Machine learning-based system for weed control on railways

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***Abstract*— In order to establish safe operation of the railway, it is very important to maintain vegetation on and near the railway. In this paper, a solution based on deep learning for detection of weeds and bushes on the railways and the control of intelligent herbicide sprayers using PLC, is presented. Hardware setup, software implementation, the configurations of the convolutional neural networks, and the datasets used to train the neural networks are described. A video stream with recording of the railway tracks in front of the train, is sent to a PC computer located in the cabin. This video stream is processed using software for detection of weeds and bushes based on multiple convolutional neural networks. This software sends signals to the PLC that controls the opening of the nozzles on the herbicide sprayer. The presented solution is developed for Serbian Railways company.**

Keywords: maintaining railways; convolutional neural networks; deep learning; weed detection; weed mapping; weed control;

I. Motivation

In order to establish safe operation of the railway, it is very important to maintain vegetation on and near the railway[1]. Control of vegetation on railways is usually based on even spraying of agrochemicals along the tracks. This is a very efficient method that requires a small amount of manual human labor, but the negative side of this approach is the environmental pollution. In 2014, the European Union introduced new guidelines limiting the use of herbicides[2]. For this reason, it is necessary to improve the approach to railway maintenance in order to reduce the use of herbicides, but preferably without increasing human manual effort.

II. Research Questions

Goal of this research is to develop system based on deep learning for detection of weeds and bushes on the railways and the control of intelligent herbicide sprayers using PLC.

Smart sprayers are able to accurately identify and locate weeds on the railway in real time and manage to spray the herbicide only in locations where it is really necessary[3].

III. Methodology

This paper describes the automated system for spraying weeds and bushes on the railway, describes the used hardware and software implementation, configurations of used neural networks and datasets used for training neural networks[4].

IV. Methodology

The Fig. 1 gives an overview of the automated system for spraying weeds and bushes on a railway line. Behind the locomotive are attached three wagons, a storage wagon, a wagon with a spray device and a wagon with a water tank. At wagon middle wagon is placed diesel generator for electricity production for the sprayer, Wilo MVI water pumps, herbicide preparation tubs, Dosatron herbicide suction pumps, Arag electric motor valves, Lechler nozzles, control cabinet with frequency regulators and PLC, monitors for herbicide levels other related equipment. Vivotek IP8352 bullet outdoor IP67 internet camera is placed on the upper part of the locomotive, which is used for recording the area in front of the locomotive. Camera is connected with a standard PC that is placed inside the cabin of the locomotive. The software for detecting weeds and bushes on and near the railway tracks is running on this PC and sending information to PLC "Unitronics Vision V1040" that controls the spraying nozzles. When the PLC receives the from signal from neural networks that weeds have been detected on the railway, it is necessary to calculate the time to open the spraying nozzles. The distance from the field view to the nozzle on the sprayer is calculated by PLC based on information from sensors that monitor rotation of wheels.

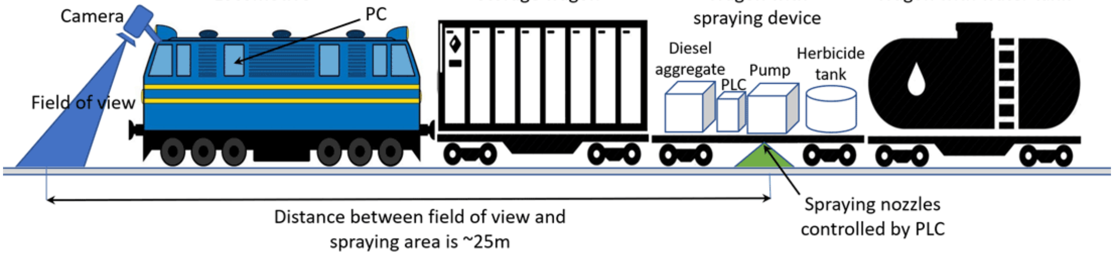

Figure 1. Camera is attached in front of the train

The overview of the software for weed and bushes detection is presented at Fig. 2. Processing begins with the extraction of individual images from the camera. Seven areas will be checked at the extracted image frame (Fig.3). Two outside areas are used for detecting bushes, and remaining five areas are used for detecting weed. Cropped images of those 7 areas are sent to CNNs that are used for detection of weed and bushes. There are four CNNs, the first network is specialized for bush detection (areas **sbl** and **sbr**). The second one detects the weed between railway tracks (area **swm**). The remaining two CNNs detect the weed outside of the railway tracks, fields closer to railway tracks (**swl1**, **swr1**), and fields farther from tracks (**swl2**, **swr2**). The positions these fields need to be corrected when the train enters a curve, for that is responsible CNN for positioning those fields (Fig. 2).

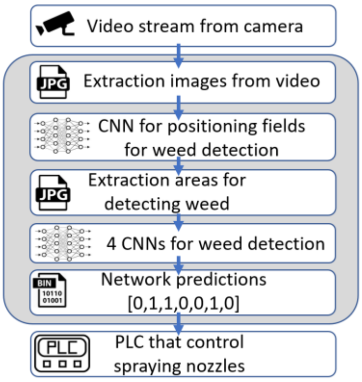

Figure 2. Overview of software for weed bushes detection

Figure 3. Position of areas for detecting weed and bushes at camera field of view

PLC controls the opening of spray nozzles based on information obtained from CNN whether weeds were detected in each of the seven observed fields. The minimum time from turning on and off the spraying nozzles is 1s during that time the train travels a distance of approximately 3.5-7m. This software allows users to adjust detection sensitivity for each filed, also there is option to switch to manual control if it is necessary. Manual control is important for side spray nozzles especially in areas near houses, cottages, orchards and fields with honey beehives.

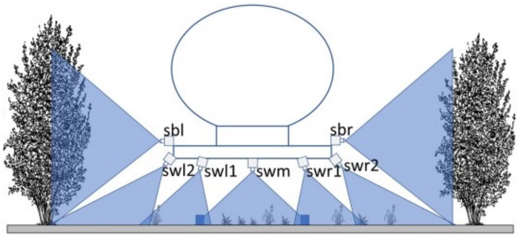

Figure 4. Nozzles controlled by PLC for spraying weed and bushes

V. Network Configuration and Datasets

CNN networks used in this project at input expect matrix (32×32×3), it contains three convolutional layers (with 16, 32, and 64 kernels, shaped 3×3), three fully connected layers (with 128, 64 32 nodes), and output layer contains one node. Those networks are trained at dataset that contains 12635 images extracted from several videos recorded on different sections of the railway. Images from the dataset were divided as 70% for training, 15% for validation and 15% for testing.

VI. Results

Graph in Fig. 5 showing the number of detections in the previous 100 extracted frames, in fields for detecting bushes (**sbl**, **sbr**), and fields for detecting weeds **swl2**, **swl1**, **swm**, **swr1**, and **swr2**. At the output gives those networks one real number in the range 0 to 1. If output value is less than threshold value (usually 0.5), it means that weeds (or bushes) are not detected, if this value is higher than threshold, it is considered that weeds (or bushes) have been detected.

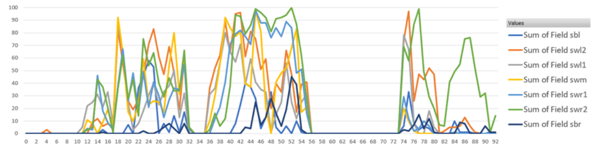

Figure 5. Number of weed detections over time

Each of the CNN networks on this system is trained to detect weed with accuracy over 98% but there are situations where for some reasons even for humans it is difficult to answer with certainty whether there is weed in the image or not, for example images with very small amounts of weed. When the CNN network analyzes such images, the output values are usually numbers approximately equal to 0.5. Final decision how this image will be classified depend on configurable parameter threshold. The presented system has high tolerance on errors, since the train moves slowly enough, one sod of weed will appear in several consecutive images. So, if we fail to detect one sod of weed in one image frame, there is a good chance that it will be detected in consecutive frames.

VII. Conclusion

The automated system for precise herbicide spraying presented in this paper was developed for the Serbian Railways, it can reduce environmental pollution and enable economic savings, without reducing efficiency.

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