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The Capabilities and Effectiveness of Remote Inspection of Wind Turbines

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Abstract

This paper evaluates the effectiveness of remote inspections of wind turbines. The first part of the paper presents a usability test where remote inspections with a robot prototype have been directly compared to manned inspections. The experiment had 31 participants that did inspections with and without the robot in a laboratory environment. As expected, it was challenging to remotely operate the robot, and the remote inspections did not perform as well as the manned. However, the difference was not very large and some possible improvements were identified. Concerns with remote inspections of wind turbines that were not addressed by the experiment is discussed in the last part of this paper. These will be evaluated in upcoming field trials.

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1. Introduction

Over the last years a large number of offshore wind turbines have been installed or planned. Advantages for offshore wind turbines are the large available areas with favorable wind conditions that are far from population. Unfortunately, offshore wind energy is significantly more expensive than onshore wind energy [1], due to large additional costs for installation, infrastructure and maintenance. A reduction in the cost of energy is necessary for making offshore wind less dependent on subsidies and a viable alternative in the future.

Maintenance is estimated to contribute to typically 20-25% [2] of the total cost of energy from offshore wind turbines, which is significantly more than onshore. One challenge is that the maintenance of wind turbines is dependent on several visits to each turbine every year, each with at least two technicians for safety reasons. The transfer to and from the turbine can be difficult and dangerous, even with advanced access systems. The turbines are often considered

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inaccessible when there are more than 2.5 m of significant wave height, which for parts of the North Sea will be as much as half of the days in a year [3]. In the winter access can be impossible for long periods. A failure could therefore result in a long downtime while the wind conditions are favorable for energy production.

This paper considers remote inspections of wind turbines, which is an alternative to the manned inspections that are performed today. A robot installed inside the turbine nacelle can be used to do inspections on behalf of a technician on land. The robot can be equipped with sensors similar to human senses, e.g. camera and microphones, thus it can gather similar information as a technician on site would be able to. It is not intended to be an autonomous system or an alternative to condition monitoring, but instead a tool for technicians to employ their experience without having to access the turbine, i.e. at a low cost and regardless of the weather conditions. A robust economic benefit for remote inspections [4] was found using the NOWIcob cost-benefit simulation tool [5].

Section 2 describes a usability experiment performed to compare remote and manned inspections. Section 3 discusses the capabilities of remote inspection in a realistic setting and how this can be evaluated in field trials.

2. Experimental comparison of remote and manned inspections

Usability testing [6] is a method for evaluating participants' ability to use a system, as a remotely controlled robot, to solve relevant tasks. The experiment presented here is the last of a series of such usability tests that has been performed to evaluate whether remote inspections with a low-cost system could perform as well as manned inspections. Compared to the previous experiment [7], the number of participants has been increased to 31 and the prototype used in the experiment has been improved.

2.1. Laboratory for comparing remote and manned inspections

To evaluate inspections, there must be something to inspect. For this purpose, we have built a laboratory, shown in Fig. 1b. It is a mock-up of an offshore wind turbine nacelle, with visually similar equipment that is intended to be used to compare the probability that an error is found with remote and manned inspections. In the laboratory this can be evaluated with a large number of participants and with full control over the equipment. The experiments performed in the laboratory should be followed up by tests in a wind turbine, as some aspects of the evaluation would require a more realistic environment.

The purpose of the laboratory is to measure the participants' ability to detect targets that represent errors or problems with the equipment. This is measured as the ratio of the targets that are found during an inspection, i.e. the detection rate, which can be seen as an indicator of the effectiveness of the inspection method. 12 error markers and 16 paper clip locations were defined for the experiment. The error markers mimic actual errors found in industrial equipment, and the participants did not know what these looked like prior to the inspections. They were

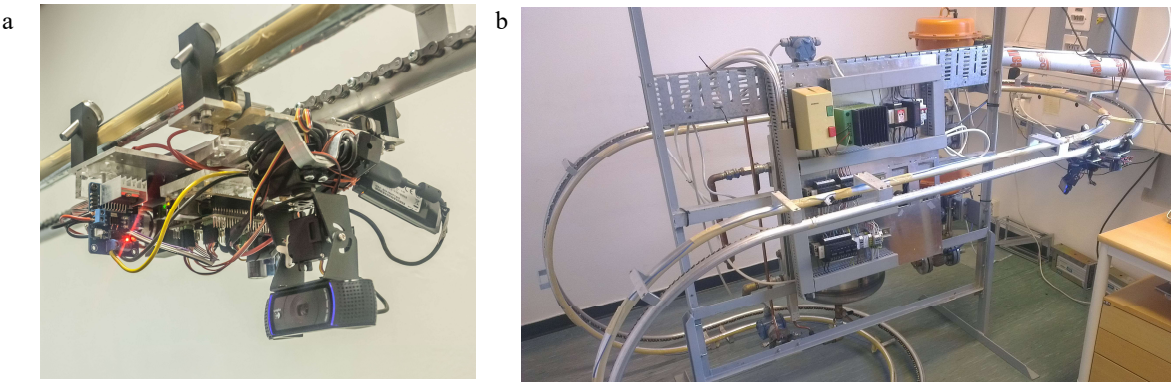

Fig. 1. (a) robot prototype; (b) prototype in laboratory