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Implementation of real-time neural networks for gesture recognition of radar signals for vehicular comfort applications

Automotive comfort functions are making our daily lives easier. One widely employed application is the so-called Easy Trunk Access (ETA) where a gesture with one's leg in front of the back bumper opens the trunk, without the need to use hands, buttons, or levers. The state-of-the-art option is a capacitive system that has proven to be nonreliable and causes high user frustration levels. Therefore, a different physical sensor principle has to be employed to overcome all the disadvantages. Radar is the solution here, known from air traffic around the world and now implemented as miniature version in cars. For the ETA application several radar systems have been designed and evaluated, best results are found with a two channel 24 GHz continuous wave (CW) radar. With this radar system a set of valid and invalid gestures have been defined and with the help of several test subjects a database was created. With the help of this database several machine learning (ML) classifiers and neural networks (NNs) are trained and evaluated. All trained classification algorithms and NNs are assessed with respect to their detection performance, their required computational power, and their real-time capability. For the 24 GHz radar system, a real-time gesture classification algorithm is designed which can run on low-cost embedded HW. This convolutional neural network (CNN) consists of two stages and allows to classify gestures with a constant processing time of 216 ms while running on an STM32 Nucleo board. The achievable true positive rate (TPR) is 93% and the false-positive rate (FPR) is 1.3 %. With the presented stage concept, it is possible to scale the NN according to the computational power of the HW. That means it is possible to design networks for high-performance workstations (HPWs) as well as for low-cost embedded HW.