator show
5.	Summary of the workshop	Results from occupational safety, feedback collection from participants. Questionnaire

2.1 Participants in OuluZone workshop

The Finnish educational system consists of nine-year compulsory comprehensive school, three-year upper secondary education and four to five-year higher education. In OuluZone workshop, the participants came from secondary education provided by vocational college (Education consortium OSAO), and from higher education by the University of Oulu and the Oulu University of Applied Sciences (Oamk). The curriculum of these schools includes infrastructure construction and automation as one field of the study program. For a Masters' Degree students of Technology there is a five-credit course called "Information modelling and automation building construction and maintenance", at the Department of Structures and the Construction

Technology Research Unit at the University of Oulu. For engineering students at the Oulu University of Applied Sciences (OAMK) there is a five- credit course entitled "Infra BIM modeling and building a construction project". The Oulu Vocational College (OSAO) provides three years teaching for construction machinery and lorry drivers as well as logistics instructors. Each workshop had the different number of the participants depending of the year. In Table 2 is presented the number of participants from University of Oulu, Oamk, OSAO and industry in the year 2019. The others are presenting the visitors who were interested to follow and visiting the workshop.

Table 2. The total number of participants was 82 from University of Oulu, Oulu University of Applied Sciences (Oamk), OSAO, and technology company organization as well as visitors.

Organization	Students	Teachers	Visitor
University of Oulu	7	10	3
Oamk	19	3	
OSAO	19	3	
Company		11	7
Total	45	27	10

Before Ouluzone workshop week, each school was preparing their students by different ways. The master's degree students of the University of Oulu had lectures and trainings by teachers and visitor lectors from technology companies in the autumn 2019. In the lectures, students learn how to make a road plan over a measured terrain model using a Novapoint program. Trimble R10 GNSS System was used to produce a terrain model. The measurement guide of Finnish Transport Infrastructure Agency Machine was followed during producing the terrain model [15]. Machine control model for each layer was made by using the 3D-win program. Machine control model is a continuous (3D) surface and/or line model needed for the automation control systems of machines [1]. Inframodel (IM) is Finnish national XML-based application specification which is based on the international LandXML schema [1]. In addition, the students visited to OSAO Haukipudas campus to learn the machine control system is working, and to test the excavator simulator (Tenstar) integrated Leica's 3D machine control system.

Oamk students are either engineering, builders or multiform level. Their lectures were already completed during spring 2019. The topics of the lectures were e.g. infrastructure in society, infrastructure project constructions and contracts, the cost planning of the infrastructure project in a project owners' perspective, construction tasks and good practices ensuring the safety of the constructions projects, and finally general terms and conditions of the construction contract, i.e YSE 1998. After lectures, students had the training period in the construction site.

The third-year students of OSAO practice their earth moving machinery such as excavator and loaders' operator skills and how to actually use 3D-machine control systems first in simulators mention above and then in practice. In Ouluzone OSAO construction driver students were doing their skill tests. The institutes each measured their own students' learning outcomes using appropriate methods.

2.2 Workshop tools during OuluZone

During the OuluZone week, the students continued to build with a help of teachers and technology experts a new Speedway track and its cutting operation in real-world conditions. The Speedway track geometry was designed first in 2D drawings and then in 3D model in open file formats (.dxf and Inframodel). The geometry was designed by using the 3D-Win program presented in Figure 1. The total length of the Speedway track is 437m in with the straight line of 65m. It was calculated that the cutting mass is 7848 m^3, filling mass 7727 m^3, and surplus mass 100 m^3.

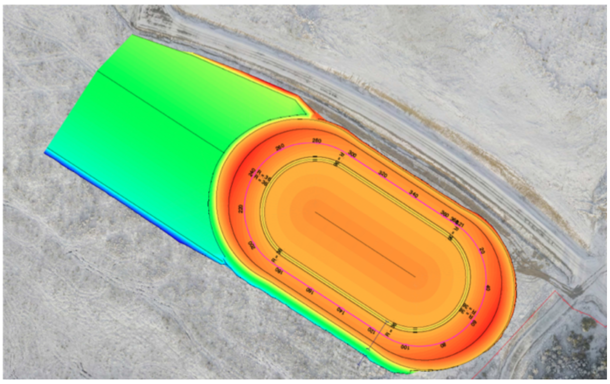

Figure 1. Speedway track geometry designed by using 3D-Win program (Mitta Oy).

The unmanned aerial vehicle (UAV) field measurements were carried out in August 2019.The Speedway track area was photographed using photometry technique to produce the digital surface model (Figure 2). First, the reference points were made by RTK-GNSS Base Station around 50 to 100 meters each other for the area to be photographed. The reference points are searched for in the 200 photos to get coordinates and the margin of error. Similar type of UAV measurements procedure than in Ouluzone were also done in sub-Arctic Mining Site [16]. In Figure 2 is presented the accurate georeferenced dense point cloud based on the targeted photos and reference points. Before workshop 2019, around 30-40% of Speedway track cutting was already made in previous workshops. The cutting operation in workshop 2019 was decided to continue in the centre of the speedway track.

Figure 2. UAV field measurements made in photometry technique to get Speedway track cutting situation in OuluZone motor center August 2019.

The students were using the latest technology tools at Speedway track construction site. Infrakit cloud service (provided by Infrakit Group Oy) was used as the open infra BIM tool to monitor real-time the Speedway track building progress. Infrakit was selected as cloud service tool based on past experience of its easy of use, and that it can be combined with several devices from different manufactures [17]. In Figure 3 shows the Speedway project view in Infrakit cloud service. For example, during the project, the construction site can be monitored in real-time. The excavator operators are measured the values of the as build point every 20 meters. These as build points are used for the quality control of the dimensional accuracy of structures during work and for monitoring the progress of the work.

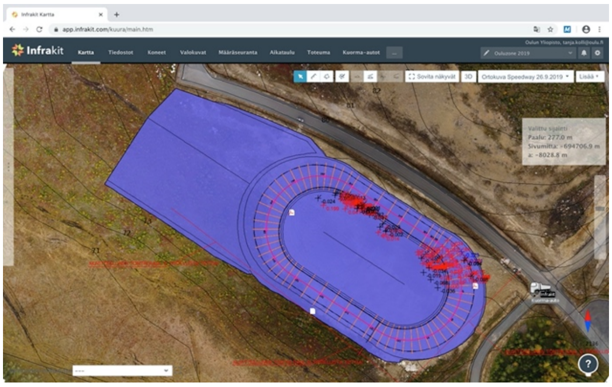

Figure 3. Speedway project in Infrakit cloud service. The combination model is a combination of Speedway track geometry integrated the drone picture.

To build the Speedway track, two excavators and wheel loader with the automatic Leica-3D control system, and two trucks and a dumper with Infrakit-android application were used, too. The other necessary equipment needed in Speedway-track construction site were RTK-GNSS- base station, three to four pieces' reference points around the Speedway track. The coordinates of the reference points were measured using the static GNSS measuring method in ETRS-GK26 map coordinates and N2000 height system [18].

2.3 Tasks in OuluZone

For the Ouluzone practical training, the students were divided into six teams. The number of students in the team was from 5 to 6. The same number of different tasks of a typical site organization were developed where students could practice practicing the work tasks involved. The teachers also organized various change and problem situations in the workshop, which students had to deal with in their various roles. The practical training tasks were:

1. Road designer
2. Speedway -project owner and surveyor
3. Construction' head manager
4. BIM Coordinator
5. Excavators, trucks, and wheel loader drivers
6. Drone-monitoring

Figure 4 shows the time schedule of for each teams 1 to 6. In the Figure Z, numbers 1 to 6 presents task mention above. Both on Wednesday and Thursday at the Ouluzone motor center, the teams followed the same time schedule.

Time	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6
8:30	Arrival, registration and grouping, morning coffee					
9:00	1	2	3	4	5	6
9:50	2	3	1	5	6	4
10:40	3	1	2	6	4	5
11:30	Lunch - cafe			free time		
12:00	free time			Lunch - cafe		
12:30	4	5	6	1	2	3
13:20	5	6	4	2	3	1
14:10	6	4	5	3	1	2
15:00	COFFEE and return of helmets and vests etc					
15:30	Departure					

Figure 4. The time Schedule of Wednesday and Thursday in OuluZone workshop for each team 1 to 6. The number in colored area is the practical tasks: 1) road designer, 2) speedway project owner and surveyor, 3) construction' head manager. 4) BIM foreman, 5) excavators, trucks, and wheel loader drivers, and 6) drone-monitoring.

Occupational safety was monitored by using MVR-form. MVR is used at civil engineering as a method of assessing working conditions and safety and for carrying out statutory weekly inspections. Throughout the workshop, the safety manager counseled students on if any problems or issues appeared. In addition, the students had the Infrakit app in their mobile phones and a possibility to use Infrakit-support during the workshop. Finally, the students had a possibility to follow the autonomous excavator [19] show provided by the University of Oulu. The tasks were located in Ouluzone in several different places e.g. judge tower and construction site.

3 OuluZone workshop

The Ouluzone workshop 2019 was contained 2 lecture days, 2 practical days in OuluZone and finally the feedback and evaluation day. In this chapter, the results and discussion about the findings and lesson learned about this workshop is presented.

3.1 Lectures

The purpose of the lectures was to go through the various stages of the construction site from the planning to handling over the Speedway track to the project owner. Here is presented few examples of the content of the lectures. Teachers and experts from technology companies prepared their presentation with slides including videos and they explained many real-life examples in their presentations. First, it was explained to students the objectives, organization and general things related to the Ouluzone workshop week. During the lectures was mentioned, Finnish legislation and requirements of the road construction that must be taken into account. Cooperation forum BuildingSMART Finland and its work to disseminate information on infraBIM and to support those in the implementation was presented. In addition, the use of the right documents for example to safety and construction site technical quality requirements (based on InfraRYL) was presented

An integral part of infra information modelling is various geographic dataset such as ground (level) model, and environmental information which can be visualised also in 3D models. Survey control is an essential element in the design and construction survey data. The using correct coordinates and high system is very important and using the correct unit of measure (meter).

Students learned the principles of road construction design and model-based quality assurance. The designer is responsible for the correctness of the initial or source data model. Therefore, it is important that all the term such as lines are defined correctly. The final planning model has gone many rounds from designer to the project owner to ensure quality. The importance of occupational safety issues was emphasized during the lectures before the practical training in Ouluzone. The principle of the MVR-form as a tool for following the safety was gone through.

A simple Kahoot-play questionnaire was conducted to found what student was learned before the workshop. The questionnaire contained 10 questions and there were four answer options in each question. The result of Kahoot-play questionnaire is presented in Figure 5. Based on the correct answers, it can be said that the students had moderate starting knowledge for the workshop.

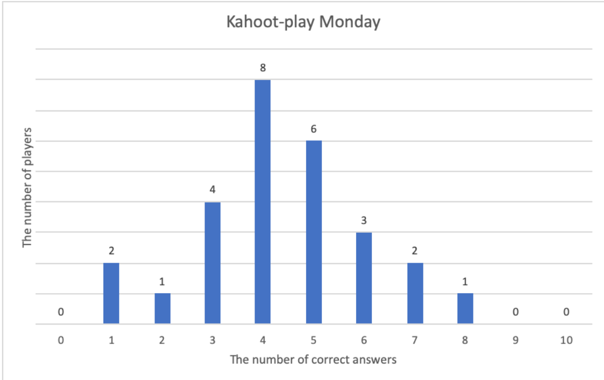

Figure 5. The Kahoot-play questionnaire in the begin of the workshop. The number of answers were 28. The average degree was 4.25 by the standard deviation 1.85.

3.2 Practical training in Ouluzone

The goals of two day practical training in the Ouluzone workshop was to learn open infraBIM-based automation and robotics in practice and problem solving. The construction site of Speedway track contained human resources, digital models, machines and devices, materials and time. It was important that everybody knows their role and responsible to optimize the high quality result. The location of the base station was vital to achieve the best connection to all machines, automation systems and Infrakit cloud service. The learning tools during the tasks were slides, videos, real-life examples, discussions, exercises and demonstrations. In each task, the main responsivities were discussed and how Infrakit cloud service was used. The learning outcomes of students for each practical task can be summarised as following:

1. Road designer: Understanding about model-based road construction work accordance to design and modelling instructions. Describe the documentation procedure to ensure the compatibility of models and absence of conflicts.
2. Speedway-project owner and surveyor: Understanding about decisions and purchase procedures for the preparation and implementation of the project. At each stage of the life cycle, the acceptance the final outcome into maintenance systems is compliant.

3. Construction' head manager: Describe the overall operations (e.g. scheduling, control, implementation, and quality assurance) of the model-based construction site responsibilities.
4. BIM Coordinator: Describe how to use and apply up-to-date information management from the construction site such as ensuring the quantity calculations, a model-based quality assurance procedure, the survey control and preparation of digital handover material.
5. Excavators, trucks, and wheel loader drivers: Understanding about the machine control equipment operation. Describe the model-based quality control procedure in accordance with as build surveys and mappings performance.
6. Drone-monitoring: Understanding about the UAV field measurements procedure to receive the digital surface model, or to follow construction site progress.

The second day at OuluZone was problem solving, and therefore construction site audit was arranged. There were two reasons: 1) the location of the construction site was suspected to be in a wrong place, and 2) the size of the rock found on the construction site. All the participants gathered at the construction site to evaluate and solve the situation.

During the Ouluzone practical days the students were requested to monitor both the positive and negative things at the construction site by using MVR-form. The MVR- form included considerations such as working and machine operation, equipment, electricity and lighting, protection and safety areas, driveways and traffic routes, and ordering and storage.

One possibility for future construction sites is autonomous machinery for example dangerous environments. All the Ouluzone workshop participants were demonstrated, how the automated control of the movements of the excavator (the Smart Bobcat E85 Excavator 6) is working.

3.3 Final day of the workshop week

The final day of the workshop was for receiving the feedback survey both from students and from teachers. The questions were about the successes and development ideas. In addition, the best practical test was evaluated. The participants mentioned time scheduling and getting industry partners as teachers involved as positive things during the OuluZone week. Each group presented their MVR-findings. It was interesting to notice that if the group had any construction site experience, the findings were more accurate. In addition, the debate on the importance of occupational safety was lively.

One of the development ideas was MVR-form as a new practical task was desired, since the discussions with the expert give the new off reinforces perspective. The construction site audit was surprise to students and therefore the problem-solving situation went unclear for some. Thus, the instructions at the beginning of the week should be more exact. This means that there could be even more communication between teachers before workshop week. The best practical tasks were evaluated to be the drone and designer, since teachers were prepared their materials properly.

Finally, Kahoot-play questionnaire was conducted to found what student was learned during the workshop. The questionnaire contained 10 questions and there were four answer options in each question. The results of Kahoot-play questionnaire are presented in Figure 6, in where can be seen that the participants received more correct answers than on Monday Kahoot-play. Therefore, it can be said that the students had good knowledge after the workshop.

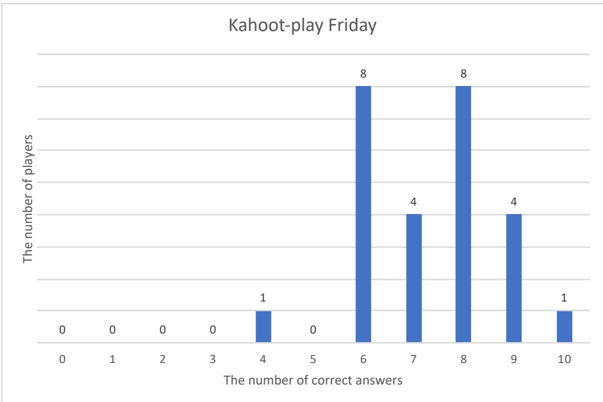

Figure 6. Tue Kahoot-play questionnaire in the final day of the OuluZone workshop. The number of answers were 26. The average degree was 7.31 by the standard deviation 2.32.

4 Summary

The results and findings from the education collaboration workshop week between the University of Oulu, the Oulu University of Applied Sciences (OAMK), and Oulu Vocational College (OSAO) is reported. The goal of the workshop week was to educate Open InfraBIM and construction Automation and robotics to students. During the week students learned from lectures and practical training in OuluZone motor center what are the typical tasks of the responsible person in the constructions site and how they are using modern tools such as automation and cloud service (Infrakit). Practical learning was found to be motivating way to educate students. Technology companies reported that they have received new ideas from the Ouluzone workshop for further product and application development. Based on good learning experience and the feedback from the participants, the development of Ouluzone workshop will be continued.

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