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Machine Learning Algorithms and their Embedded Implementation for Service Robotics Applications

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Ph.D. thesis summary for the Board Secretary

1. Summary

As the world of the XX century has been reshaped by computers and industrial robotics automation, the XXI century will be progressively transformed by intelligent machines. Among all research fields, the multidisciplinary branch of service robotics works precisely towards a vision of the world where autonomous machines will coexist with humans, assisting them in their daily lives. Contrary to common belief, humanoid robots are only one possible form of service robots: quadrotors (UAV), rovers (UGV), quadrupedal and underwater robots are examples of embodiment of these future autonomous agents. Nevertheless, full autonomy requires effectively perceiving and acting, interacting with the surrounding environment to accomplish goals, and considering the possible long-term consequences of actions.

Within the last decade, advances in deep learning, coupled with the creation of large available datasets and the boost in computing capabilities, have resulted in remarkable progress in computer perception, natural language processing, machine reasoning, and sensorimotor mapping. Consequently, deep learning solutions constitute a promising instrument to bring intelligence and endow agents with the necessary level of autonomy to confront our reality. However, most deep learning models consume vast amounts of power, limiting scalability and applicability to energy-constrained applications. On the contrary, the brain is amazingly efficient, requiring less than 20 W to operate. Moreover, unlike our brain, the generalization of data-driven techniques is limited, and they usually require a well-defined application to maintain their performance. Indeed, domain shifts from training data and affine transformations of target objects constitute an important challenge for current models. All together, represent a real bottleneck for applying deep learning to service robotics which requires systematic generalization and efficiency to live our world.

Within such a context, the presented thesis aims at investigating machine learning algorithms for service robotics, working on the whole data pipeline, from remote sensing data to ground vehicles (e.g. UGV) navigation. It starts proposing DL solutions to extract value from long and short-range remote sensing data levels in support of autonomous agents. Indeed, extracted information from these levels can be a valuable support for navigation and decision-making in practical applications.

Subsequently, novel perception and sensorimotor planning solutions for ground vehicles are presented, bringing intelligence at the edge, that is, directly on-board machines. Model accuracy is juxtaposed with power consumption and efficiency at this level, and algorithms build a strict bond with dedicated hardware. However, efficiency is not enough, and generalization always constitutes an essential piece of the problem for service robotics. Consequently, systematic generalization and domain generalization are recurrent themes of the thesis, whether it be bridging simulation to reality gap or overcoming current architecture, training procedure, and data limitations.

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