Decentralized multi-map self-organization

BISCUIT team, Loria

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1 Context

1.1 Unconventional computing for robotics

The BISCUIT[1] team of the Loria laboratory has been created recently, gathering researcher interested in unconventional computing. The idea is to investigate new computational paradigms for tackling challenging problems as autonomous robotics, situated cognitive computation, etc. The relevance of such unconventional paradigms comes from the idea that the brains perform better than human made technology to drive autonomous agents (animals). Moreover, even if this controversial (Jones, 2000), when some more recently evolved nervous system architectures are considered, as for example the cortex, it seems that the genetics rather codes for the anatomical development of quite homogeneous systems that get tuned while the animal faces the interaction with the world (Miller et al., 2001; Ballard, 1986; Stavrinou et al., 2007). When considered as a biological way to solve a robotic problem, brains show that computing by gathering a large population of small computational elementary circuits (e.g the microcolumns in the cortex (Mountcastle, 1997)) is an robust and efficient way to control artificial agents. Nevertheless, computer scientists do not clearly understand why, since reproducing the computational skills of brains is not achieved yet.

The BISCUIT team focuses on "actually doing something with **S**patialized and **D**ecentralized **P**opulation (SDP) computing", rather than accuratly modeling brain structures. The PhD proposed here is a step further in that direction.

1.2 Self-organization

Among all the features that could be transfer from biology to computer science, the purpose of the PhD is to focus on self-organization. Seminal work by Kohonen (Kohonen, 1997) on self-organizing maps (SOM) refers to biological inspiration of the cortex while it is today an experienced machine learning algorithm for unsupervised learning. Previous work of the team members have also addressed self-organization, insisting on an actual SPD approach (Alecu et al., 2011), which is not central in classical SOM. The idea is to consider self-organizing SPD modules as an elementary block for multi-map architectures (Ménard and Frezza-Buet, 2005). The problem of how several self-organizing modules should be connected is crucial in this approach. SPD modules can be connected to themselves as well, recursively. Then, they are able to deal with the temporal nature of information (Khouzam and Frezza-Buet, 2013). These previous works have currently two main limitations. They have been applied to 'proof of concept' toy problems, and they require a large amount of parallel computation (Gustedt et al., 2010), since the intrinsic mechanisms rely on large scale populations of elementary computational units. This reduces the possibility to explore architectures made of many SPD modules.

[1] Bio-Inspired Situated Cellular and Unconventional Information Technology

1.3 Robotics

The PhD is not a contribution to robotics, since the purpose is to address SPD computation rather than providing a robot with skills outperforming the current state of the art. Nevertheless, a challenge for the PhD is to use a real robot as a validation platform. To do so, the `smartroom` at CentralSupélec will be available: applications to UAV[2] or rolling robots[3] can be considered easily, thanks to ROS[4].

2 PhD objectives

As previously said, self-organizing modules have been addressed previously in the team, focusing on fine grain population computing. Nevertheless, understanding how multi-module architectures could be set up is not understood yet. The objective of the PhD is to rely on the analogy of such modules with SOMs (Baheux et al., 2014) in order to build up multi-map architectures with many components, and analyze their dynamical behavior. Multi-map approaches to self-organization have been proposed in the literature (Johnsson et al., 2009), as well as recurrent ones for temporal processing (Voegtlin, 2002; Hagenbuchner et al., 2001), but the number of modules, when greater than one, is quite always less than three.

The PhD should also address some robotic validation experiment, as previously stated. It means that self organization should occur online, as the robot interacts with its environment. Classically, SOMs are used offline, on datasets collected in advance. Indeed, for SOMs, the temporal decorrelation between data sample is crucial for convergence. For example, if a SOM is fed by the sensor output of a robot that stops, it may receive the same information for a bunch of consecutive time steps. From a classical SOM point of view, this means that the distribution of input becomes constant since the inputs feeding the SOM before the stop are not stored and thus these inputs have no chance to be submitted anymore. In this case, the whole SOM units progressively converge to the current input value, producing a *catastrophic forgetting* of what has been learnt during the motion. This problem, basically illustrated here, is fundamental to any online learning system, and it is much more than a technical SOM tuning issue. Modifications of SOM have been proposed by the members of the team (Rougier and Boniface, 2011) to tackle this issue at the level of a single SOM. Extending this approach to multi- and recursive SDP modules is another challenge of the PhD.

3 Working conditions and requirements

The PhD student will be hosted at the Loria laboratory, that is located at Nancy and Metz[5], in the East of France. S/He will be working on both sites, at her/his convenience, under the supervision of Hervé Frezza-Buet and Yann Boniface. Scientific collaboration with other members of the team is expected, as more general scientific discussions and communications with the members of the laboratory. The expected duration of the PhD is three years.

A taste for innovation and multi-disciplinary approaches is expected, since references to biology may be considered. Good programming skills are required as well. The team will provide a set of programming tools, robotic platforms, and all the human support required for technical aspects, enabling the PhD student to focus on scientific issues.

Being comfortable with `C++` would be a plus, the code production will be made under linux.

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[2] Parrot quadricopters

[3] Kheperas, turtlebots

[4] see `www.ros.org`.

[5] at the Metz campus of CentralSupelec.

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