Výsledek výzkumu a vývoje projektu TN01000024

Identifikační kód výsledku:	TN01000024/02 - V5
Název:	Demonstration platform for anomaly detection
Typ výsledku:	Gfunk – Funkční vzorek
Anotace:	Funkční vzorek je postaven na bázi kamerového snímacího systému s výpočetním zařízením typu embedded NVidia/Jetson a Raspberry/Pi,Pico. Platforma umožňuje kontinuální vícepohledovou kontrolu kvality v reálném čase na základě statistického vyhodnocení obrazových dat. Hlavním rysem systému je schopnost řešit tzv. jednotřídní klasifikační úlohu na omezeném datovém souboru cca desítek vstupních vzorků. HW realizace i SW vybavení funkčního vzorku (pořízení obrazových dat, konektivita a rozhraní platformy, výpočetní náročnost a GUI programového vybavení) odpovídá průmyslovým standardům.
Termín dosažení:	12/2022
Vlastníci výsledku:	Vysoké učení technické v Brně, DFC Design, s.r.o.

Tento výsledek byl vytvořen se státní podporou Technologické agentury ČR v rámci programu Národní Centra kompetence, projekt č. TN01000024, Národní Centrum Kompetence-Kybernetika a umělá inteligence (NCK KUI).

MVG – AnDetDemoPlatform

Demonstration Platform for Anomaly Detections

URL: http://vision.uamt.feec.vutbr.cz/data/MVG_RD_results_list.php
Item: FEEC/DCI/MVG_2022_AnDetDemoPlatform

Description:
The demonstration platform for anomaly detection is a modular platform developed for several class of machine vision inspection problems:

1. only OK samples available → one-class classification (no NOK definition = anomaly detection)
2. very limited number of OK samples → approx. tens of samples
3. complex sample shape → multi-camera scenario has to be used (data fusion).

The AnDetDemoPlatform is a standalone multi-camera laboratory device equipped with the proprietary inspection software Anubis. Basic specification of a circular carousel shaped platform ("phonograph"):

- multi-camera system (up to 4 cameras)
- synchronous camera-illumination-sensor modules driven by FW/SW
- variational parameters of image acquisition
- modular image processing pipeline

HW part of the platform consists of a rotating table on a honeycomb optical table. The circular carousel base table is designed to simulate an industrial linear conveyor belt. The platform enables to automate image acquisition and processing of the broad variety of objects and to test methods under high-fidelity conditions.

MVG-AnDetDemoPlatform	
Overall dimensions	(440 x 440 x 350) mm
Overall weight	Approx. 12kg (depending on configuration)
Rotational speed	33,3 rpm
Rotary table dimensions	(ø 400 x 9) mm

Table 1. MVG-AnDetDemoPlatform HW base general specifications

The HW base of the platform is built on top of a universal honeycomb optical table (M6 thread, 25mm pitch) allowing a configuration of measurement equipment to be altered to suit needs of a particular measurement in a modular fashion. The rotating carousel itself has several different interchangeable covers in order to simulate different surfaces or types of conveyor belts e.g. wood, metal or rubber.

Sensors and lighting
Image acquisition is accomplished by up to four industrial based cameras of GenICam interface – specifically by the Allied Vision Technologies MANTA G-125Bcameras attached on a universal mount. The cameras are presently positioned to capture an object on a given view (representing top and side projections), however the pose and position of cameras is fully configurable either in respect to the inspected object or to the on-board lighting.

Lighting modules are assembled from light sources (LED belt sections) and a diffuser to achieve an uniformly radiate illumination. Brightness intensities of the lighting modules are adjustable via GUI, realised by the PWM on hardware level. Camera and lighting specifications are in the tables below:

Allied Vision Manta G-125B	
Sensor	Sony ICX445
Sensor type	CCD Progressive
Sensor format	1/3″
Resolution	1.23MPx
Lens mount	C/CS mount
Filter	IR cutoff
Communication Interface	GigE

Table 2. Allied Vision Manta G-125B

LED belt	
LED type	60 x 5050/m
Temperature	cool white
Electric power	14,4W/m
Power supply	12 VDC (controllable)

Table 3. LED BELT

AnDetDemoPlatform Circuitry

The demonstration platform requires a 24V/3A voltage power source, which is fed to internal DC/DC converters to supply PWM modules, cameras, proximity sensors, rPi Pico and NVIDIA Jetson. Because of the power demands, each camera has a common DC/DC converter with its illumination, rPi Pico is powered together with the proximity sensors and internal switch, NVIDIA Jetson has its own converter.

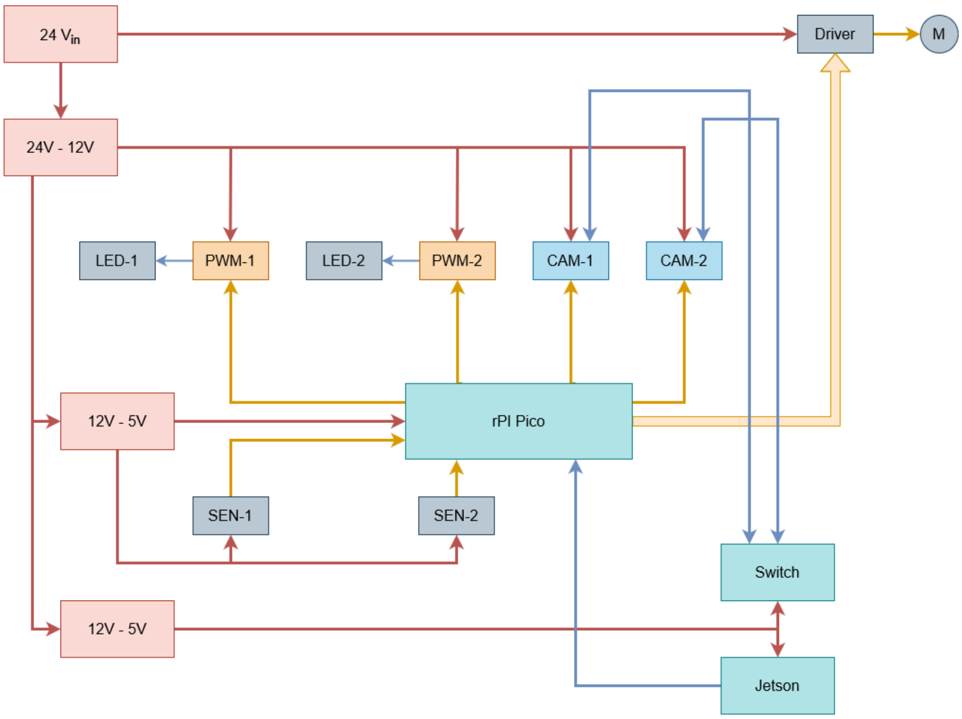

Fig. 1. Internal circuitry – a block scheme

The stepper motor SMR 300-100 used as a driving unit of the carousel is powered with 24 V through its driver, which is controlled by rPi Pico and works in a half-step mode. To ensure easy connection of the rPi Pico to the motor driver, lights, trigger inputs and other controlled modules, a custom control PCB board has been designed (the PCB on the right in the picture below).

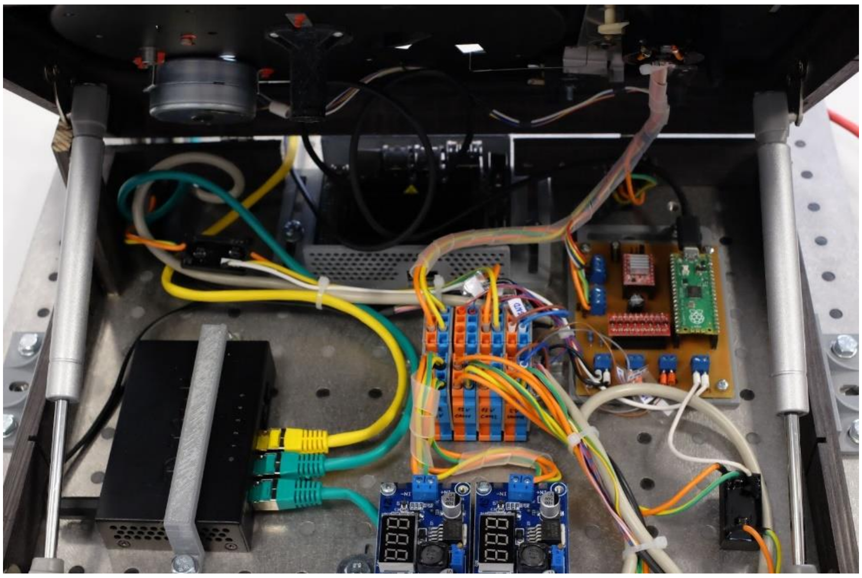

Fig. 2. Internal circuitry – HW layout inside “phonograph” case

Both cameras and NVIDIA Jetson units are connected to the closed LAN 1 GB network switch allowing up to four cameras as total or debugging on an external working station.

Fig. 3. Overall view of the demonstration platform for anomaly detection with no connections, no task-specific base and no inspected samples – core structure

Image Processing Method

Basically, the AnDetDemoPlatform employs a modification of a so-called DeepSVDD method intended originally for a specific anomaly detection task on the images of the samples. A main concept of the method is to use convolution networks to create features, which tries to collect OK samples in hypersphere in features space and creates a sharp boundary for classification decision.

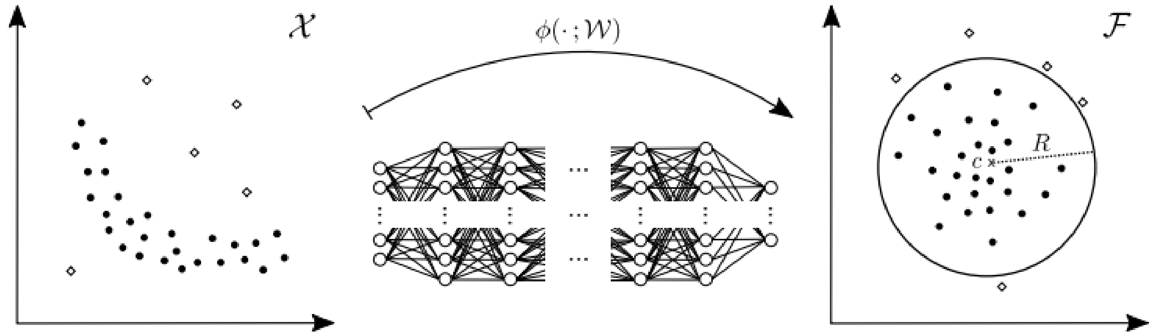

Fig. 4. Visualisation of the Deep SVDD principle transforming original feature space onto a so-called hypersphere

The mentioned method uses a modified Variational Autoencoder (VA) for feature extraction and sample classification. Training process computes loss from score values according to selected objectives. Then backpropagate loss and tune encoder.

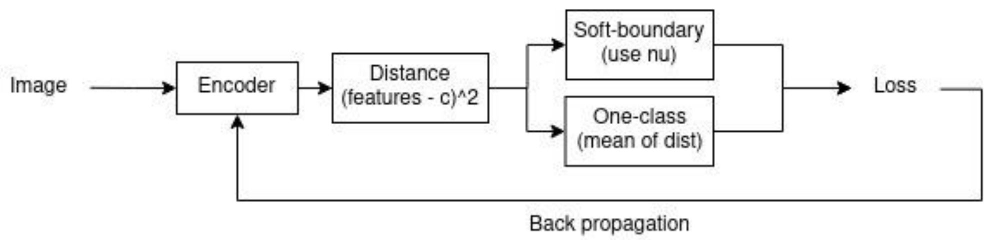

Fig. 5. VA - training block structure

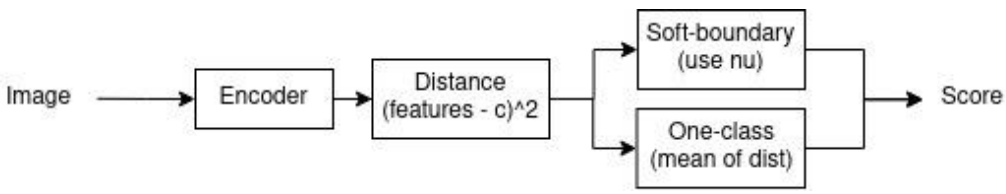

Fig. 6. VA - predicting block structure

The image processing module introduced above employs the CAE (a convolutional auto-encoder) as a first stage of the data-processing pipeline. For a software module design, a comparison of the feature extraction quality of a basic CAE implementation BAE1 with six convolutional (simplified proprietary) versions with four convolutional layers BAE2 and the architecture suggested by MVTec (with sixteen convolutional layers) has been performed.

As the dimensionality of the input samples is too high for the anomaly detection task, there is a need to reduce the number of input features to approx. 50 with the PCA algorithm and then to 2 with the t-SNE method. The latter mentioned is used for the reconstruction error metrics-based feature space. For this purpose, the L2 metric together with the SSIM has been chosen in order to create a two-dimensional feature space pictured below.

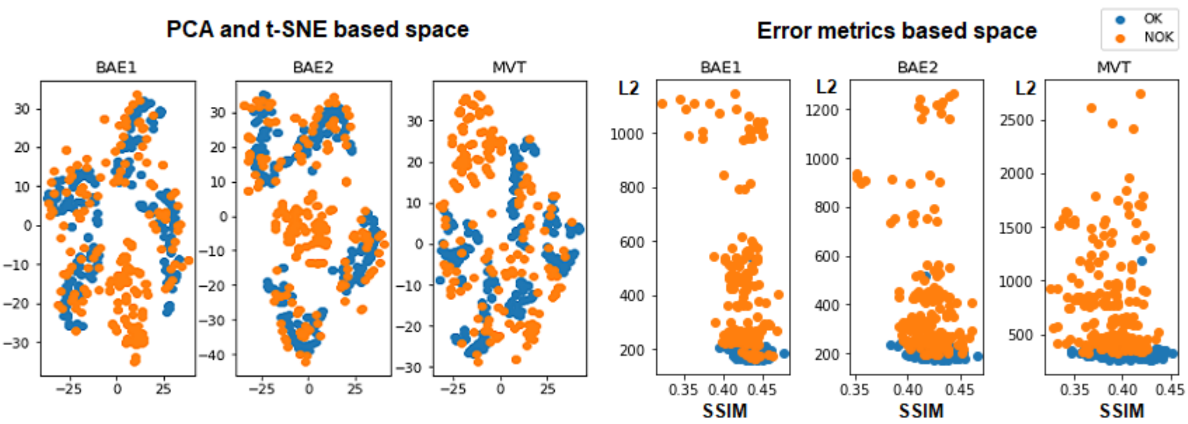

Fig. 7. Error-metric-based feature space used for anomaly detection evaluation

Results from the PCA and t-SNE based dimensionality reduction facilitate to separate one class of the NOK samples, but the other NOK classes blend with the OK class due to their structural and shape similarity. The MVTec CAE architecture gave the best results with the lowest overlap of the OK and NOK class, although the OK class does not create a closed cluster. The disadvantage of this approach is that the t-SNE method has a stochastic behaviour and the feature space slightly differs after each adaptation. The feature space based on the L2 and SSIM reconstruction error metrics performed better in the OK and NOK classes separation, although the OK class cluster still overlaps with a part of the NOK data.

Software Application - Anubis 2.0 Multi-cam

A proprietary Anubis 2.0 Multi-cam software servers as a main application for image acquisition and processing. It allows to set all devices parameters (cameras, illumination, stepper-motor, etc.) via the GUI, perform image acquisition and processing on up to four cameras views.

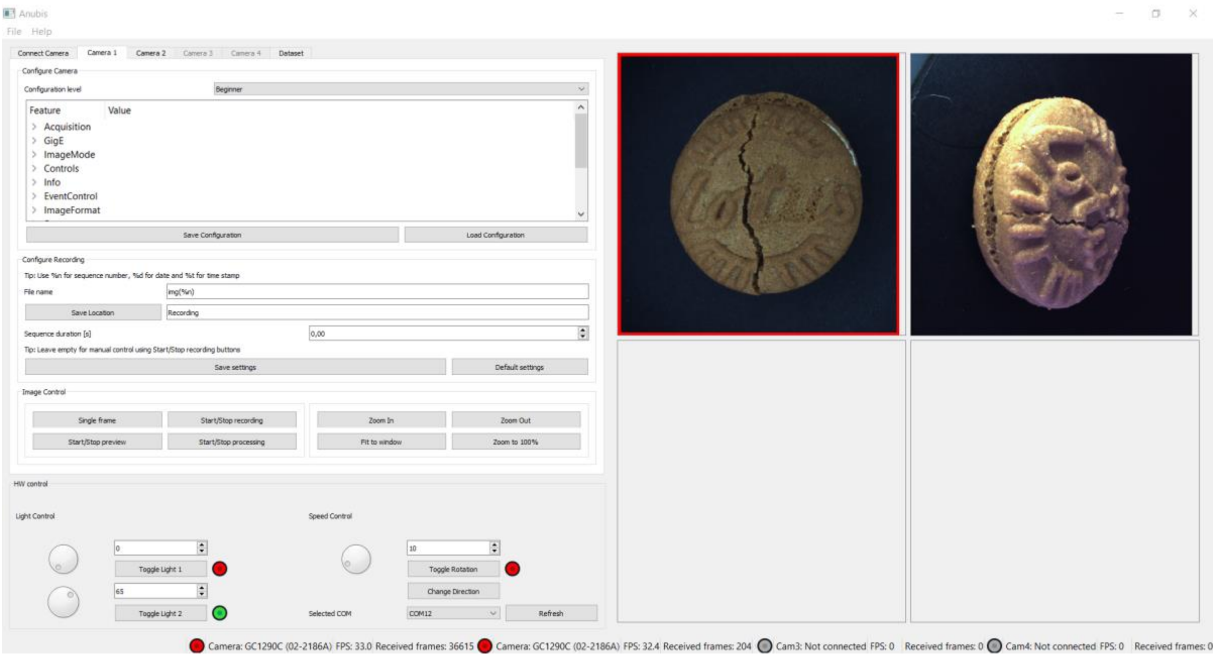

Fig. 8. Anubis 2.0 Multi-cam software GUI – alg. performed anomaly detection on NOK sample (TP result) on the Cam1 view (the Lotus-cookies case-study)

As a case-studies, there have been performed two extensive experiments on two industrial datasets: Lotus cookies and Rigid plastic parts, both based on the shape and colour intraclass differences.

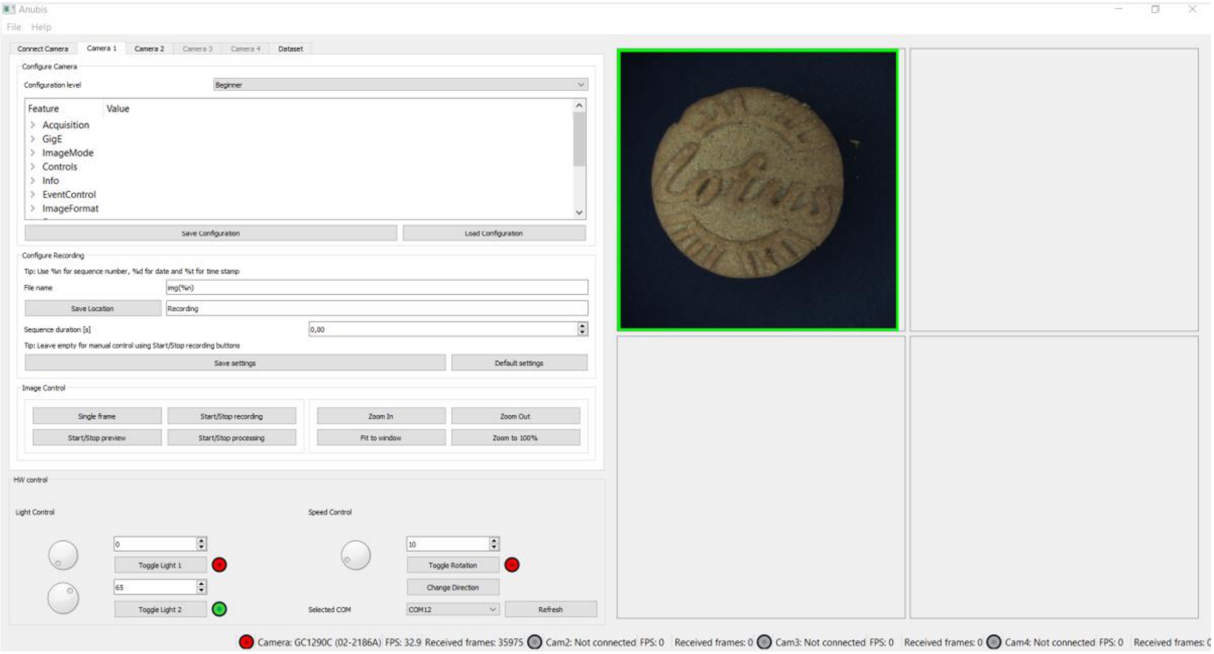

Fig. 9. Anubis 2.0 Multi-cam software GUI – alg. performed no anomaly detection on OK sample (TN result) on the Cam1 view (the Lotus-cookies case-study)