The Selfsandingbot System

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Maintenance of timber structures has long been a significant issue to be concerned. Exposing to sunlight and weather is the most common threat to wood, which leads to ongoing decay of the material. Required measures might include painting, water repelling, stain removing and so on, while different measures have different maintaining periods.
For normal weathering of exterior wood materials, basic sanding, cleaning and coating every 2-3 years is both economical and sufficient.
Inspired by the City Climber developed by CCNY, the Selfsandingbot is hence introduced, in aid of this periodical and manpower-demanding maintenance work. With a built-in suction motor, the Selfsandingbot is capable of moving up and down the building façade, sanding it automatically without the need of scaffolding. Not only is it capable of moving around flat surfaces, the two-plate design allows the Sandingbot to rover across rough areas like places with cracks and bumped surfaces like window frames. The flexibility between the sanding machine and the vehicle enables the sanding plate to slightly rotate according to the surface feature. To enhance, the sanding machine is designed to be detachable from the vehicle and could be replaced by oiling or painting gadgets.
The Self-Sanding System is then developed, considering the implementation of the Selfsandingbot on site. Through assessment, the number of Selfsandingbots which are required to release concurrently could be decided. Next, boarders and openings of the façade should be accurately defined and imported into the computer which remotely navigates the Sandingbots. One technician is therefore in this case adequate for the total maintenance work of a medium sized timber structure.

Keywords*: Wall climbing robots, Sanding machine, Timber structures maintenance*

1. Introduction

The use of timber as a building material has been quite common since the beginning of human civilization. Traditionally, timber in buildings are referred to post-and-beam structures, while recently an increasing attention is being placed on the usage of laminated mass timber. Advantages of using timber as a construction material are that it is remarkably strong in relation to its weight, that it's a regenerative resource, and that it to some extent adjusts indoor humidity and temperature. However, despite widely used, the maintenance of timber structures is still an issue to be concerned.
Attempting to solve one of the most common problems on timber facades - weathering, a designed system combining robotics and building refurbishment technique is being presented in the following context. Not only aiming on reducing manpower and time through robotic implementation, but also on improving the efficiency of maintenance work by a detailed system planning.
The paper shall give insight into the design through project description, graphic demonstrations and finally, design details followed by possible future developments.

2. The project

The project focuses on designing a robotic system which could improve the condition of existing timber facades. For common weathering of outdoor wooden structures, sanding is generally required. The goal is to simplify the procedure of normal façade sanding, which requires scaffolding for surfaces above a certain height and a high demand of manpower, making façade refurbishing in the future more efficient and applicable.
The Leis Houses of Peter Zumthor at Vals, Switzerland (Fig. 1) [1] was selected as an illustrating example for the project. They are a series of three story high housing buildings using planed solid timbers to stack up the exterior walls.

Fig.1. The Leis Houses

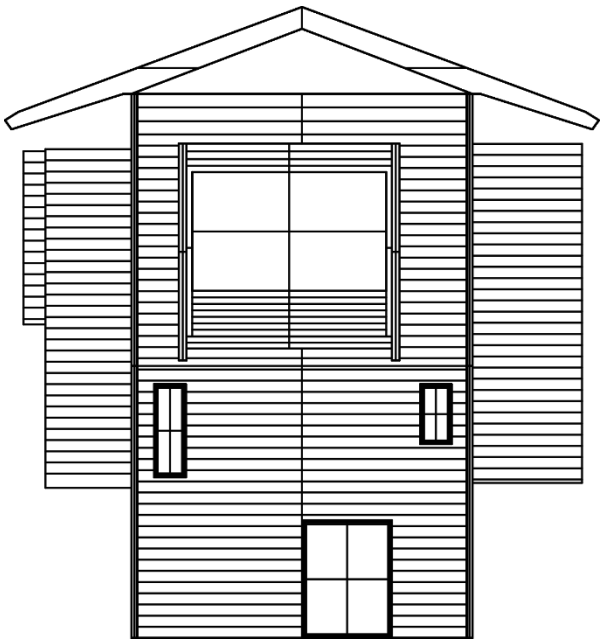

Fig.2. Front elevation of the Leis Unterhus

Built in 2009, the façades of the Leis Houses today show moisture and weathering stains under window frames and around corners. [2] (Fig. 3)

Fig.3. Current condition of the façade, Leis Unterhus

3. Design approach

The design approach was based on the axiomatic design theory[3]. According to the theory, design is composed of four domains: customer, functional, physical and process as shown in Fig.4.

4. The design

Going through from the customer domain to the process domain, design of the Selfsandingbot System can be divided into three major parts: the sanding machine, the wall-climbing robot and the operating system.

4.1 Sanding machine

The choice of sanding machines requires considerations on its weight, its sanding movement patterns and its dust extraction function. In order to guarantee the mobility of the Selfsandingbot, a weight no more than 4kg for the sander is desirable. Sanding actions considering mobility, shall affect the movement of the entire Selfsandingbot as slightly as possible. With a possibility of working high up on building facades, the sander should also be equipped with its own dust extraction device to avoid dust generated during the work affecting the surroundings.

BLACK & DECKER KA300-QS Sheet Sander was selected accordingly. [4] (Fig. 5) It is an orbital sander with 1.5kg in weight and extracts sanding dust with a vacuum adaptor.

Fig.5. BLACK & DECKER KA300-QS Orbital Sander

Customer)Domain	Functional)Domain	Physical)Domain	Process)Domain
Timber#facades#well#maintained#	Periodical#efurbishing	Sanding#and#oiling#procedure	to#elect#the#proper#grit#ize
			to#dentify#the#tained#ocation
To#reduce#nterruptions	Easy#pplication#	Robotization#sanding#ystem	define#coordinates#of#the#façade
			technician#perating#longside
	Short#working#period		multiple#sandingbots#working#t#once
	No#scaffolding	Wall#climbing#machine	extraction#of#awdust#uction#adapter
			period#of#mptying#dust#bags

Fig.4. Axiomatic design table

4.2 Wall-climbing robot

To have the ability to move vertically around rough surfaces was the only, yet hard-to-meet requirement for the wall climbing robot. Through research, the City Climber came into sight.

The City-Climber (Fig. 6) [5] is a wall-climbing robot developed by CCNY robotics lab. Through aerodynamic attraction, it could easily move around on rugged surfaces like brick walls and could even transit between different surfaces.[6]

Fig.6. City-Climber prototype-I approaching a window on brick wall

The City-Climber is 1kg in weight and can take 4.2kg additional payload when moving vertically on brick walls, [5] while in this project, they are only required to move on smoother timber surfaces. This makes it easy for the City-Climber to carry the 1.5kg sheet sander. So far, several prototypes of the City-Climber have been presented, including the one selected for this project: prototype-II. (Fig.7) [5] The 2-connected-panel structure allows the robot to transverse between planar surfaces.

Fig.7. Two robot modules connecting by a hinge in +90°

Combination of the sanding machine and the City-Climber works by connecting the sander between the two robot modules with hinges, allowing rotation of the sanding machine against the vehicle when transiting between planes.

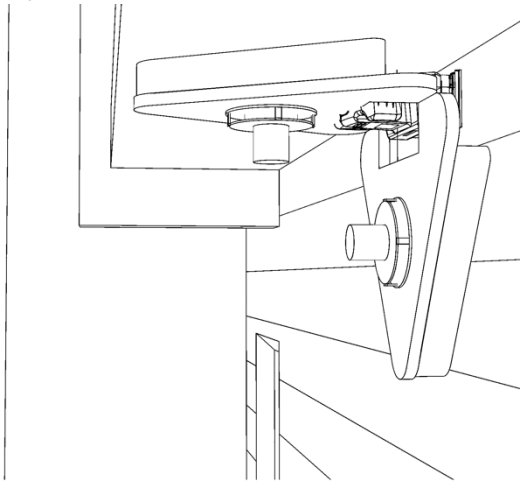

Fig.8. Selfsandingbot at corners

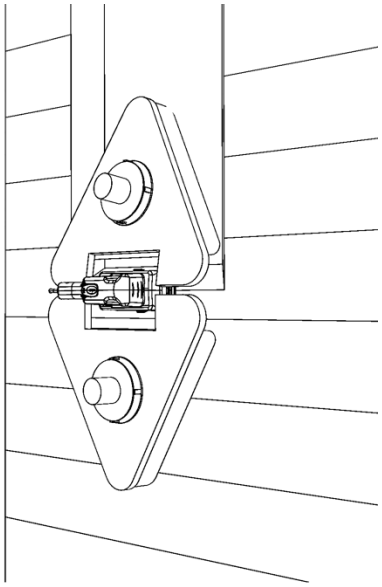

Fig.8. Selfsandingbot crossing over window frames

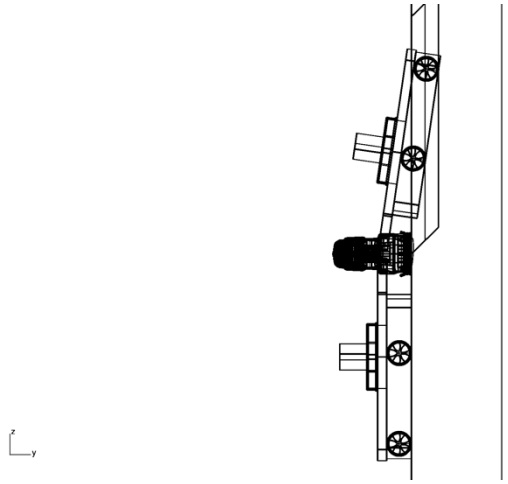

Fig.10. Perspective view of Selfsandingbot crossing over window frames

4.3 Operating system

A simple procedure of operating the Selfsandingbot system contains 3 steps.

Step1: Assessment

Assessment includes identification of the wood species used, the type of decay and the location of stains. Wood species determine the sanding speed and grit size selection of the sanding pad. The type of decay decides whether sanding procedure is required or not. Identifying the location of stains is at this stage also manually done.

Step 2: System setting

The locations of stains observed from the first step are noted in coordinate formats. Setting the system requires inputting the location of the stains as well as defining the boundaries and corners of the façade.

Step 3: Operating

The entire system requires a technician to launch the Selfsandingbots. Depending on the workload, multiple Selfsandingbots shall work simultaneously. (Fig.11) The dust bags will be emptied periodically by the technician alongside and at the end of the work retrieved with the Sandingbots.

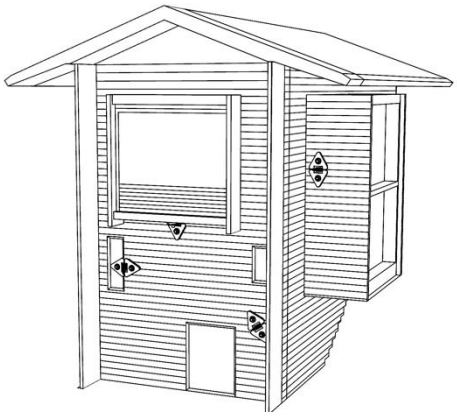

Fig.11. Selfsandingbots working simultaneously

5. Future developments

For future developments, oiling gadgets can also be designed to attach to the City-Climber. After completing the sanding procedure, designed painting equipment can replace the sanding machine and carry out oiling services for the finishing of timber facades, improving the performance of the Selfsandingbot system.

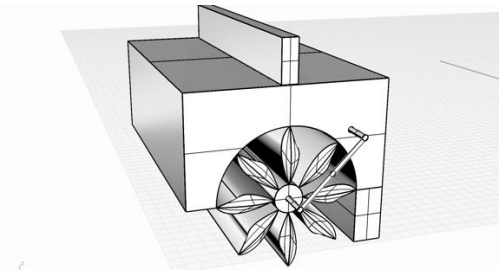

Fig.12. Designed oiling gadget

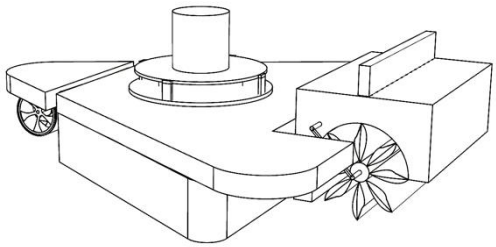

Fig.13. City-Climber equipped with designed oiling gadgets

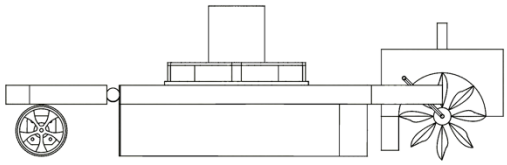

Fig.14. Side view of City-Climber equipped with designed oiling gadgets

6. Conclusion

Timber in the modern days has regained its popularity among architects, due to the advancements in wood treatment technology and the rising awareness of environmental protection. By utilizing the Selfsandingbot system, the maintenance issue for outdoor timber materials could be minified. Timber used as building facades can be easily refurbished after weathering and maintain its condition.

Through inputting the technique of the City-Climber, it enables the sanding work to proceed without the need of scaffolding, which not only cuts down maintenance cost but also ensures safety of technicians, moreover, the input of robotic systems reduces total working hours in repetitive tasks.

The performances of the Selfsandingbot in different façade situations are graphical demonstrated along with step-by-step illustration of the operating system in the paper.

Next steps of the Selfsandingbot system could be enhancing the functions through attaching auxiliary gadgets including oiling devices or adding stain recognizing sensors to improve the intelligence of the robot on navigation, reducing manual workload on stain identification and surface boundary defining.

Another direction could be to upgrade the device with ultrasonic echo techniques. Not only aiming on eliminating the superficial flaws but also providing the system with the ability to detect serious decay within structures.

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