How rich motor skills empower robots at last: Insights and progress of the AMARSi project

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How rich motor skills empower robots at last: insights and progress of the AMARSi Project

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Zusammenfassung **Schlüsselwörter** Adaptive Behaviour · Compliant Systems · Learning · Robotics

Flexible, robust, precise, adaptive, compliant and safe: those are some of the qualities robots must have to interact safely and productively with humans. Yet robots are still nowadays perceived as too rigid, clumsy and not sufficiently adaptive to work efficiently in interaction with people. The AMARSi Project endeavours to design and implement rich motor skills, unique flexibility, compliance and state-of-the-art learning in robots. Inspired by human-recorded motion and learning behaviour, similarly versatile and constantly adaptive movements and skills endow robots with singularly human-like motor dynamics and learning. The AMARSi challenge is to integrate novel biological notions, advanced learning algorithms and cutting-edge compliant mechanics in the design of fully-fledged humanoid and quadruped robots with an unprecedented aptitude for merging in our environments.

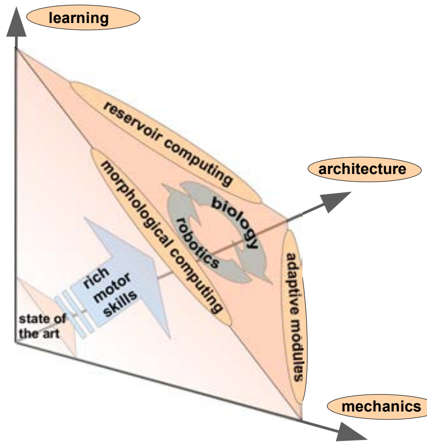

Abb. 1 The AMARSi project strives to advance science and technology in the three main directions of mechanics, architecture and learning. The progress in rich motor skills applied to robotics derives from the combination of these orthogonal fields with the bio-inspired paradigms of reservoir computing, adaptive modules and morphological computation.

1 Inspiration

Compared to animals and humans, the motor skills of today's robots are still poor. Their movements are still perceived by people as abrupt, unpredictable or unnatural. In fact, the behaviour of robots is often limited to a narrow set of carefully programmed motor patterns that operate a rigid mechanics and display limited adaptation to complex, task-oriented behavioural patterns. On the other hand, the smoothness, efficiency, elegance and safety of movements of humans and other animals are aspects that makes the human-to-human or human-to-animal interaction still qualitatively superior to that of any robot.

The AMARSi Integrated Project (Adaptive Modular Architectures for Rich Motor Skills) is a EU funded four-year research project that aims at a qualitative jump towards biological richness of robotic motor skills. Richness is intended as a novel conception of motor primitives as basis to a large repertoire of motor behaviour, ranging across the entire hierarchy from simple periodic and aperiodic motions to complex, task-oriented interaction sequences between a robot and a human caretaker. The AMARSi project proposes a coordinated research effort in different areas (Fig. 1) to implement rich motor skills. The research

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on rich motor skills extends also to the identification and definition of different features of motion, thereby not only aiming at their implementation but also at a rigorous scientific definition and benchmarking.

The challenging research objectives are pursued by a consortium of twelve international leading research laboratories from the fields of bio-robotics, robot engineering, compliant mechanics, morphological computing, human motor research & bio-mechanics, theoretical biology, machine learning, neural networks & reservoir computing. The challenges of merging these difference areas are tackled by an intense collaboration programme encompassing seven work packages shared across all research laboratories.

2 AMARSi towards its objectives

The AMARSi project started in March 2010 and is currently progressing towards its objectives in three main fields: biology, mechanics and algorithms.

The research on human primitives is contributing to the study of human motion [1,14], from skills in new born babies [8], gate transition [15,37] and recovery [34], crawling [26], anatomy and posture [42], muscle synergies [6], catching [3], motor neuron oscillations [2], spatio-temporal tuning [4] and control behaviours [5]. These studies cast new light on our understanding of how humans learn new motor skills and eventually perform complex and accurate movements. These notions are used in the design of robotics platforms and control algorithms.

The development of compliant actuators for AMARSi has led to novel features in humanoid robots [40,38] that can now cope with accidental impacts [10], perform fast bipedal walk [24,23] featuring a range of human-like properties [25,28]. The COMAN robot, Fig. 2A is currently at an advanced stage of development. Compliant legs have also been adopted in a novel design of a quadruped robot [39], Fig. 2B.

Morphological computation allows robots to perform movement naturally and efficiently. Progress in AMARSi contributes to morphological computation both theoretically [12,33] and in robotic design [7,13], in particular with compliant actuators [36,27] and evolution-designed body parts [16].

While biological notions and hardware components are rapidly developing, the control architectures and learning algorithms are faced with increasingly complex tasks. In AMARSi the application of learning to robotics has further advanced, in particular imitation learning [19,11], learning of nonlinear systems [18,17] and learning of motion dynamics for catching [20].

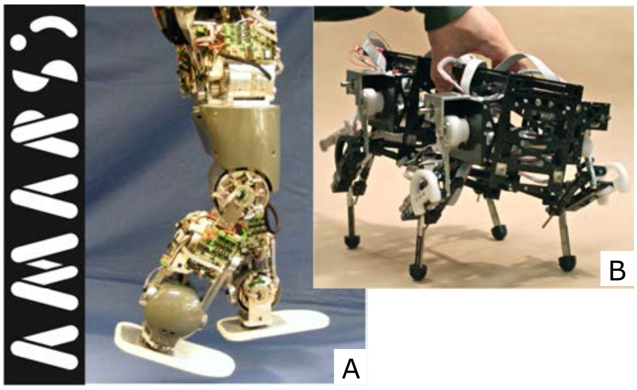

Abb. 2 (A) Legs of the AMARSi COmpliant huMANoid (COMAN). Thanks to cutting-edge compliant mechanics, novel control strategies and learning, this robot can walk, reach and perform various tasks with the smoothness and efficiency typical of humans. See the latest demonstrations on the AMARSi YouTube channel. (B) A prototype of the Oncilla: the quadruped compliant AMARSi robot. This robot can walk softly and smoothly across a variety of surfaces and with different paces in a fashion that resembles our domestic cats and dogs.

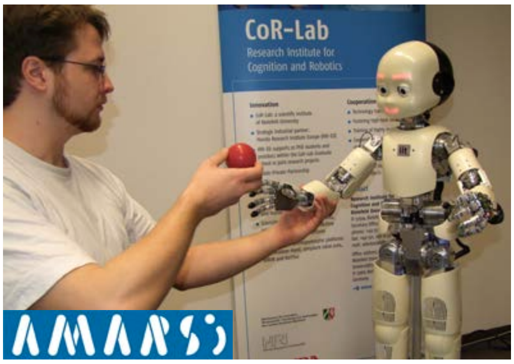

Abb. 3 The AMARSi compliant humanoid robot during a session of kinesthetic teaching. The new compliant mechanics and learning algorithms allow the robot to learn movements from interaction while being guided by a human teacher.

Novel learning methods developed in AMARSi focus in particular on bio-inspired neural networks and reservoir computing. Not only are neural networks biological plausible control structures, their use also helps understanding important aspects of neural control architectures, how movements are generated, how learning and plasticity occur. Advances have been achieved in learning the inverse kinematic with reservoir neural computing [32], learning visuo-motor coordination [9], devising control strategies with minimal energy control [22], continuous on line adaptation [21] and human-machine interactive learning [41,30] as shown in Fig. 3. Networks of spiking neurons have been used to implement probabilistic models [31]. Changing scenarios and behavioural policies have been investigated in [29], with particular focus on the role of reward [35].

The AMARSi partners report ongoing developments currently submitted for publication in all work-packages, Human Motor Primitives, Compliant Systems, Morphological Computation, Adaptive Modules, Learning, Architectures and Software. Public deliverables, open source software, publications and other support material like images and videos are constantly updated on the project website http://amarsi-project.eu.

3 Conclusion

Rich motor skills promise to change the role of robots in our society. Progress in AMARSi shows that robots are becoming less clumsy and begin to show increasingly more accurate, flexible and richer motor behaviours. Such an extended range of behaviours and skills allows robots to perform increasingly complex tasks in diverse human environments like homes and offices. More importantly, the smooth and efficient motion under a variety of conditions gift robots with unprecedented human and animal-like resemblance. The contribution of this research project to natural, interactive and safe movements make robots finally ready to blend into the everyday routines of human society.

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