48 Learning and Intelligent Image and Signal Analysis

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The rapidly developing fields of neurocomputing and fuzzy logic, often combined under the term "computational intelligence" or "learning and intelligent systems", have proved their efficiency in a number of practical, hard real-world problems. Especially, signal processing, image analysis, pattern recognition, control, and fault diagnosis are the most central application fields of artificial neural networks and fuzzy systems in industry. This was one of the applications fields chosen in the national technology program "Adaptive and intelligent systems applications", launched by the Finnish Technology Development Centre (TEKES) in 1994.

The research activities in this field were collected under the multi-partner project "Learning and Intelligent Image and Signal Analysis" (LIISA), started in 1995 and ending in February 1998. The LIISA consortium was composed of university and VTT laboratories, selected for their proven ability in solving real world signal and image processing problems by neural and fuzzy techniques and in the formalization of the theoretical aspects in research; and industrial companies, selected for their experience in application development using the modern methodologies, and also for their knowledge of up-to-date industrial needs and capacities for offering challenging practical problems for piloting cases.

The LIISA project group was relatively large, consisting of *12 research laboratories* and *15 Finnish companies* in the fields of electronics, instrumentation, telecommunications, pulp and paper, steel manufacturing, and marketing. For this reason, and also because of the constraints set by the participating companies, it was divided in four *subprojects* (the main responsible university shown in brackets):

- Adaptive image analysis (Helsinki U. Tech.)
- Neuro-fuzzy systems (Tampere U. Tech.)
- Intelligent signal analysis and the required component technology (Oulu U.)
- Sensus - intelligent utilization of sensors by neural computing (Lappeenranta U. Tech.).

The major research partners were Helsinki University of Technology (Laboratory of Computer and Information Science), Tampere University of Technology, Lappeenranta University of Technology, and Oulu University. The responsible leader of the project was E. Oja from Helsinki University of Technology.

The project applied *neurocomputing and fuzzy logic in the estimation, preprocessing, detection, and classification of images and signals.* Typical applications were in industrial fault diagnosis and classification. In most cases, the measurement data was obtained from the industrial partners, and depending on the problem, this data was preprocessed and analyzed using neurocomputing and fuzzy logic tools. Because image and signal analysis is typically very application-oriented, the specific pre- and postprocessing algorithms had to be adapted to the problem. The generic neural and fuzzy computing tools that were used throughout the project were the Self-Organizing Map (SOM) and the Learning Vector Quantization (LVQ) classifier, developed at Helsinki University of Technology by prof. T. Kohonen; the Principal Component Analysis (PCA) and Partial Least Squares (PLS) preprocessing methods and the related Averaged Learning Subspace Method (ALSM) classifier; the Multi-Layer Perceptron (MLP) and the Radial Basis Function (RBF) neural classifiers; and fuzzy logic including the trainable ANFIS neuro-fuzzy model. In the use and development of all these neural and fuzzy computing methods, the participating research groups have a long tradition. Thus also good quality software was already available in the laboratories, which helped in the fast start-up of the pilot projects. Some pilot cases concentrated on hardware implementations. It is characteristic of the applications of real time image and signal processing that the computational requirements are very high. Some applications will be impossible without dedicated hardware, either based on VLSI or signal processors. Especially in the subproject on Neuro-fuzzy systems, there was a special task on developing a neural computer for industrial purposes, not only for the LIISA project but for the whole TEKES technology program.

As for the *main results*, working pilot applications were realized in all the subprojects to give guidelines to the companies for further development. The research phase terminated officially in February 1998, and the project has now entered a phase in which the companies are integrating the results into their own solution methods. Several product development projects are under way in the participating companies. Research experience in the field was an important criterion for choosing the university partners, and one important output of the project were also the numerous research papers in journals and conferences. In addition to the research papers, several internal reports have been written within the project, and Ph. D. and M.Sc. theses have been completed on the results. In our research group, two doctoral degrees were attained within this project: Dr. Jorma Laaksonen in 1997 and Dr. Jukka Iivarinen in 1998. Detailed reports on the substance of this research are given as separate Sections in this report.

Starting in March 1998, a continuation of this consortium project was launched, the IMPRESS project (Intelligent Methods for Processing and Exploration of Signals and Systems). The total budget is about 11 million FIM and there are 17 companies involved. Our laboratory is involved in this research effort in several tasks, like on-line character recognition, fault analysis of a running paper web, and process monitoring and modelling using the SOM. There are reports on all of these activities in separate Sections.