Semi-automated Handling of Manhole Covers for Tank Wagon Processing Using Industrial Robots

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OVERVIEW

01 Introduction

02 Process Analysis

03 Development of the Robotic System
   Geometric Feature Identification
   Mechanical Design
   Operator—System Interaction

04 Conclusions and Outlook
01 INTRODUCTION

MOTIVATION

- Transport of petrochemical products via railway using tank wagons.
- Production as well as the actual loading process is automated to a large extend.
- Directly before and after the loading process additional manual steps are required:
  1) Controlling of wagon identification plate.
  2) Opening the manhole cover (on top of the wagon)
  3) Inspection of lid sealing and check for objects inside the wagon.
  4) Depletion of remaining liquids using valves on the tank bottom.

These steps inherit a number of ergonomic and immediate risks for the operator and therefore should be executed by an automated system.
Issues/ risks for operator:
- Outside work/ weather influence (-20°C..+35°C )
- Heavy lifting (> 25 kg)
- Stooped postures
- Exposed to (potentially explosive) fumes
- Danger of getting hit by cover
- Danger of falling off the tank wagon

Support (by a robot) for the wagon handling task is highly appreciated from the operator side.
Due to different manufacturers and a patched age distribution the tank wagons vary in:

- Total volume and dimensions
- Position and design of the manhole covers (wagon top)
- Position and design of the valves (wagon bottom)

The total number of possible variations is not known and is subject to change (repairs/modifications).
Assistance system, which enables handling of the manhole covers:
- by its sensory capabilities (identification of key geometrical features)
- by its mechanical design

HMI has to enable:
- *Confirmation of the target points* before task execution
- Processing of unknown variations / *Manual specification of target points*
- Manual robot movements for maintenance or in case of malfunctions

Control of the robotic system has to be coherent with existing control interfaces.
The operators are no robot experts!
TANK WAGON INQUIRY

- Inquiry on 200 tank wagons: Determination of process characteristics
  - Range of geometrical features
  - Loosening/ tightening torques
  - Required lifting forces
- Evaluation of operator risks for each step – operations on ground level not critical.

Focus on cover opening (and closing).

→ Manhole covers summarized in three types:
  a) DIN EN 12561-6 or similar (75 %)
  b) Semicircular handle, one fastening screw (10 %)
  c) Variety of special mechanisms (15 %)

Target is a solution to process type a and b.

Wagon groups (10—15) positioned by skid (±10 cm)
Central reference point: Automated loading station (C)
Cycle time: Approx. 10 minutes per wagon

A – Cover opening
B – Liquid depletion
C – Loading station
D – Cover closing
No need for frequent reprogramming of the robot (main task sequence)
- Regular interaction required to confirm/ adapt program points
- Operators are robotic Novices and skilled/ Experts regarding the process.
- Sufficient information exchange required

Several standards addressing such issues: ISO 9241–110, ISO 11064–5, etc.
- Design functionalities considering the user: Main goal is support of the user task.
- Reconsider system complexity: Reduced vulnerabilities to failures and better system understanding
- Make the main functionalities obvious: Reduced learning time/ user can immediately perform targeted actions.

Complexity of new processes and poor ergonomic design of the respective visual display units are an (emerging) human factors risk¹.

¹: European Agency for Safety and Health at Work: The human machine interface as emerging risk.
Utilisation of *Kinect sensor* (modifiable compliant to ATEX directive).

Identification in a number of consecutive tasks:
- Tank wagon position of the track
- Position of manhole cover on wagon & opening direction
- Number and position of tommy screws
- Suitable point for magnetic gripper positioning

Storage of tank wagon information in data base
Automatic opening possible for ca. 90 % of the covers (type a, b and subset of type c covers)

Identified positions are *compared against stored information* and have to be approved by the operator.
03 DEVELOPMENT OF THE ROBOTIC SYSTEM
MECHANICAL DESIGN

Gripper prototype with integrated sensor
- Validation of individual components (end-effector, sensor) within the industrial facility.
- Validation of complete chain in laboratory, using actual manhole.
Three operators:
- One in control room (responsible for all four tracks)
- Two on ground level (responsible for two tracks each)

Four modes of operation: **Automatic** – semi-automatic – manual – maintenance

Interfaces designed according to internal and international standards and after consultation with operators.
03 DEVELOPMENT OF THE ROBOTIC SYSTEM INDUSTRIAL PROTOTYPE (IN PREPARATION)
Conclusions

- Variations of the main task made a full automation impractical
- System developed to identify and handle most of the processed tank wagons
  - Automated execution as standard case
  - Semi-automated execution increases the number of processible variations
  - Most of type c covers cannot be handled

→ *Reduce operator risks by approx. 90 %*

Ongoing work and Future work

- Setup industrial prototype in actual facility
- Evaluate complete handling chain in actual process
- Improve user interface according to feedback
- Transfer to cover closing
- Enable processing of type c covers
Thank you for your attention!

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