Deformation Analysis of a Gantry Crane during Workload

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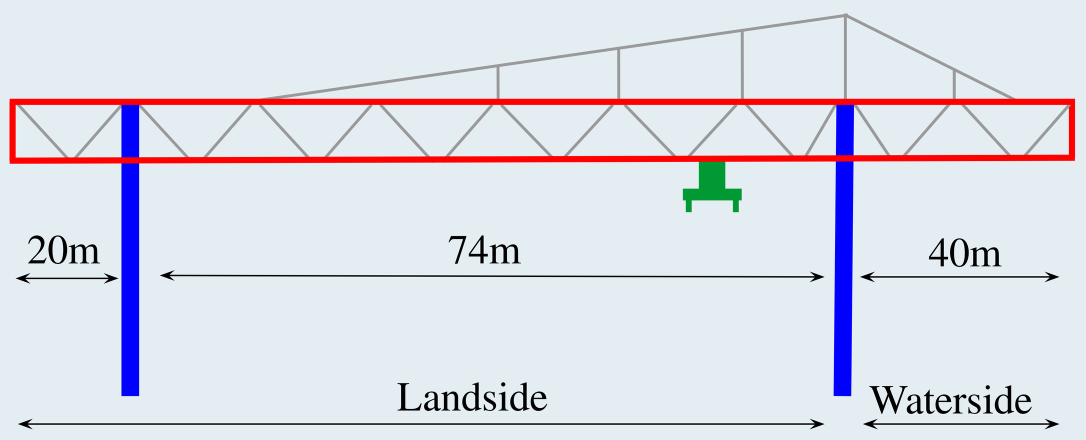
Motivation

Gantry cranes are subject to an aging process due to their permanent utilization by loading of goods. This aging process should be monitored periodically by analyzing the deflection of a gantry crane's main beam (red). The shape and the magnitude of the deflection depend on

- the position of the trolley (green) that moves the containers and
- the weight of the container.



The present study proposes a deformation analysis of a specific gantry crane based on these two inputs. Because of external preconditions, the data acquisition had to take place during normal workload without any interruption of the workflow.

Data Acquisition

Sensors

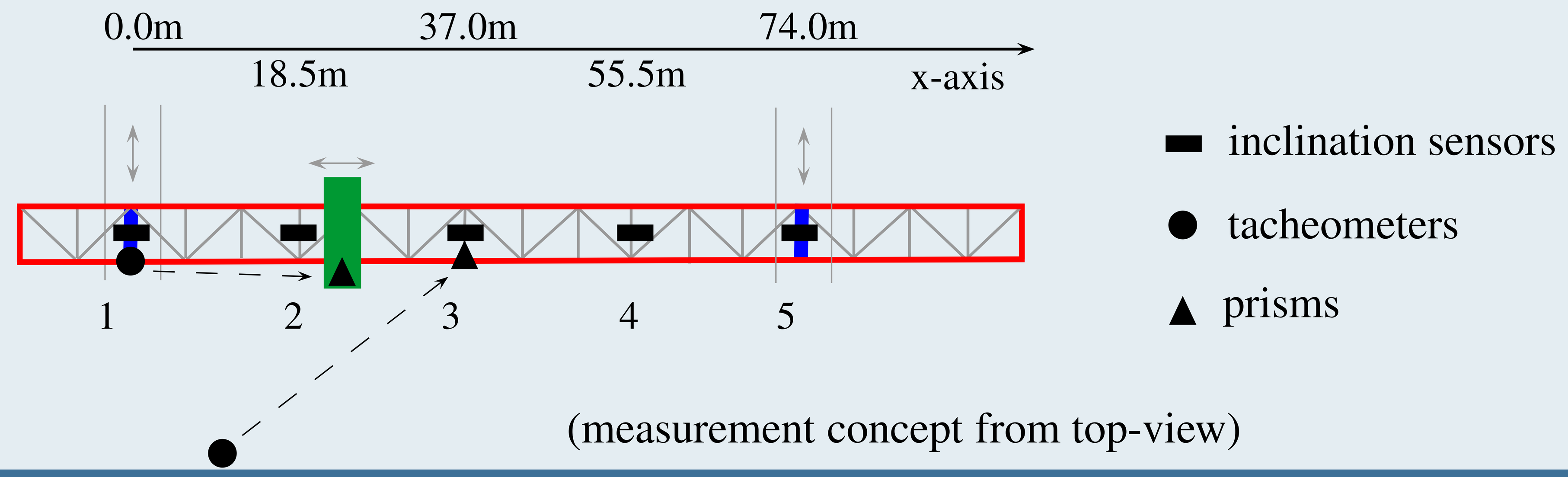
- 5 uniaxial inclination sensors observing the tilt along the main beam
- 1 tacheometer positioned external observing the height change at the middle beam position
- 1 tacheometer positioned on the crane itself observing the position of the trolley along the main beam
- 1 balance measuring the container weight uniquely per loading operation

Measurements

- collection of 18 loading operations during ordinary workload
- no interruption of workflow
- container weights between 0 tons (no loaded container) and 25 tons
- sampling frequency between 2-3 Hz (tacheometers) and 5 Hz (inclination sensors)

Pre-Processing

1. interpolation of all observations to 5 Hz
2. detection and filtering of the crane's eigenfrequency
3. definition of temporal starting point at specific trolley position and resetting of relative observations at this point
4. temporal synchronisation of all observations of each loading operation

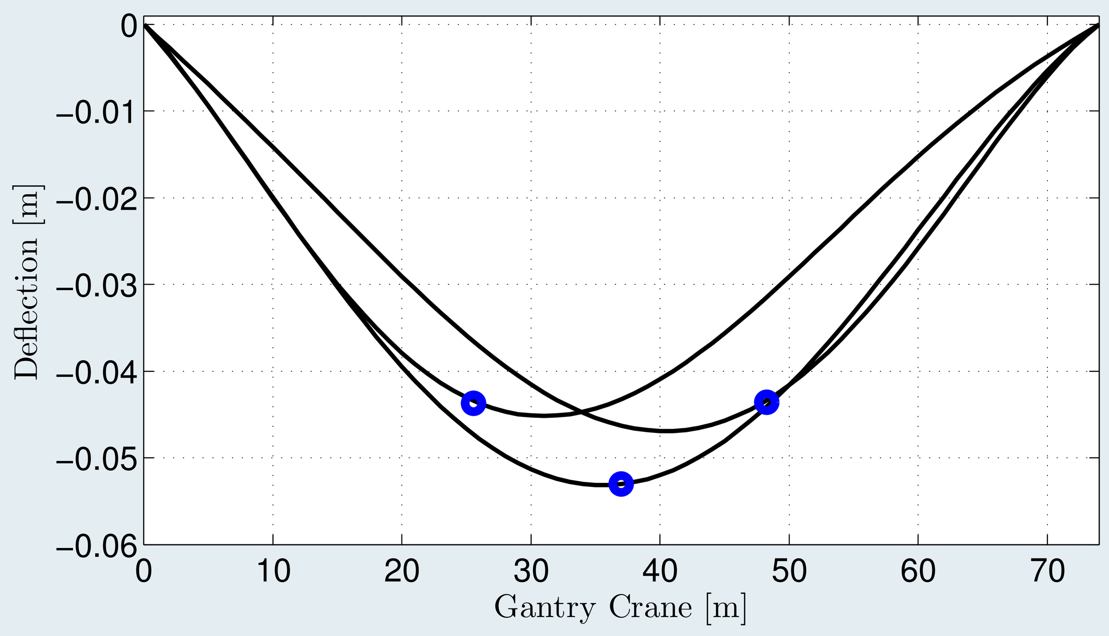


(measurement concept from top-view)

Deformation Analysis

1. One-dimensional modeling

- describing the beam deflection of the main beam (x-axis) spatially by a one-dimensional polynomial
- each trolley position (blue) and each loading operation build up a new polynomial (black) that is estimated
- no link between different trolley positions and different loading operations does exist yet

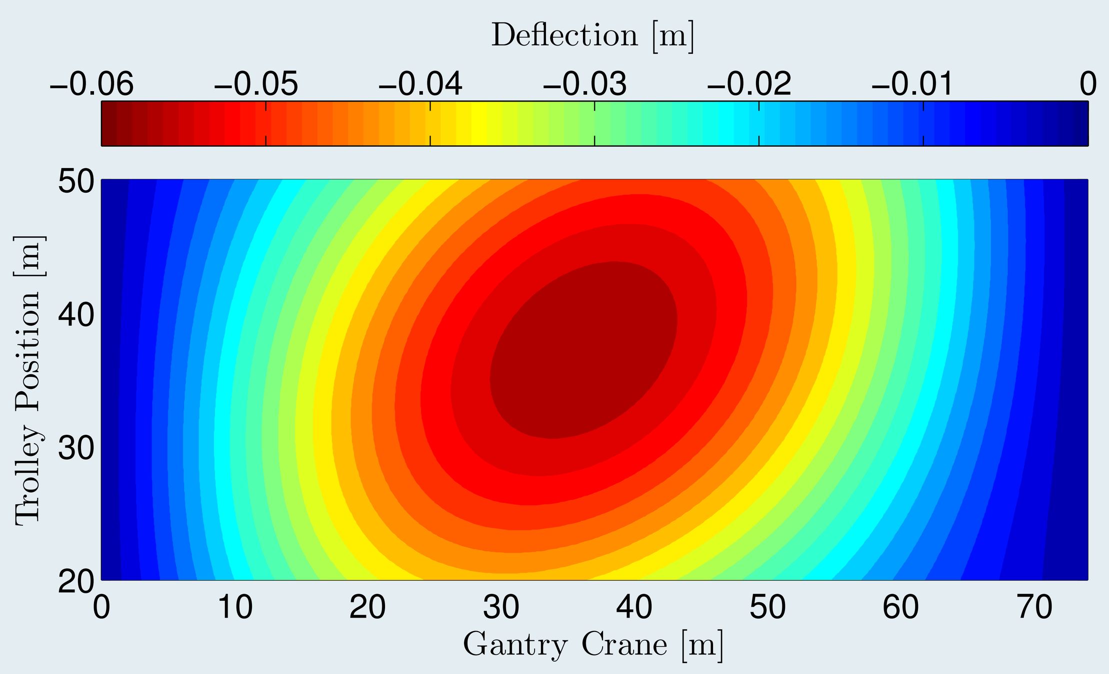


2. Two-dimensional modeling

- expanding the deflection curve (modeled as x-axis) by the trolley positions (modeled as y-axis) to a bivariate polynomial
- combining each loading operation into one single two-dimensional deformation model
- no link between different loading operations does exist yet

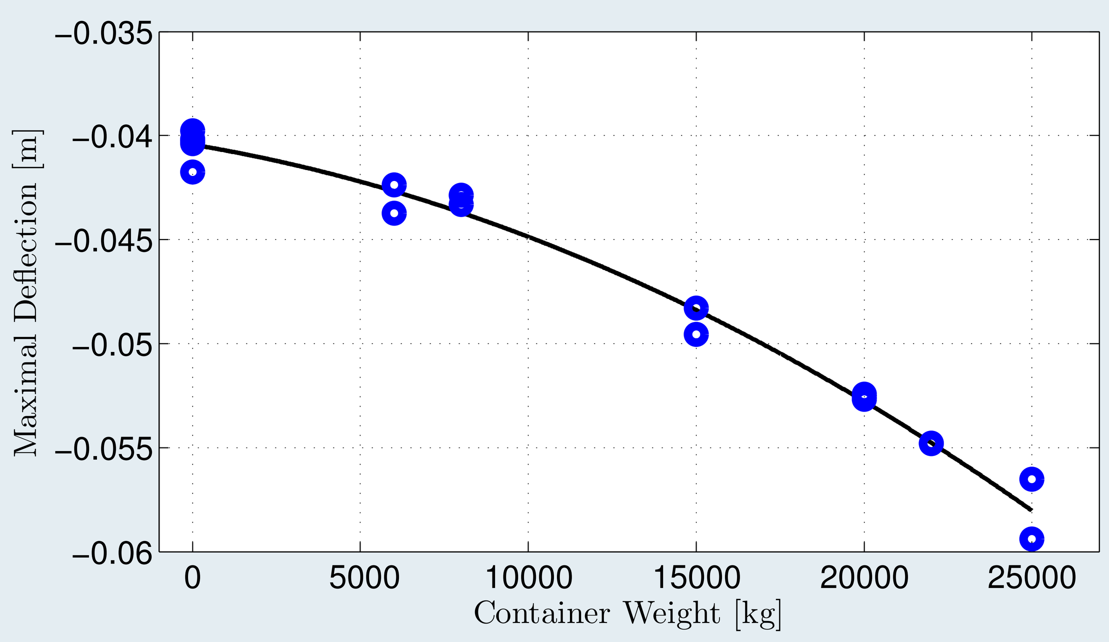
3. Two-dimensional loading operation-dependent modeling

- combining all loading operations and trolley positions into one single polynomial model (parameters $p_{i,j}$)
- adding a scale factor to the bivariate polynomial for each loading operation
- all loading operations are linked now, but no link between different container weights does exist yet



4. Two-dimensional load-dependent modeling

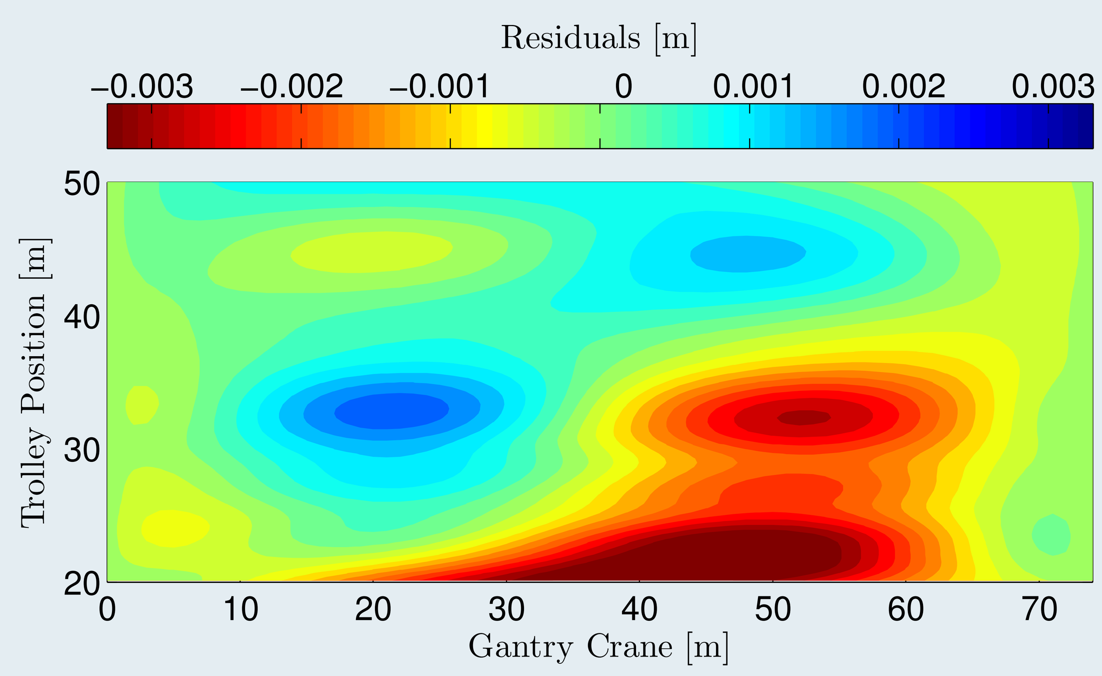
- building a relation between the different scale factors (blue) and the container weights g by polynomial (black)
- replacing the different scale factors by the polynomial parameters b_0, b_1, b_2
- identifying the final non-parametric and static deformation model $z(x,y,g)$ of polynomial orders a_x and a_y



$$z(x,y,g) = (b_0 + b_1 \cdot g + b_2 \cdot g^2) \cdot \sum_{i=0}^{a_x} \sum_{j=0}^{a_y - i} p_{i,j} \cdot x^i \cdot y^j; \quad i + j \neq 0$$

Discussion

For verification, the residuals between this model and an independet reference loading operation are estimated. They are smaller than ±3.5 mm.



This magnitude is satisfactory considering the limited number of sensors and thus the limited spatial resolution of the main beam and the fact that all measurements were collected during normal workflow.

Conclusion

The final deformation model estimates the shape of the deflection as well as its magnitude along a gantry crane's main beam axis x. Based on geodetic terminology of deformation analysis,

- the container weights g and trolley positions y are the system input,
- the static model $z(x,y,g)$ equals the object behavior and
- the measured deflections equal the system output.

The model precision being in the range of a few millimeters achieves the desired quality.

- Holst, Ch., Burghof, M., Kuhlmann, H. (2013): *Deformation analysis of a gantry crane during workload*, in: 2nd Joint International Symposium on Deformation Monitoring, 09-10 September, Nottingham, UK.
- Holst, Ch., Burghof, M., Kuhlmann, H. (2013): *Modeling the beam deflection of a gantry crane under load*, J. Surv. Eng., in press.

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