Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences
**Graduation Plan: All tracks**
The graduation plan consists of at least the following data/segments:

<table>
<thead>
<tr>
<th>Personal information</th>
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<tr>
<td>Name</td>
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<td>Student number</td>
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<td>Telephone number</td>
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<th>Studio</th>
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<tr>
<td>Name / Theme</td>
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<td>Teachers / tutors</td>
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<th>Argumentation of choice of the studio</th>
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<td>My interests in the topic of construction robotics mainly originates from the 'modernization complex' in my childhood. Chinese have tried to realize 'modernization' in every aspect of the country for over half a century. This enthusiasm is even reflected in the preschool education. Robots, as the most attracting image of modernization for children, appears in all kinds of children’s publications, as a symbol of the 'future world'. Thus, from my childhood, robots in my mind are something representing future and modernization. Nowadays, the concept of robotics in construction has largely expanded, and robots applied in construction look greatly different from the humanoid robots which impressed me when I was young. However, the thing that stay unchanged is that robotics still represents the modernization. During my college, I entered the construction industry, which is, as in most nations, the largest industrial sector in China. In my study and internship, I realized that in the construction field, the robotization level is relatively lagging behind. It is a pity that my childhood image of the future fails to completely come true in my career field. Therefore, I am particularly interested in how to promote the robotics level in construction, to improve the effectiveness in this sector and to enhance the 'modernization' in the construction industry.</td>
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<td>In the recent two decades, there are some new trends in the research of construction robotics. By reviewing the papers in the ISARC (International Symposium Automation and Robotics in Construction)(^1) proceedings, two main trends can be observed. The first one is that the focused fields in construction robotics and automation research has expanded. At the beginning of the robotization of construction, the main focus was on the development of the single task robots or robotic systems which were designed to replace human labors in specific repetitive tasks, for instance,</td>
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\(^1\) The ISARC is the only conference only concern the field of construction robotics and automation, held by IAARC (International Association of Automation and Robotics in Construction). The first symposium was held in 1984, and the
the polishing and plastering robots, and the automated product line in prefabricated factories (Bock, 2006). In the 21st century, more attention has been paid to enhance the performance of some less visible tasks in construction to promote the efficiency of the industry, for instance, the software integration in construction, the sensory data acquisition, safety operation, etc.

Another obvious trend is the appearance of new technologies in construction fields. In the hard robotics era, most of the technical innovations in construction can be classified into mechanical and control fields; in recent years, however, new technologies have been dramatically increasing, and most of these new technologies are introduced from other sectors into construction.

The fast appearance of new technologies in construction, especially those are not familiar to the practitioners, caused difficulties for practitioners to choose technologies to enhance the robotics level of their projects. In such a context, a brief but explicit overview of the available technological innovations in the construction industry is needed, formulating their potential benefits and possible costs. Furthermore, for those companies who want to invest in R&D activities to enhance their performance in business, it is important to know which technologies which have potential to be used in the fields they are interested in, thereby a clue would be revealed that to which direction the R&D activities should be oriented.

Unfortunately, by now very few literatures provides an overview on either the currently used technologies in construction innovations or those are potentially to be applied in the future. This gap to some extent has hindered the promotion of robotization level of the construction industry.

<table>
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<th>research questions and design assignment in which these result.</th>
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<td>With the current background in construction automation and robotics, what technologies have been applied to enhance the level of robotization of onsite construction activities and what are the possible future of the use of technologies in these activities?</td>
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### Process

**Method description**

The main research will be decomposed into three sub questions. The research methods will be elaborated according to different sub questions.

Different methods are used to answer different sub questions. They will be elaborated as following.

**Sub question 1: What are the states of the art of construction robotics?**
The answer to this sub question will be consisted of four part.

1. The first part is to identify the tasks that construction robotics currently concerns. Methods used in this part is literature study. Construction robots are developed to finish specific tasks, therefore, the classification of robots can be used as a clue for the identification of construction tasks. Using two resources (IAARC 1998 and Bock 2016) related to this classification, a preliminary list will be identified. However, as previously mentioned, more ‘invisible’ works in construction process are now concerned by the construction robotics, some of which are comprehensive, e.g. the logistics optimization onsite, and there are not specific single-task robots designed specifically for these tasks. To supplement the omissions, the papers from recent five years’ ISARC proceedings will be examined to see the construction tasks they contribute to. As the number of papers examined is considerably large (572 in 5 years), it could be assumed that the list is complete after the supplement. Then, 4 tasks will be selected from this list to be studied in detail.

2. The second part is to identify the currently available technologies in construction robotics. Literature study and survey will be employed in this part. Historically, most of the innovations in construction come from the manufacturing sector (Oesterreich & Teuteberg, 2016); therefore, technical innovations in manufacturing has indicating significance for construction. By examining the literature about ‘industry 4.0’ in construction context, a series of most mentioned technologies will be identified. Again, the papers from ISARC proceedings are used to supplement the possible omissions. There is still another possibility of missing in this part. Technologies are fast developing and evolving all the time, it is possible that some new innovations have not been reflected in the academic publications. Therefore, a survey about the currently applied technical innovations in construction will be conduct to the contractors, construction robot companies, and other related actors in case that some technologies are missed in the literature study.

3. With the identified tasks and technologies, the third part is to confirm the previously mentioned new trends in construction robotics: the expansion of application areas and appearance of new technologies. The research method employed in this part is literature study. The papers from ISARC will be classified according to their focused tasks and focused technologies, to see whether the previously stated trends in construction robotics are true. Some literature related to construction robotics research trends will also be studied for cross validation.

4. The final part of this sub question is to identify the pattern of technologies’ application in different tasks. Using the identified technologies and tasks, a Technology-Task Matrix can be made (Figure 2.5). The papers from the recent five years’ ISARC proceedings could be mapped into the matrix, to figure out which technologies are likely to be applied in which tasks.

The deliverable of this question contains the following components: a list of tasks that construction robotics concerns currently, a list of the identified technologies currently applied in construction robotics, confirmed new trends in construction robotics, and a Technology-Task Matrix indicating the pattern of technologies’ application in different tasks. Deliverables of the first sub question are important for the further study in this research.

Sub question 2: What are the states of arts of the application of these technologies in the selected construction tasks?

This question will be answered by literature study and survey.

In sub question 1, a pattern of the technology-tasks corresponding relationship has been abstracted by the Technology-Task Matrix, from which it can be observed what technologies are mostly used in the selected tasks. The same problem in sub question 1 appear in this sub question: there is possibility that the technologies on cut edge have not been noticed by the academic circle. Therefore, the survey will also cover this sub-question to identify a complete list of applied
technologies in the selected tasks. 

A detailed literature study will be conducted to the application of these technologies’ application in the selected tasks, to examine the state of the art of their application and added value using the PESTLE (Political, Economic, Social, Technical, Lawful, Environmental) framework. A brief SWOT analysis will be employed to each technology to figure out its advantages and possible development in the future.

The conclusions from the literature study and survey will be verified by interviews. The interview will mainly take construction companies as respondents, asking about the application of different technologies in practice, including the frequency and extent they are used (in each project or in particular projects), the motives of their application (economic feasibility, higher performance, requirements of the clients, etc.), the effect of their application (whether the results reach the original expectations), etc.

The deliverable of this sub question is a list of the technologies applied in the selected tasks, with more detailed description of their advantages and disadvantages, possible risks, the state of the art of application, and opportunities in the future. This list could be used as a reference for those practitioners who are facing problems in specific construction tasks, to adopt technologies to enhance performance in practice.

Sub question 3: What are the possible future of the use of technologies in the selected construction tasks?

This question will be answered by literature study and interview.

Literature study will answer the question in two steps. First, figure out the most oppressing problems to be solved in the selected tasks; second, to analyze the features and working principles of the currently available technologies and identify the technologies most proper to solve the problems.

Interviews will be conducted to verify and supplement the result of literature study, by consulting contractors, construction robot companies and other experts.

The deliverable of this sub question is a list of the most pressing problems to be solved in the selected tasks, and a prediction of the possible future of the use of technologies, to indicate the possible directions for R&D activities in the automation and robotics of these tasks.

Literature and general practical preference

Literature that will be used in this research include:
ISARC proceedings of the recent five years;
Publications about the construction robotics research trend analysis;
Publications about the classification of construction robots;
Publications about the technical innovations in the selected construction tasks;
Publications about the most pressing problems in the selected construction tasks;
Publications about the technologies applied in the selected construction tasks;
Blog posters, news, articles online related to innovations in construction;
Other possibly used literatures.
Candidates of the respondent of interview and surveys:
  Contractors;
  Construction robot companies;
  Construction technology companies.

The list of the currently used literature:


https://doi.org/10.1016/j.aei.2006.09.001


https://doi.org/10.1016/j.proeng.2016.04.165


https://doi.org/10.1108/09699980810886874

https://doi.org/10.1080/01446199000000008

http://www.kfmr.com/robotics-transforming-construction-industry


Kumar, B. (2010). Cloud computing and its implications for construction IT.


Reflection

I chose construction robotics as my graduation lab because of the personal experience during the childhood. Two decades ago, robot, as a representative image of the idea of ‘modernization’, which Chinese have put great effort to pursue in the last half century, appeared a lot in preschool educational publication in China. Some cartoons also take humanoid robots as leading role, for instance, the famous Doraemon. Therefore, robots are quite impressive images in my childhood.

During my college, I entered the construction industry. Robots are also applied in this industry to enhance the efficiency, although the appearance of these industrial robots are quite far from the humanoid ones. However, compared with other sectors, the construction industry suffered from a relatively lagged level of robotics, leading to a low productivity in this sector. Therefore, I am always interested in how to improve the robotics level in my career field.

At the very beginning, I wanted to research the relationship between robotics of onsite construction works and prefabrication, to see whether prefabrication helps to improve the level of robotics of onsite works. Because my first impression of the Dutch construction activities is the very high level of prefabrication level when compared with the construction processes in China. Most of the components are prefabricated offsite. I thought maybe it is the prefabrication level that affect robotics level of the construction industry, especially after our excursion to the prefabrication factory in Amsterdam.

In the first draft of the research proposal, I adopted a quantitative strategy, by measuring the levels of robotics and prefabrication in a set of cases, to evaluate the relationship between them. However, this strategy was later proved to be unpractical. First, the defining and measuring of robotics level and prefabrication level are difficult, and lack technical support from existing sources; second, projects are unique, therefore it is impossible to set double blind experiment circumstance to exclude all the other factors which may affect the robotics level of a project except prefabrication level. Therefore, this strategy was finally given up.

Then another strategy was adopted: examine the appearance and disappearance of different types of construction robots, and compare with the development in prefabrication technology, to analyze the possible mechanisms that interact between the prefabrication and robotics. At the same time, I performed another work: reviewing the abstracts of the ISARC papers since 1984, to see what are researchers concern in construction robotics. By doing so, I found that it is multiple technologies, rather than a single technology, affect the robotics level. Focusing separately on prefabrication, without taking the intervention of other technologies into consideration, actually does not have too much significance for the development of construction robotics. At the same time, compared with the starting phase of construction robotics, currently the technologies applied in construction are much more diversified, concerning more tasks in the construction process than before. This diversification can be a gap for those practitioners who are not familiar with the technical innovations in construction. However, there is not a simple and concise overview of these technologies, which could be used by the practitioners as a reference to adopt new technologies to solve the problems they may meet.

My second mentor, Pieter Stoutjesdijk, suggested that maybe it will be more scientific and practical relevant to expand the focus from existing technologies to the possible future of their application in construction. Therefore, the final research question was decided to focus on the various technologies applied in construction to enhance a higher robotics level, including both the states of the art and the states of the future.

Relevance

Scientific relevance

Currently very few overviews of the technologies used in construction are available, especially for those construction tasks which came into the vision of construction automation and robotics in recent years. The existing overviews were mostly published before ten years ago, while in the recent decade, some new trend appears in the research and practice in the construction robotics and automation, therefore, they do not suit to the current situation any more. This research aims to fill
the gap. At the same time, the pattern of technologies’ application in construction tasks will be figured out and analyzed, for instance, which technology is generally used for which kinds of construction tasks and the possible explanation. There is still not such a research in academic circle.

Societal relevance

The research helps to achieve higher level of robotization and automation in construction, therefore enhance the efficiency of this large, unneglectable economic sector. The construction industry is always reluctant to adopt new technologies, compared with manufacturing. Now, caused by the new development in this field, new construction tasks are focused and new technologies are being used. With this background, the difficulties in getting familiar with these innovations exacerbate the reluctance of adopting new technologies. This research aims to help to improve that. At the same time, the recognition of possible future of the technologies’ application in construction, will give clues for R&D activities.

Utilization relevance

Utilization relevance of the research is closely related to the societal relevance. As mentioned previously, this research helps to improve the robotization level of construction by two ways: promoting the adoption of available technologies and providing possible directions for R&D activities in construction. Therefore, the utilization relevance of this research mainly reflected in these two aspects. The results of this research will contribute to the works of those involved in these two kinds of activities.

Time planning

The work has been finished in P1 and P2 stages are show in the first graph on the following page. The P3 phase of graduation will start on January 27th, following the final exam of an elective course on 26th. In the following five weeks, the literature study will be finished. The literature study will be organized according to different sub questions. This work is expected to be finished by March 3rd. at the same time, preparation for survey and interviews will be done. Questionnaires for survey and interview will be formulated before March 4th, based on the knowledge from the literature study; the interviewees and respondents will also be finally determined.

From March 5th, the interviews and surveys will be conducted. They are supposed to be finished within the following two weeks, at the same time, the data retrieved from interviews and survey will be processed. This will be included in the P3 report, which is supposed to be submitted before the end of March. This report is expected to be a 70% final draft report. After that, the P3 report will be presented on April 7th.

After P4 starts, the works combining and integrating the data from literature study, surveys and interviews will be done. Supplement literature study and interviews will be conducted if necessary. A draft final report will be finished before May 19th, and the P4 presentation will happen before the May ends.

In the following month, the report will be finalized. This work will be finished at the end of June. The second graph on the next page illustrates the plan.