Chapter 1

Introduction

The core area of research in the Neural Networks Research Centre (1994 - 2005) has been 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 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. Some work along those lines has been conducted in our laboratory, too.

However, aside from this, another part of the field has developed into purely 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. Prompted by some urgent new problems in information sciences, the computational methods have merged with other related fields like advanced statistics, pattern recognition, signal and data analysis, machine learning, and artificial intelligence, to a new field sometimes termed *statistical machine learning*. This is the major research area in our research today. Also the range of application fields has grown from pattern recognition and control to cover many new disciplines such as bioinformatics, neuroinformatics, and multimedia data analysis. To better emphasize this paradigm change, the name of our research unit was changed to "Adaptive Informatics Research Centre" as of January 1, 2006.

Pattern analysis and statistical machine learning are the central tools for structuring raw information, which needs to be filtered and restructured before it becomes usable. Techniques that can quickly analyze complex patterns and adapt to new data will be indispensable for maintaining a competitive edge in information-intensive applications. The basic scientific problem is to build empirical models of complex systems, based on natural or real-world data. The goal is to understand better the underlying phenomena, structures, and patterns buried in the large or huge data sets. Real-world data means e.g. images, sounds, speech, or measurements, contrary to symbolic data like text. However, today the statistical machine learning methods are migrating into the analysis of symbolic data, too, such as large text collections, Web pages, or genomic sequence data, exhibiting real-world complexities and ambiguities. If the datasets are large enough, even the symbolic data can in many cases be analyzed with statistical methods, complementing the conventional string processing or grammar-based algorithms.

Natural data has properties such as nonlinearity, nongaussianity, and complex interactions that have not been taken into account in classical multivariate statistics. Therefore, such models must be based on new information processing principles. In our approach, the intrinsic latent features or components of the observations, and their mutual interrelations, are learned from the data using automated machine learning methods. In this way, we build data-driven statistical models of the complex systems and structures that underlie natural or real-world data. The goal is to understand better the underlying phenomena, structures, and patterns buried in the large or huge data sets, in order to make the information usable.

In the Neural Networks Research Centre and its successor Adaptive Informatics 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. Our present research largely builds on these methods.

Our focus is to create and maintain research groups with internationally recognized status. Figure 1.1 is a concise description of our internal project organization during 2004 - 2005. The Research Unit consisted of 3 major research groups, each having a number of projects. Typically, these project groups consist of senior researchers, graduate students, and undergraduate students. The number of doctor-level researchers in the NNRC (Dec. 2005) was 20, and of full-time graduate student researchers 34. 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.

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

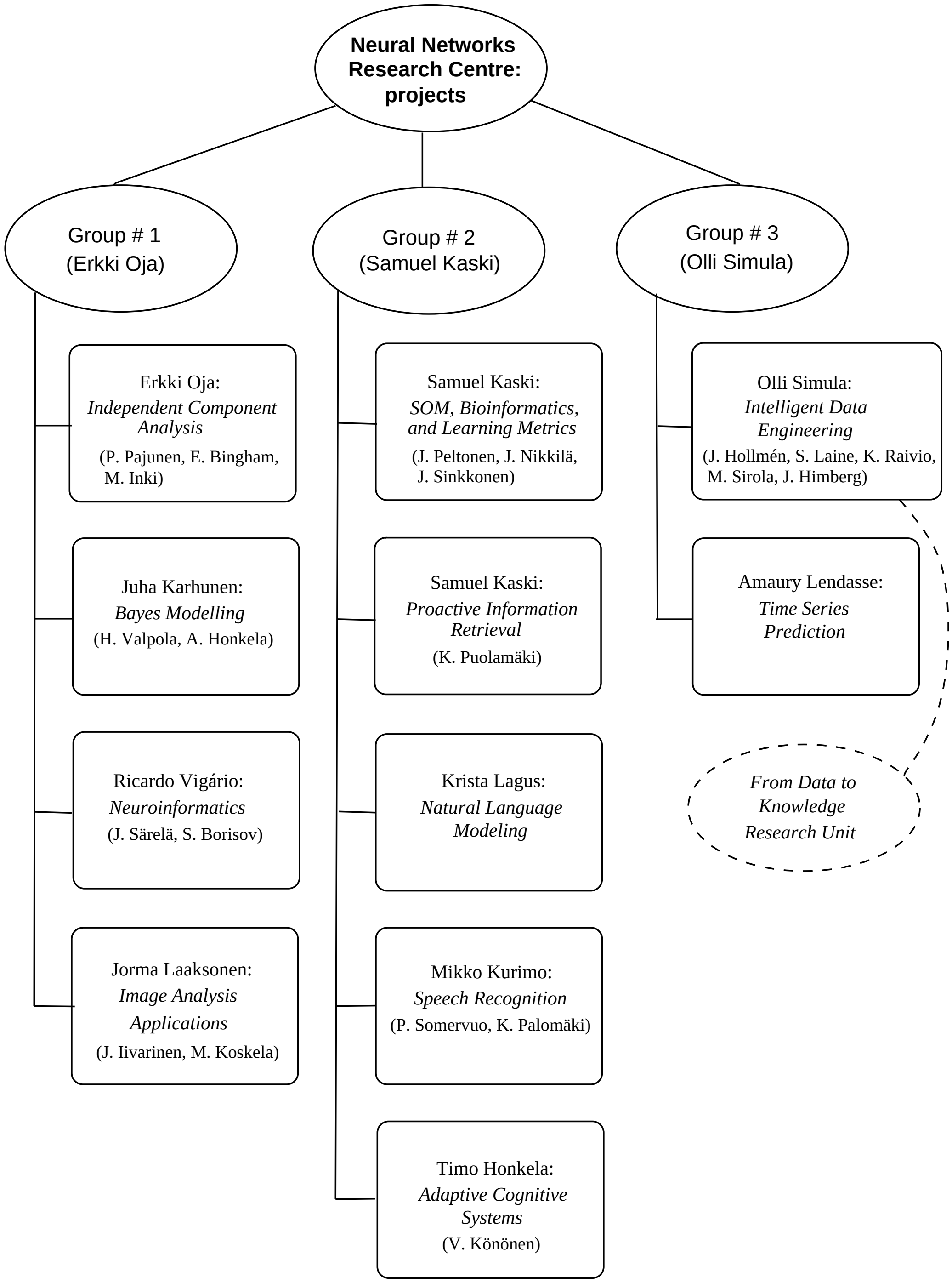

Figure 1.1: The Neural Networks Research Centre in 2004 - 2005 consisted of three major groups, each having a number of smaller project groups. The leader of each group and the research topic are marked within each box, as well as the names of the post-doctoral researchers within each project. The dotted line indicates co-operation with the other Center of Excellence in the CIS laboratory.