Chapter 1

Introduction

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The core area of research in the Neural Networks Research Centre is neurocomputing. We have traditions dating back to late 1960's in some areas like associative memories, learning algorithms, and self-organization, as well as related methods in pattern recognition.

By the early 2000's, the field of neurocomputing has experienced considerable changes compared to its pioneering days. Most of the early artificial neural network models, now classics in the field, were strongly motivated by insights from neurobiology. Even today, there is a strong research effort in biologically motivated neural models and computational neuroscience, but aside from this, part of the field has developed into computational science and engineering that has very few, if any, connections to biology. These two directions, that of neuroscience and that of computational science, have largely diverged and found their own research societies. The computational methods have merged with other related fields like advanced statistics, pattern recognition, signal and data analysis, machine learning, and artificial intelligence.

In such a situation, it may be difficult to define what neurocomputing really means. The way we understand it is that we build *empirical data based models of complex systems*. Natural data has properties such as nonlinearity, nongaussianity, and dynamic interactions that have not been taken into account in classical multivariate statistics. Therefore, such models must be based on new information processing principles. The new insight is that although the models are not available in closed form, the intrinsic features of the observations and their mutual interrelations can be *learned* from the data using a great number of simultaneously co-operating simple processing units or operations. This is in analogy with the operating principles of the biological neural systems.

In the Neural Networks Research Centre, we develop such models, study their theoretical properties, and apply them to problems in signal, image, and data analysis. All the work is based on the core expertise stemming from our own scientific inventions. The most classic of these are the Self-Organizing Map (SOM), introduced by Prof. Kohonen in early 1980's, and new learning algorithms for Principal/Independent Component Analysis which have been intensively studied in the 1990's. Both have been thoroughly covered in a large number of articles and books and have been extensively cited – the SOM method alone has been used in more than 4400 scientific works. Our present research largely builds on these methods.

Our focus is to create and maintain research groups with internationally recognized status. Figure 1 is a concise description of our internal project organization at the moment. The Research Unit consists of 3 major research groups, each having a number of

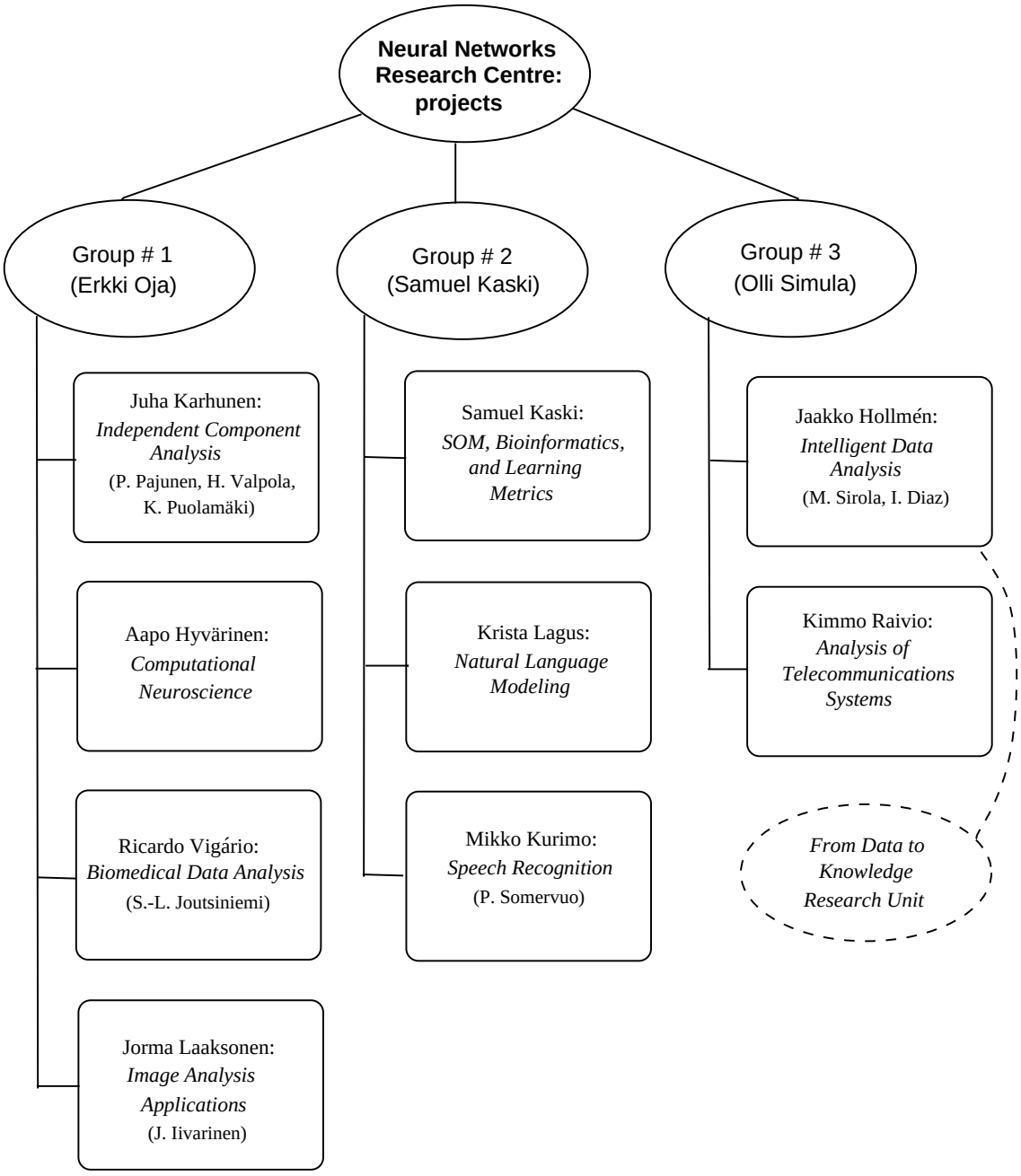

Figure 1.1: The Neural Networks Research Centre consists of three major groups, each having a number of smaller project groups. The leader of each group and the research topic are marked within each box, as well as the names of the post-doctoral researchers within each project. The dotted line indicates co-operation with the other Center of Excellence in the CIS laboratory.

projects. Typically, these project groups consist of senior researchers, graduate students, and undergraduate students. This kind of organizational chart necessarily gives a very strict and frozen view of the research activities. The topics of the projects are heavily overlapping and there is a continuous exchange of ideas and sometimes researchers between the projects. In the following Chapters, all of these projects are covered in detail. There are also some quite new research initiatives that do not fit under any of the projects;

at the end of this report, there is a separate Chapter for the other research done in our Centre.

Additional information including demos etc. is available from our Web pages, `www.cis.hut.fi/research`.