Chapter II
Bionics:
Learning from "The Born"

Tobias Limberger
TU Darmstadt, Germany

ABSTRACT

In this chapter we will focus on distributed approaches to answer the scalability challenges in ubiquitous computing (UC) with so-called bio-analog algorithms. Based on decentralization via use of autonomous components, these algorithms draw their examples from the realm of biology. Following a motivating introduction to bionics and socionics, we will give an overview of bio-analog algorithms structured as follows. First we will have a look at algorithms based on phenomena found on the organism level of biological systems. Next we will examine algorithms imitating procedures on the cell level, then turn to algorithms inspired by principles found on the molecular level. Finally we will extrapolate bio-analog approaches to data management.

INTRODUCTION

Definition and Classification of Terms

Historically, the term "bionics", a combination of "biology" and "technics", was introduced by Steele (1995) at a 1960 congress in Dayton, Ohio. "Bionics" or "biomimetics" (Greek: bios = life, mimesis = mimicry) covers all approaches to finding solutions to technical problems by imitating nature. Bio-analog computing can be seen as just one field of bionics, and will be the one we will emphasize. Unless stated otherwise, we will therefore simply use the terms "bionics" and "bio-analog computing" as synonyms from now on. Other classifications consider bio-analog computing as strongly related to or as a subarea of fuzzy logic, soft computing, or artificial intelligence. "Socionics" on the other hand investigates political organisms. While it is often considered a scientific field of its own, bee hives and ant colonies are just two obvious examples of overlap with bionics. Therefore, socionics is sometimes also seen as a subarea of bionics.

Scope of this Chapter

The present chapter emphasizes the scalability problems in UC and how to counter them with decentralization and autonomy of components. From our common knowledge, we understand these concepts as approaches to providing components with the capability to form long-lived and highly scalable "composites". In such a "composite" the whole is far more than the sum of its components. Of course, serious studies reveal "decentralization" and "autonomy" to be quite complex and interwoven with other concepts. Nevertheless, they seem to be important for composite formation, suggesting them as promising bionic and socionic approaches for quantum leaps in scalability issues in UC. This is the main motivation for including the present chapter in the book. The reader should be aware, however, that we have to face three pragmatic constraints:

- We will have to introduce basic concepts of bionics as a foundation since we cannot assume them to be prior knowledge of the average reader. Therefore, the chapter has to be rather introductory;
- In order to provide a consistent picture of the field, relevant areas such as neural networks have to be introduced, but their treatment must remain much more superficial than their general importance would suggest;
- In most cases, concepts from biology or society are initially ported to computer science in the form of simulations. These simulations are typically executed on a single computer and compared to traditional computing methods. Therefore, much of what follows will not be recognizable as a scalability approach to distributed computing at first sight. In most cases, we will even have to restrict ourselves to coarse descriptions of how the state of the art can be extended towards solving UC specific issues.

Chapter Structure

In order to structure the contents of this chapter, we have to find a classification of bio-analog computing approaches. Since we identified bio-analog computing as a subarea of bionics, we will have to have a look at bionic approaches first. In fact, the principle of imitation for problem solving is definitely older than the term itself. The first bionic attempts are traceable back to 16th century, when Leonardo da Vinci designed aerofoils inspired by his studies of birds.

In doing so, da Vinci followed the *constructive approach* to bionics. He first identified biological paradigms, and then transferred them to technical domains in order to look for appropriate fields of application. That means that the constructive approach (also called bottom-up or abstraction bionics) seeks to first understand known natural methods in order to apply them to technical problems later on.

The *analytic approach* instead starts from problems in technical domains. It searches for feasible paradigms in nature in order to identify their essential features and use them to build a solution. So the analytic approach (also called top-down or analogy bionics) identifies known similarities in problems of both domains in order to get inspiration for solving the technical ones.

Since we are looking for alternatives to solve the scalability problems in UC, we start from a defined set of problem constraints. Therefore we will follow the analytic approach by looking for similarities in natural information handling. Basically, UC scalability problems stem from the limited capacities of devices regarding memory, computing power, communication range, and so forth. These in turn result from demand for characteristics such as small size, unobtrusiveness, low price, and so on. Solutions are typically based on countering these limitations by distributing algorithms over numerous devices.

Highly distributed concepts for information handling on the other hand can be found in