Bachelor thesis

Trajectory planning and obstacle avoidance in cluttered environment

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1. Introduction

Gas turbines are machines widely used in the power industry to produce electricity. They are very complicated mechanical devices consisting of many parts and systems that have to cooperate in order to produce power reliably and efficiently. To do so, they require periodic inspections and maintenance that can last up to several weeks. Speeding up this lengthy process can reduce the costs of turbine downtime even by 100.000 €. Currently, research is conducted on methods of making the inspection process more automated.

Main goal of the thesis

The thesis aims to create an algorithm that will find a trajectory of robot's TCP in the near vicinity of compressor blades without any collisions. The algorithm should work for geometry of any given gas turbine and any chosen tool.

2. Mathematical model

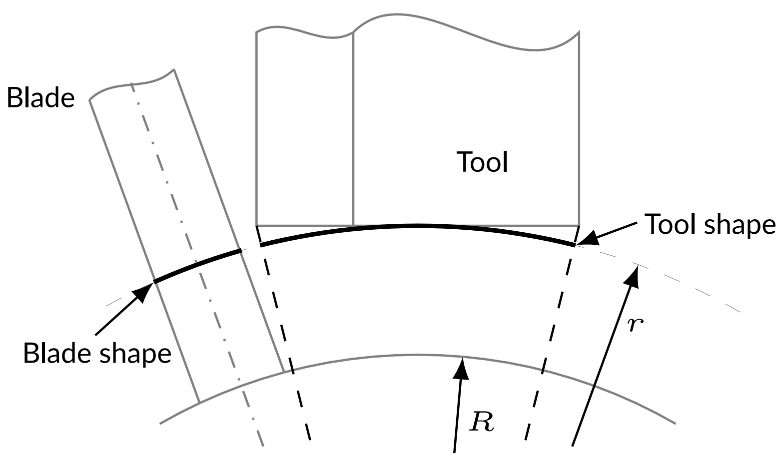


Figure: Two-dimensional representations of camera and compressor blade

The described model creates mathematical basis for the algorithm determining trajectory. In order to make calculations fast and efficient, the model simplifies the shape of the compressor by using polyhedrons as approximations of several parts of the compressor geometry.
Since polyhedrons consist of linear elements, trajectory can also be expressed as linear change of all the parameters that determine it. Additional assumptions allow to replace the problem of calculating correct trajectory with two two-dimensional problems of finding it's beginning and end.

3. Optimization method

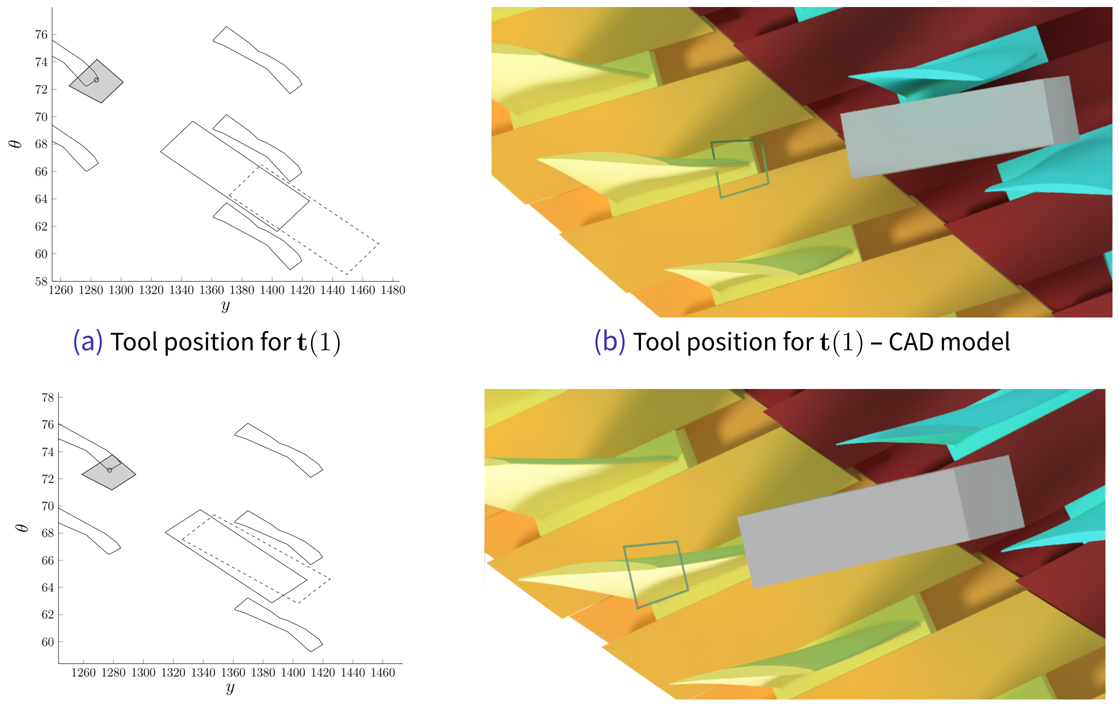
$$\begin{aligned} \text{minimze:} \quad & f(\mathbf{x}) \\ \text{subject to:} \quad & \mathbf{c}(\mathbf{x}) \le 0, \ \mathbf{A}\mathbf{x} \le \mathbf{b} \end{aligned}$$

$f(\mathbf{x})$ - distance between the chosen tool and the closest obstacle,
$\mathbf{c}(\mathbf{x})$ - non-linear constraints describing tool workspace

Advantages of the method

1. Little sensitivity to local minima
2. Convenient description of tool's workspace
3. Easy collision avoidance algorithm implementation

4. Results



(a) Tool position for $\mathbf{t}(1)$
(b) Tool position for $\mathbf{t}(1)$ – CAD model
(c) Tool position for $\mathbf{t}(0)$
(d) Tool position for $\mathbf{t}(0)$ – CAD model

Figure: Results from script determining trajectory for camera inspecting compressor blade damage

5. Conclusions

- The algorithm can find correct solution even in the most difficult cases – e.g. when the tool is represented by non-convex polyhedral. Moreover, by the appropriate selection of objective function, the emphasis is placed on safety of the tool and compressor.
- The software developed in the thesis can be used in gas turbines maintenance processes. However, in order to solve difficult problems, further code optimization may be necessary. Application of optimization method probably rules out implementation of the algoritm on robot controller.
- The software can also be used to automate the planning of maintenance processes e.g. in packages such as *Roboguide*. The user could launch a script calculating every trajectory around compressor blades and then use another tool to validate results.