Demonstration Projects

Call for Ideas to Boost the Competitiveness of the Estonian Manufacturing Industry

Final Report

Please fill in the Final Report in English
The content of the Final Report is published also in [AIRE GitHub]()
To be filled by the Lead of the Development Team

Demonstration Project Title

A follow-up project for testing the robot assembly of intelligent bag filters at the company Vado Filters OÜ
(Jätkuprojekt intelligentse kottfiltrite robot-koostamise töökoha arendamiseks ja testimiseks ettevõttes Vado Filters OÜ)

Company

Company Representative Name *(First name, Surname)*	Markel Voit
Company name	Vado Filters OÜ

Development Team

Development Team Lead Name *(First name, Surname)*	Martinš Sarkans

Objectives of the Demonstration Project

The aim of the demonstration project was to continue the development and testing of an intelligent robotic assembly workstation to produce bag filters at Vado Filters OÜ.
During the testing in the first demo project, it revealed bottlenecks in the compatibility between the existing filter frame and the robot workstation. It was concluded that automation of the workstation with the existing filter-frame solution was not feasible.

AI & Robotics Estonia (AIRE-EDIH) is co-funded by European Digital Innovation Hubs Programme of the Digital Europe Programme and the Estonian Ministry of Economic Affairs and Communications
Project ID: 101083677

Thus, Vado Filters OÜ has invested in a new frame solution and has a new frame prototype that will enable robotic workplace assembly of filters and improve the quality of the final product.
The aim of this demo project was to develop and test the robotic installation of bag filter pockets in a new frame solution and the attachment of the frame and the filter material in such a way that the required quality (no leaks and all components intact) is guaranteed.

Activities and results of the Demonstration Project

Challenge addressed (i.e. whether and how the initial challenge was changed during the project, for which investment the demonstration project was provided)

Now, the frame is assembled by hand from various parts (using profiles and corners). The filter pockets are manually mounted next to each other on the springboard, with the "pocket mouth" open to connect the pockets with a plastic joint.
The fitting of the plastic joint is carried out by manual installation using a manually operated pneumatic tool to close the lock of the plastic joint. The interconnected pockets are manually inserted into the U-profile of the filter frame and secured with plastic clips, which ensure that the material remains firmly in place and provides the required air density for the filter. The fastening clips are then manually inserted into the frame and fastened either by finger force or with a pneumatic tool.
During this demo project we tested the suitability of a new frame solution for the creation of a smart robot assembly workplace. The challenge in developing the technical solution is to attach non-shape-holding textiles to the solid frame and to close the frame in such a way that the quality of the final product is guaranteed. All the manual activities described above will be addressed by an automated smart and self-configuring Workstation (intelligent fixture solution).
Another technical challenge is the integration of AI technologies into the product assembly process to ensure product quality in the assembly process and in final product control. This will require ongoing modification of the assembly program based on data from the manufacturing process to find the right position for the assemblies and not break assemblies during assembly.

Activities implemented and results achieved

Project activities and results:
The first step was to specify the technical task, map the assembly operations and describe them. This provided the necessary information for the development of an intelligent fixture for the product and for the selection of a collaborative robot.
In the second phase, work started on the development of ideas for fixing the frame and filter bags. This involved testing the suitability and performance of different technical solutions to achieve the expected quality and repeatability of the assembly.
The third phase included the development of an intelligent fixture concept for the installation of the top and bottom frames. This solution was also physically implemented to test the real assembly process and its performance.

In the fourth step, a virtual model of the workplace was created and simulated. For this purpose, the RoboDK software was used to check the robot's operating range and cycle duration.
In the last step, the assembly cell was tested with the product, data collection, data analysis and model verification were performed.
This involved the use of AI tools such as machine vision to perform product identification on the workbench (supplying the coordinates of the product to the collaborative robot), pre-production quality control of the filter bag (location and presence of seams), and quality control of the final product assembly (presence of all filter bags in the assembly).

Data sources (which data was used for technological solution)

For implementation of the project, research articles in this field were studied and analyzed. In addition, the following software solutions were used:

- Cognex In-Sight Explorer and Basler Pylon software for machine vision testing and training
- RoboDK simulation software for robot application testing, simulation and program generation
- SolidWorks CAD software for intelligent fixture design and concept development
- Python programming language for creation and generation of robot parametric programs in RoboDK

The following data was gathered during the project for the analysis and verification:

- production data, process information (time for assembly of filters)
- machine vision data (Picture data of the filters, filter elements, final product and their features) for training the model for product recognition, position detection and quality control
- product position data for creation of the robot´s parametric programs

The algorithm for generating a program for robots and the principles for defining robot system positioning. Stages:

- Identifying the product on the table
- Determining the location of the product by the points of intersection
- Importing the coordinates of the coordinates into the simulation environment.
- Adjusting robot programs based on points
- Program simulation, training and verification

For the Machine Vision training, the following data was gathered about the product: as the shape of the product on the table is quite well determined, it provides the basis for generating the robot program (corner of the product and pick-up point). By transferring the image program to the Cognex In-Sight Explorer system, the corresponding detection algorithms can be added, such as: Product presence check; Horizontal edge detection; Vertical edge detection; Edge intersection detection (basis for robot program zero coordinate). For the training, the dataset of product specific Pictures was used.

Description and justification of used AI technology

For each stage of the project, a detailed description has been documented, the necessary simulations have been carried out, test data have been collected (assembly data, measurement and product detection data, quality control data). The solutions have been tested and verified at different stages of the project. These are the following results:

- physical testing for filter bag assembly process has been carried out on intelligent fixture, data collection about forces, technical solution suitability assessment.
- generation of the cobot program in a simulation (RoboDK) environment, based on a script for generating the code, testing of the solution's functionality.
- testing machine vision functionality, collection of data on the product, evaluation of the suitability of different detection algorithms, testing of the performance of machine vision solution on a real test set-up.
- carried out a workplace planning in the simulation environment, created a new workstation layout, designed a cell for product positioning.

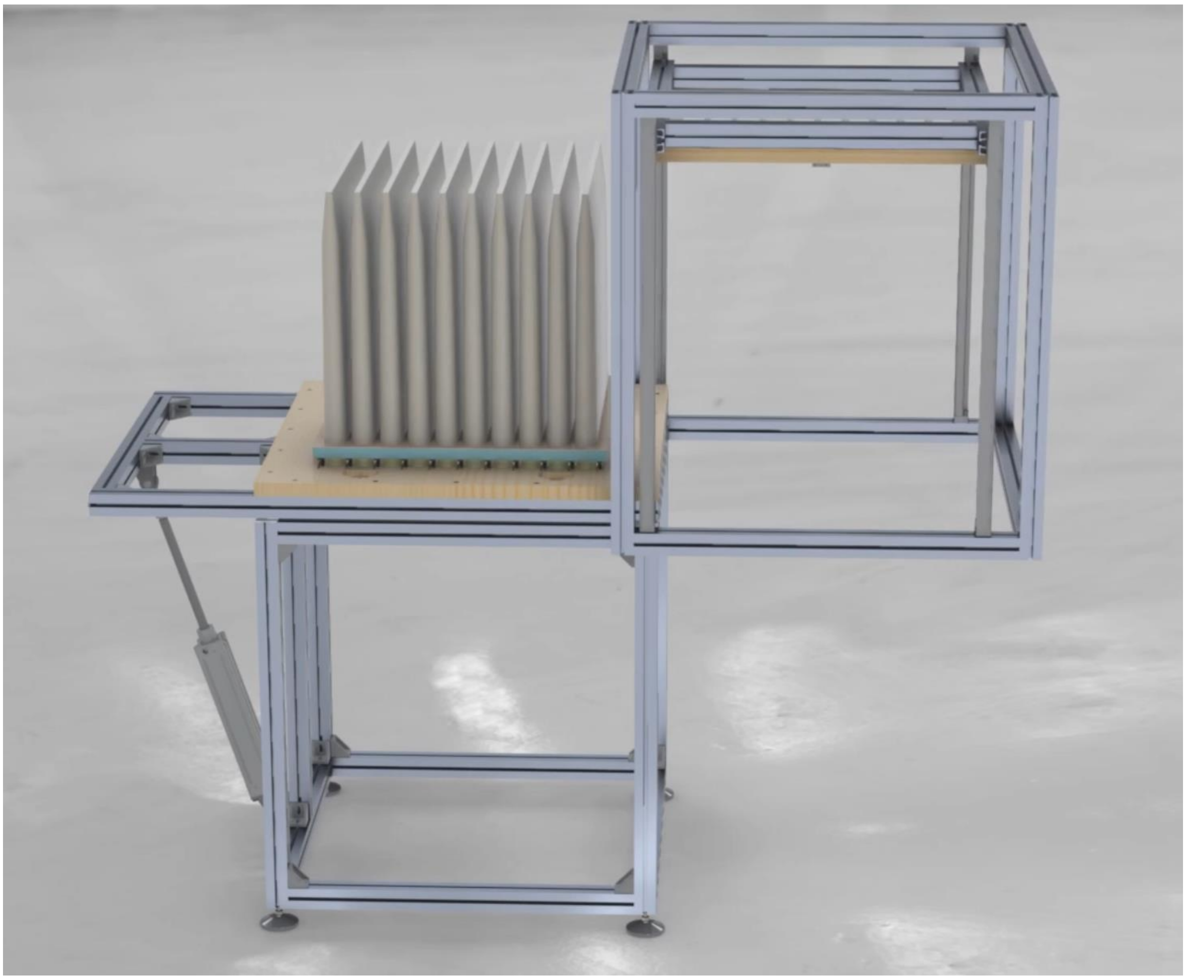
Product detection, position detection and sewing lines detection is based on image recognition and it checks the position of the product based on the edges and the location and pattern of the sewing lines on the contours of the filter bag. Based on AI technology and image recognition, it decides whether the product is correct, identifies the coordinates of the filter bag and sends the commands to a collaborative robot, which selects the appropriate program and positioning for the product.

Machine vision solution testing and validation.
At the filter bag assembly workplace, it is necessary to identify the type, location and coordinates of the product to provide the collaborative robot with the necessary parameters to generate and run the assembly program. In this case, the product is a filter bag (placed on a flat surface) of a fairly fixed shape before the handling by the cobot. The cobot picks the filter bag from the material buffer, and the position of the product is not always the same. Therefore, it is important to provide the robot controller with the coordinates of the position of the bag filter. The following software and hardware have been used as a solution to the problem: Cognex camera Cognex In-Sight 7905C (color camera, 5 MP), Cognex In-Sight Explorer software, Optics Fujinon HF12.5HA-1S (C-mount), Optics Moritex LMC-ML-M2516UR (C-mount), lighting (LED, flood light, background light).

Generating the robot program (RoboDK)
The robot program uses a script to create the target points, which helps to read in the coordinates of the position of the filter bag. This is a machine learning technique that helps speed up the programming of the robot system. This is when the pattern or shape of the filter bag changes. Then, generating a new program for the robot is several times faster than doing it manually.
It is important to use correct coordinate systems when generating waypoints and working trajectories: robot base (workobject UR20 Base), Tool TCP (workobject Tool), Workobject of the application (workobject MyWorkObject).

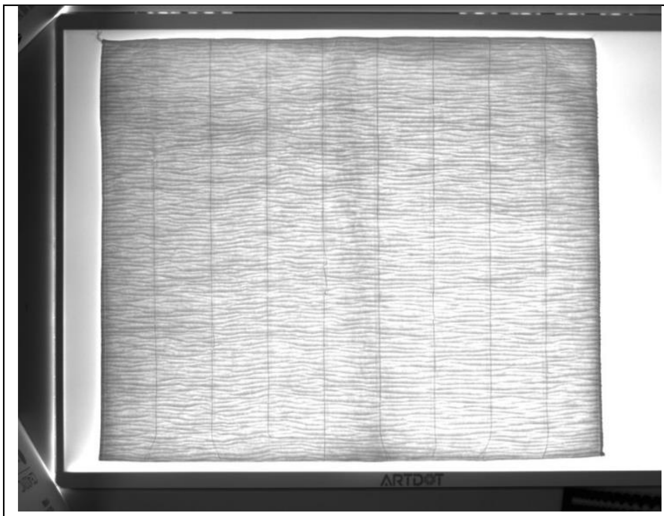
Results of testing and validating of the technological solution

The following intelligent fixture concept was developed and tested as a result of the development of technical solutions. This intelligent fixture was also physically realized to test the assembly process in real life. As a result of testing, a high quality final product was achieved.



Intelligent fixture concept developed together with the product

Testing of AI tools included testing of machine vision solutions for product quality control, filter bag location detection and for quality control of the final product. As the product assembly process could be improved by technical solutions, AI tools were introduced additionally to increase the robot's adaptability and partly for additional product quality control.



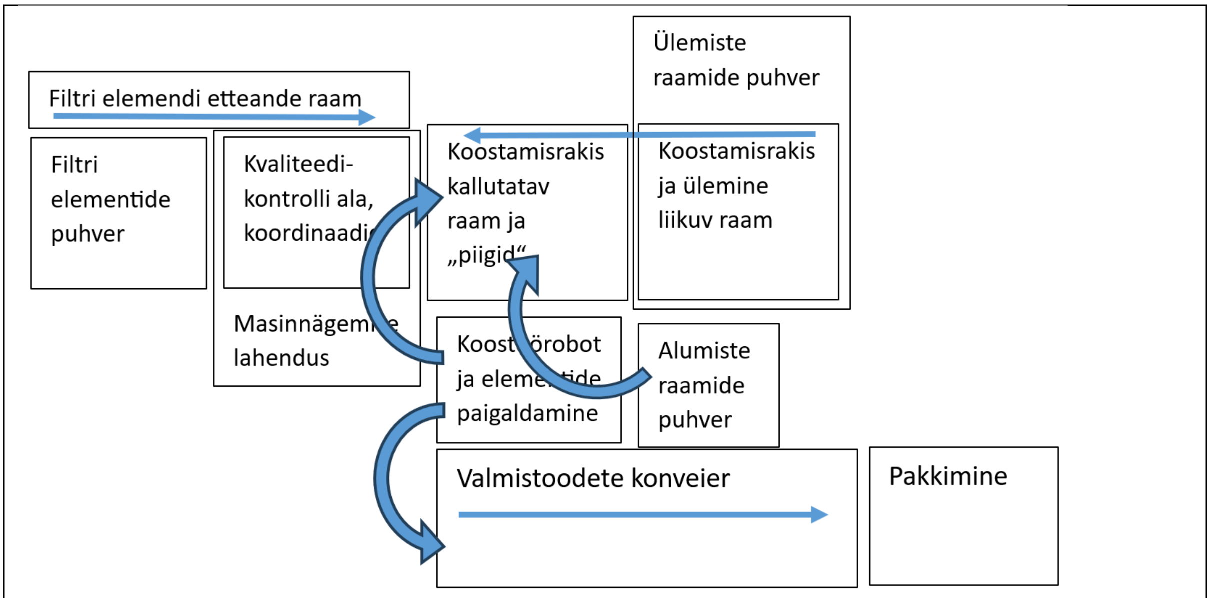
Pre-check and position detection of the product with a camera system 1

Final product quality control for a product with camera system 2

The testing showed that the machine vision solution allows to perform pre-product inspection, position detection and quality control on the product.

Technical architecture of the technological solution (presented graphically, where can also be seen how the technical solution integrates with the existing system)

As a result of the mapping and analysis of the product manufacturing technology, a suitable layout for a robotic assembly workplace was proposed. Experiments were carried out to test the performance of the machine vision solution as well as the feasibility of robotic assembly. The proposed production workstation integrates (via input) with the upstream filter bag sewing line to the intelligent workplace (with the fixture and cobot) and as output moves to the finished filter (final product) packaging line.



Flowchart of a collaborative robot assembly workplace

Potential areas of use of technical solution

The data collected and the solutions developed can also be used to automate the production processes of other textile companies or to apply artificial intelligence. In particular, we see similarities in the processes of sewing companies, where soft and stretchy textile materials are combined with form-holding components.

Description of User Interface (i.e. How does the client 'see' the technical result, whether a separate user interface was developed, command line script was developed, was it validated as an experiment, can the results be seen in ERP or are they integrated into work process)

As the development of a user interface was not the aim of this demo project, there is no separate user interface as such. The UI solutions are related to the specific tools that were used (RoboDK simulation environment and script, and Cognex In-Sight Explorer environment for machine vision). These environments were used to validate the performance of the robot workstation and to validate the quality control capability of the product.

Follow-up activities and plans for future (e.g. developments, potential for scalability, creation of spin-offs aso)

The need for robotisation in the enterprise is primarily to automate monotonous work, increase flexibility, boost productivity and increase production volumes.

The company's ambition is to develop new intelligent automated workplaces based on human-robot collaboration to improve the working environment and reduce costs for workers and the working environment.

Potentially, the economic benefits of the introduction of 2 robotic workstations (estimated investment of around EUR 300 000) are around EUR 70 000 per year. In addition, it will be possible to increase production capacity without hiring additional labor and thus expand in existing markets and enter new markets. We are currently exporting products to the EUR 100 million market in Finland for about EUR 3 million. We see the Finnish market as the main growth potential.

The KPIs are a reduction in labor costs per product and an increase in profitability through more efficient production.

KPI1 - expected increase in production capacity of up to 20% (Since the filter assembly process is about half of the total labor resource used to manufacture the product, the expected increase in profitability through automated production is up to 20%).
KPI2 - reduction of production (workforce) costs up to 80% (If we are able to automate the current manual processes within the expected cycle time, the expected reduction in labor costs for filter assembly is about 80%.)
KPI3 – reduction of material costs up to 10% (by using the new filter frame solution)

The company plans to manage the smart robotic assembly workstations through a production programme, so that the workstations work and set themselves according to the production schedule.

Lessons learned

i.e. assessment whether the technological solution actually solved the initial challenge

As it is a complex end product that does not hold a fixed shape, the technical solution was to find directions to position the different elements of the product as well as possible and make them hold their shape. An intelligent fixture developed for this purpose made it possible to achieve a situation where the filter bags could be well positioned to obtain a high quality end product. The solution developed during this demo project helped to solve the initial challenge well.
In addition, the simulation tools used, the use of machine learning, the use of AI tools (during this project) helped to check the previous quality of the product, its location and the final quality of the product.
When manufacturing complex products, it is also important to physically test the performance of the solutions and build test equipment to do so. Simulations and the use of AI tools can add the necessary additional flexibility to the robot and the intelligent fixture for such products.
Generally, several iterations of both the simulation and the technical solution are required before a suitable and mutually satisfactory result is reached.

Projekti lühikirjeldus (AIRE kodulehele, eesti keeles)

Projekti pealkiri, millist väljakutset lahendati, projekti eesmärk, millist tehisintellekti tehnoloogiat valideeriti, projekti tegevused ja tulemused, kuni 10 lauset

Jätkuprojekt intelligentse kottfiltrite robot-koostamise töökoha arendamiseks ja testimiseks ettevõttes Vado Filters OÜ
Demoprojekti uudsuseks on vormi mittehoidvate tekstiilmaterjalide ja tahkete raamimaterjalide ühine käsitlemine intelligentsete ja paindlike roboti/koosteroboti jaamade poolt. Aktiivkontrolli meetodil tuvastatakse roboti tööorganite sooritus ja kontrollitakse kvaliteeti tagavaid andmeid tegelikega. Läbi kogutavate andmete analüüsi ja mustrituvastuse peab tehisintellekt olema võimeline tegema muudatused koostamisprotsessi. Testimise käigus kogutakse andmeid ja luuakse algoritmid tehisintellektile otsuste tegemiseks.

Project description (to be published on AIRE webpage, in English)

Project title, what challenge was addressed, aim of the project, what AI technology was validated, project activities and results achieved, max 10 sentences

A follow-up project for testing the robot assembly of intelligent bag filters at the company Vado Filters OÜ
The novelty of the demo project is the joint handling of non-form-retaining textile materials and solid frame materials by intelligent and flexible robot/assembly robot stations. The active control method detects the performance of the robot's working organs and checks the quality assurance data with the real ones. Through the analysis and pattern recognition of the collected data, artificial intelligence must be able to make changes to the drafting process. During testing, data will be collected and algorithms created for artificial intelligence to make decisions.