Pavement mapping using convolutional neural networks

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The problem

Today most of the cars and robots driving autonomously need to have a map. The map is used for localisation and also has information about where the not moving objects are like: buildings, roads, traffic lights. The map is created to reduce the computation needed to be done during the driving. So during driving the autonomous vehicle can compare the surroundings, understand what are the statical objects and what are the things not in the map, that can be dangerous. The non-static objects are other cars and pedestrians that are unpredictable.

In this work, one of the Starship Technologies' mapping process is made automatic. The process consists of creating feature map for the robot so that it can localise itself and marking the drivable area. In the scope of this work, the aim is to evaluate if a neural network model can be used to automate the drivable area (pathway) marking process.

Pathway marking

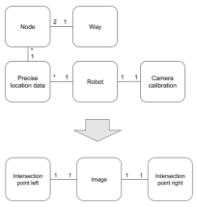
The pathway is annotated to the robot's front-camera images (image in the right). The employees are marking the pavement centre points with nodes (yellow circles) and drawing ways between them (green area). With the help of the images, the way width and position is adjusted to match the reality.

Solution

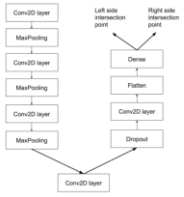
For the automation, the picked approach will use front camera images from the robot for detecting the intersection points of the pavement edges with the lower edge of the image (rightest and leftist red dots on the right image). A convolutional neural network with regression will be used.

Work process

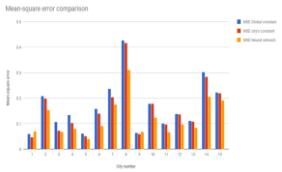
The work included data gathering, neural network construction and the evaluation of results. Data was gathered from previously annotated paths. During the gathering process, the necessary data was connected, coordinates where calculated and transformed. The data was created city by city and in total there were 2 million data rows.



Convolutional neural networks where used. The network creation process was experimental, trying out different solutions and measuring the result with the mean-square error. The data was split into training, validation and testing datasets. The final model has five convolutional layers and 15 epochs.



Evaluating results against a constant model



Type of model	Mean-square-error score
Neural network	0.1194
City's specific constant	0.1541

To analyse the neural network result it was compared with the constant model. Evaluating a constant model will tell if the neural network model is better than just always predicting mean values. Two constant models where made: one that estimates global mean values and another that is city specific.

To sum up, the neural network got a smaller MSE score than city's specific constant model (Table to left). This means that the neural network model is more accurate than using the simple model.

Manual Evaluation

A manual evaluation was done to understand more clearly how the neural network predicted and where the mistakes came. Therefore, the author looked through the images generated by the constant model and images generated by the neural network to get another perspective of the models' performance. Altogether 45 000 images were looked through manually.

The lines on the right side images are drawn from the intersection points to the centre of the image. The red represents neural network and green is the training data.

Three sample images are brought out in the left. On the first image is seen that the neural network result and the input data is very similar. On the second image, the neural network mistakes the drainage with the pavement edge. And on the left side, it can be seen that there is a mistake in training data and the neural network is correct.

In conclusion, the neural network model performed a lot better than the constant model and also better than the training data itself.

Type of model	Number of images inspected	% of correct predictions by visual inspection
Neural Network	20698	94.55
City's constant	14236	77.23
Training data	9336	86.20

Conclusion

The neural network model works better than the constant model. Manual evaluation results show that 94% of the neural network results are correct. The neural network result is better was better in the manual evaluation process than the training data. This means that the neural network was capable of learning from data that had mistakes in it.

To sum up, this model can be used to pre-generate the pathway marking, to make the process faster but it cannot be used yet as fully automatic. As the process can be made better the work is considered successful.

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