Preface

This volume is the collection of papers presented and debated at the 8^{th} International Symposium on Evolutionary Robotics (ER2001), subtitled From Intelligent Robotics to Artificial Life, held in Tokyo on the 18^{th} and 19^{th} of October 2001. A paper by Dr. Hiroaki Kitano of Sony Computer Science Laboratory, who also presented at the symposium, unfortunately could not be included because of the severe time constraints under which the invited speakers had to prepare their manuscripts.

Eight years have passed since we first organized our Evolutionary Robotics symposium (ER'93) in Tokyo in April of 1993. During those eight years, we have run a total of eight symposia with the same title and objectives. That itself is rather surprising. Many sophisticated and complex robots have been developed during this period and launched into society. Yet the subjects we decided to study back in 1993 have remained important throughout the research and development community, if not becoming more important.

We have noticed, through the life of this series of symposia, the existence of some fundamental research themes that seem to demand attention beyond the immediate scientific and technological concerns associated with intelligent robot research. We call such issues philosophical, as philosophy by definition deals with fundamental themes that underlie what can be readily observed using existing science and technology. History shows us that philosophy itself has its own history. We also know that something mankind has come up with through his conscious effort remains effective only for a certain period of time, a few centuries at most (with the notable exception of the Flat Earth Society). It could be that we need to examine the philosophy itself on which today's science and technology are constructed and maintained. If so, unless we focus our attention accordingly and deepen our understanding of key subjects, we will never enjoy the company of sufficiently intelligent beings which we anticipated producing. Thus it became a tradition of the symposium series to each time invite a philosopher or two, as well as those who are philosophically oriented in their daily practice. We have already seen some remarkable results in which revised philosophy has clearly, unquestionably, and considerably improved robots' performance. Incidentally, this year we had two winners of the respected "Computers and Thought" award as invited speakers. However, the philosophical inclination at ER2001, as well as at our previous symposia, did not remain there. All invited speakers have, through their exceptional careers, deepened their thought and inquiry to the point of being widely praised and accepted as hallmarks in their own sub-disciplines. They each raised their level of awareness to try to answer some fundamental questions in the field such as "What is computation?", "Where are we heading with our search for intelligence?", "What is intelligence?", and "What is life?"

At the Advanced Study Institute workshop on intelligent robotics held at historic Monte Verita in Switzerland in the fall of 1995, a participant briefly

talked about Gray Walter's tortoise robot built in 1951. Owen Holland had just unearthed Walter's fascinating robot built with two vacuum tubes and a few primitive sensors. The concluding session of this two-week intensive workshop spent a considerable amount of time on the impact of the excavation and the impact of Gray Walter's work which had already incorporated *behavior-based* principles, the very subject the workshop was supposed to examine in depth. Participants asked then, "Have we made any progress since Gray Walter?". Today, several years later, and exactly half a century after the tortoise robot, the question is still valid. In his paper at ER2001, Holland discussed and analysed the classical work in detail, then turned to the question of *consciousness*. Maybe *consciousness* is totally out of the question at this point, or not so far away as we always think. Who knows?

Dario Floreano has been one of the most active among researchers who pursue Evolutionary Robotics through experimentation. He has left a trail of incredibly novel and successful experiments since his very first, and the world's first, experiment on embodied and *in situ* evolution of a physical robot in early 1990s. Recently, he has been focussing on two topics. One is the use of spiking neurons as an element of a robot's autonomy generation mechanism. The other is to use vision inputs as the principal source of sensory signals to robots. Both topics are very welcome selections as we know that spiking aspects of natural neural networks and the dynamism such networks afford play a significant role in generating the intelligence animals require. In artificial neural networks, such a transient aspect of the network's operation is often ignored and networks with a quasi-steady state processing model are routinely used. Floreano's early experiments also assumed such networks. His initial success in spiking neuron circuits reported here is already very encouraging.

It is similarly exciting that Floreano is concentrating on evolving a robot's ability to handle visual inputs as the dominant source of signals from its operational environment. We already know that vision plays a major role in the sensory processing of a vast number of animals. Technology, as well as methodology to implement scientific findings, had not been quite at par in vision processing until recently. He was successful in obtaining some initial results in this area, as reported here. It is reassuring to see these results, particularly knowing that Floreano always places emphasis on less or no interference from human experimenters while conducting his increasingly sophisticated and always lengthy experiments.

Jordan Pollack attacks the issues of co-evolution in order to study minute yet essential interactions between a robot and its environment. To study such phenomena successfully in artificial evolution, both body and its behavior, or "body" and "brain", as in natural systems, need to be co-evolved. According to Pollack, the interaction between such a co-evolved robot and its environment would result in a unique form of self-organization. This theme was originally very effectively demonstrated by Karl Sims in his pioneering co-evolution study done in a virtual world (shown at ER'94). Pollack pushed the concept further to literally create morphologically evolved physical robots coming out of a co-evolution by a clever use of 3D printing technology. Though the process was very

time consuming, he was successful in the automatic manufacturing in plastic of Sims-like creatures and running them after evolving them in virtuality. The success of his experiment drew a lot of attention and was reported in *Nature* in the summer of 2000. Here at ER2001, Pollack discussed his innovation in the backdrop of the recent world-wide push towards creating increasingly more intelligent robots, and critically reviewed the trend towards their acceptability in society, including their economical viability.

When Rodney Brooks participated in the first ER symposium (ER'93), he was still coping with both positive and negative reactions to his Subsumption Architecture of 1986 coming from the real world as well as the research communities. Also he had just started his humanoid project at MIT's Artificial Intelligence Laboratory. His new intelligent robotics company (now called iRobot) had just one year under its belt with only 2.2 employees, 0.2 being Brooks. He was still a few years away from his directorship of the AI Laboratory. Since then, a lot of things have happened. Under his directorship, the 230-researcher AI Laboratory regained liveliness, and his company grew rapidly to become the largest company in the world solely dedicated to intelligent robotics, with 125-plus employees. Many projects involving robots are conducted there for a wide range of real world applications. The survival and growth of his business alone is a testimony, at least in part, to the effectiveness of his theories, most vividly represented by Subsumption Architecture. After chasing *intelligence* for these years, Brooks this time came up with a more fundamental topic, *life*. In a way, *intelligence* itself is an abstraction that our New AI tends to frown upon. The *frame of reference* prejudice could well apply in our effort to seek *intelligence* even though we are very aware of the *problem* and the pitfalls it sets up. Maybe we need to go deeper and investigate what distinguishes *life* from *non-life*, as Brooks pointed out. At ER2001, Brooks discussed the process of finding the "juice" that makes the difference between the two by examining a few primitive biological systems. *Intelligence* surely must be a side effect of a living organism. By focussing our attention on issues beyond *intelligence*, we may eventually see a light at the end of the *intelligence* tunnel.

Inman Harvey, a Sussex computer philosopher, is also a theoretical big wig in the field of Evolutionary Robotics. Jointly with Phil Husbands and David Cliff, he had proposed a new framework to explain evolution, artificial or otherwise, called SAGA (Species Adaptation GAs) in the early 1990s. It was presented at various times in our symposia. Then in 1998, Harvey proposed the concept of Neutral Networks to elaborate events and processes that occur in the course of evolution and most visibly in fitness landscape. At ER2001 Harvey attempted to explain Neutral Networks by linking it to other highly acclaimed research at Sussex by Adrian Thompson on evolvable hardware. SAGA emphasizes the importance of viewing evolution free of the biases we tend to attach to it, so that we can learn more about evolution. The group has been highly critical of much research on computational evolution where researchers casually and almost routinely adopt a notion of "progress", or "optimization" into their evolution. As such, the concept of SAGA renders itself both controversial and philosophical.

With his extensive background in biology and related fields, his current position as head of a laboratory closely related to Birobotics, and his enviable accumulation of experience in transferring his academic achievements to the real world in a large number of projects already conducted with industry, Robert Full is in a unique and excellent position to overview what biologically inspired artificial systems would mean and what their potentials as well as drawbacks are. His paper at ER2001 documented some of his extensive experience and thoughts in very readable form, summarizing points quite effectively for the far less experienced.

That said, his view on natural systems is not as idealizing or romantic as some might wish. He points out a number of shortcomings in design that biological systems must endure, as well as those in the way they are implemented in their legendary and often mythical functionalities. While the engineering approach for example, here juxtaposed against the biological approach, requires a collapse of dimensions and gives up the incredibly rich, complex, and elegant motions of animals, he stressed that biological evolution has created creatures based on a "just good enough" principle. "Organisms are not optimally designed and natural selection is not engineering," he pointed out. Then he talked about some five hundred million species that went extinct because of basic compromises in design and implementation, leaving only a few million, as natural evolution works more "as a tinkerer than engineer." I could not help but feel some philosophical issues cutting in. Reliance on evolutionary process will not necessarily result in design that is better than a human engineer can do, he also stressed. However, it is now widely accepted that a good part of that five hundred million species went extinct since we began mastering greatly more efficient engineering methodologies, to the point of leaving only a few million to go. What happens next? His view, or my interpretation of his view, opposes that of others in the ER community in several ways, making his study a thought-provoking one.

Regardless, his research is unquestionably interesting and entertaining, particularly when it is presented as crisply as at ER2001. He even began describing how biologically inspired robots should be constructed.

After making the Khepera robot available to the world's intelligent robot research community, and then launching K-team as a mechanism to handle the distribution, Francesco Mondada took a turn which puzzled many around him. He could have achieved easily a so-called "commercial success" with his talent and prowess. Instead, he directed and consumed a good part of his resources to satisfy researchers in universities and research institutions. He had been extremely stubborn about this, keeping product quality high to the point of often sacrificing monetary accountability in the conventional business sense. Many failed to understand his intentions, but I was very fortunate to be one of the few who did, at least to a certain degree. In effect, he began an entirely new trend in robotics and robotic business: robots for the betterment of society in the true and ego-less sense of the words, and business for the same purpose. Despite the objections and constraints the reality around him imposed, he immediately demonstrated his excellence in such an unconventional business framework. He

ventured into a few education+entertainment (so called "edutainment") applications. I am reluctant to classify his robots in that category, however, because there is a fundamental difference in the way Mondada plunged into his development and the way he made available the result of his innovation and efforts. Other edutainment and similar robots for the real world are developed and delivered for the direct material gain of the innovator, a common practice in society which culminated in the 20^{th} century. Perhaps my desire to see an idealistic future has clouded my view, but I somehow feel that he was aiming at something a bit more exciting than that, something that is more fit for the 21^{st} century. I sincerely hope you see that too.

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We are also thankful to industrial sponsors that gave us financial support to look after the surprisingly vast logistics, most of which are invisible on the surface.

We are also very thankful to all invited speakers who so generously gave their time to prepare materials so that attendees and other readers can be introduced to this exciting new field in advanced robotics. More importantly, we thank them for gladly accepting our invitation and coming all the way to attend the meetings in Japan. Their attendance gave a unique opportunity to many young researchers in particular: face to face discussion and bouncing of ideas with the world's top researchers in the field of advanced robotics. I am very sure that these were useful in passing on knowledge, experience, and passion to younger generations, as well as to the more seasoned researchers.

We are also thankful to the participants who took the trouble to find sources of financial support or funding and devoted a considerable amount of time to come to Tokyo and spend two days there, either domestically in Japan or from overseas. To some this must have been a major financial burden. We appreciate the courage and effort of those attendees.

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