Bibliometric mapping as a science policy and research management tool
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7 Actor Analysis in Neural Network Research: The Position of Germany*

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Actor Analysis in Neural Network Research: The Position of Germany

Abstract

In this paper the results of a bibliometric study of neural network research are presented. This evaluative study includes bibliometric mapping and actor analysis of main players in the field on a macro level (countries, in particular Germany), and, on a lower level, of the main players in Germany. We found that Germany is among the leading countries in the field. This study, together with Noyons and Van Raan (1998), is also a blueprint for evaluative bibliometric studies of emerging or strongly developing science and technology fields. The monitoring of major developments in the field, and a detailed actor analysis were integrated into one study.

7.1 Introduction

This paper is a follow-up of Noyons and Van Raan (1998), in which we proposed a method to structure bibliographic data in order to evaluate a scientific field. In the present paper, we discuss the results of such a quantitative study.

The objectives of the study are (a) to generate an overview of the main and, in particular, the recent developments in the field, and (b) to identify and position the main German actors. The field under study is neural network research.

In our attempt to combine these two objectives, we found that they are in fact conflicting. The first requires that the structure is generated continuously each year, month, or whatever time unit. The changes in the structure from year to year are considered to represent cognitive processes going on in the field.

The second objective requires that the structure of the field remains unchanged during the whole period studied, in order to have some stability in the comparison of one year with another. More specifically, we want to compare the activity of actors from year to year. If the structure of the field differs for each year, so will the definition of the sub-domains. This makes it almost impossible to compare an actor's activity in year t with its activity in year $t+1$. Thus, we will not be able to determine whether the activity of an actor actually has increased in a particular sub-domain (see, for instance, Katz and Hicks 1995).

This paradox is addressed by adjusting the interpretation of the concept 'field dynamics'. The field dynamics we investigate, is restricted to the evolution of the sub-domains in a quantitative sense, and to the way they form a joint structure during the studied period. This structure is analyzed on the basis of a two-dimensional representation (a bibliometric map based on co-classification code analysis). The definition of the sub-domains (sets of classification codes) remains unchanged over the whole period of time. By 'zooming' into the individual sub-domains with co-word maps from year to year, we are able to monitor the dynamics on a smaller scale.

We let the bibliographic data itself generate the structure of the field ('self-organized mapping'). The question is: what data will we use to achieve this. In our foregoing paper (Noyons and Van Raan, 1998), we suggested that there are three options:

- Data of the whole period;
- Data from the first year of the period ('the past');
- Data from the last year of the period ('the present').

In this previous paper, we concluded that, for the kind of studies we are concerned with here, the latter is the best. Thus, the structure of the field (i.e., the definition of sub-domains in the field) was (and is) determined by the most recent data (the present). One of the crucial arguments for this choice is found in the application of bibliometric field structures for actor analysis. The activity of actors (countries, organizations, firms, and so on) within the present structure shows the actual, recent situation. If we take this present situation of a field as a starting point, and look at the activity of authors in the past 'based on the present', it will tell us something about the 'activity history' of those actors in relation to the most recent situation. For instance, if country A is very active in a sub-domain which has become important only recently (and not visible in the structure of five years ago), and if A was already active in this sub-domain five years ago, we conclude that A has been on this 'successful' track all along. If, however, the present structure is 'derived from the past' data, this sub-domain will probably not be identified, so that this remarkable past performance of A will not be recognized.

It should be noted that the proposed method requires that the structure of the field (identification of sub-domains) must be revised every year, because it must be based on the *present* data. As a consequence, this structure (sub-domain definition) used to evaluate the 'past' is adjusted as well, so that the past performance will be viewed from a new perspective each time the structure is 'updated'.

7.2 Method

The field neural network research is represented by all publications in INSPEC (1989-1993) containing the truncated term "NEURAL NET" in any bibliographic field (title, abstract, controlled terms, uncontrolled terms or classification codes). We found in total 21,437 publications. By using the INSPEC database, we restrict ourselves to the physics and computer-engineering-related research of neural networks.

We identified 18 sub-domains of the field by determining clusters of the most important (that is, the most frequent) classification codes attached to the publications. These clusters were determined by cluster analysis applied to the co-occurrence matrix of 90 selected classification codes (see Noyons and Van Raan 1998). The definition of the 18 sub-domains is given in Table 7–1.

Table 7–1 Definition of 18 sub-domains in neural network research by classification codes (1992/1993)

Cluster number	*Number of pubs*	*Classif. Code*	*INSPEC Code Description*
1	967	B6140C	Information/communication theory; Optical information and image processing
1	6130	C1230D	System theory & cybernetics; Neural nets
1	1474	C1240	System theory & cybernetics; Adaptive system theory
1	1539	C1250	System theory & cybernetics; Pattern recognition
1	1289	C5260B	Computer vision and picture processing
1	4728	C5290	Neural computing techniques
2	91	A8732S	Psychophysics of vision, visual perception, binocular vision
2	176	B6120B	Information theory; Modulation methods; Codes
2	330	B6130	Information/communication theory; Speech analysis and processing techniques
2	270	C1220	System theory & cybernetics; Simulation, modelling and identification
2	109	C1330	Optimal control
2	249	C1340K	Nonlinear systems
2	236	C4130	Interpolation and function approximation
2	81	C7120	Computer applications; Finance
2	105	C7410D	Electronic engineering
3	145	A8730E	External and internal data communications, nerve conduction and synaptic transmission
3	122	A8770E	Diagnostic methods and instrumentation
3	87	C4220	Automata theory
3	99	C4240	Programming and algorithm theory
3	362	C7410B	Power engineering
3	613	C7420	Control engineering
3	90	C7440	Civil and mechanical engineering
4	161	B1285	Analogue processing circuits
4	628	C1290L	Application of systems theory; Biology and medicine
4	155	C3120C	Spatial variables
4	395	C7330	Computer applications; Biology and medicine
4	64	C7450	Chemical engineering
4	67	C7460	Aerospace engineering
5	157	B0260	Mathematical techniques; Optimisation techniques
5	62	B1265F	Microprocessors and microcomputers
5	827	B1295	Electronic circuits; Neural nets
5	89	C5160	Computer hardware; Analogue circuits
5	597	C5190	Computer hardware; Neural net devices
5	73	C7310	Computer applications; Mathematics
5	158	C7480	Production engineering
6	363	A8710	General, theoretical, and mathematical biophysics

Cluster number	*Number of pubs*	*Classif. Code*	*INSPEC Code Description*
6	134	B4120	Optical storage and retrieval
6	361	B4180	Optical logic devices and optical computing techniques
6	121	B4350	Holography
6	62	C1110	Algebra
6	131	C4240P	Parallel programming and algorithm theory
6	353	C5340	Associative storage
6	70	C6180N	Computer software; Natural language processing
7	83	A4230S	Optical information; Pattern recognition
7	238	C1230	System theory & cybernetics; Artificial intelligence
7	417	C4210	Formal logic
7	768	C6170	Computer software; Expert systems
8	297	C1160	Combinatorial mathematics
8	712	C1180	Mathematical techniques; Optimisation techniques
8	150	C3340H	Electric systems
9	89	A8730C	Biophysics; Electrical activity
9	70	B4270	Integrated optoelectronics
9	79	B7510B	Biomedical engineering; Radiation and radioactivity applications
9	395	C3390	Robotics
9	189	C7320	Computer applications; Physics and Chemistry
9	124	C7410F	Communications
10	317	B6140	Information/communication theory; Signal processing and detection
10	440	C1260	Information theory
10	173	C1310	Analysis and synthesis methods
10	278	C5260	Digital signal processing
11	283	C1250C	Speech recognition
11	78	C1340B	Multivariable systems
11	320	C1340E	Self adjusting systems
11	184	C5260S	Speech processing
11	98	C7430	Computer engineering
11	70	C7470	Nuclear engineering
12	159	B2570D	CMOS integrated circuits
12	159	B8110B	Power system management, operation and economics
12	379	C5270	Optical computing techniques
13	73	A8728	Bioelectricity
13	95	B7210B	Automatic test and measurement systems
13	273	C5220P	Computer hardware; Parallel architecture
13	66	C6130B	Computer software; Graphics techniques
13	101	C7340	Computer applications; Geophysics
14	299	C1140Z	Probability & statistics; Other and miscellaneous
14	132	C5320K	Optical storage
14	99	C5440	Multiprocessor systems and techniques
15	125	A8730	Biophysics of neurophysiological processes
15	63	B1130B	Computer aided circuit analysis and design
15	145	B2570	Semiconductor integrated circuits
15	107	C1320	Stability
16	94	B0240Z	Probability & statistics; Other and miscellaneous
16	68	B8110D	Power system planning and layout

Cluster number	*Number of pubs*	*Classif. Code*	*INSPEC Code Description*
16	74	C6185	Simulation techniques
16	106	C7410H	Instrumentation
17	235	C1250B	Character recognition
17	75	C5530	Pattern recognition and computer vision equipment
18	102	A8732E	Physiology of the eye
18	81	A9385	Instrumentation and techniques for geophysical, hydrospheric and lower atmosphere research
18	80	C5585	Speech recognition and synthesis

By using this scheme, we divided the neural network publications over 18 sub-domains. Thus, each sub-domain is represented by a set of publications. A publication can be assigned to more than one sub-domain. Each sub-domains was labeled with a name, referring to most frequent classification codes. An overview of numbers of publications included per sub-domain per two-year block (overlapping two-year blocks within the period 1989 to 1993) is given in Table 7–2.

Table 7–2 Numbers of publication per sub-domain by year (1989-1993) in neural network research

Cluster number	*1989/ 1990*	*1990/ 1991*	*1991/ 1992*	*1992/ 1993*	*Sub-domain label*
1	2756	5836	8987	9190	NN-general
2	684	1159	1527	1508	Non-linear Systems
3	630	943	1248	1482	Control Engineering
4	934	1253	1463	1441	Biology & Medicine
5	335	924	1438	1329	NN devices
6	543	943	1280	1321	Optical NN
7	4297	3918	1931	1291	Expert Systems
8	465	739	973	1111	Optimisation
9	512	727	894	953	Robotics
10	477	851	1009	922	Signal Processing/Information Theory
11	614	907	1027	917	Self-adjusting Systems
12	378	480	600	696	Optical Computing Techniques
13	181	410	576	612	Parallel Architecture/Geophysics
14	394	534	586	547	Probability & Statistics
15	307	446	498	425	Circuit Design
16	90	203	295	353	Instrumentation
17	144	265	336	291	Character recognition
18	213	268	275	263	Vision
Total	5907	8841	10778	10439	

Subsequently, we counted the number of publications per country. A publication was assigned to a country on the basis the address of the *first* author[10]. The results per country by sub-domain were used to characterize the research profile of the most active countries in the field. For this purpose we used the 'activity index' (see Engelsman and Van Raan 1993, Noyons *et al*, 1994). This index normalizes the number of publications per country by sub-domain, to the activity of that country in the whole field, with a further normalization to the same ratio worldwide. A range of scores in the 18 sub-domains characterizes a country's activity in the field with respect to focus of attention ('preference').

The sub-domains, defined by clusters of classification codes, were monitored with respect to the joint structure they formed together during the period 1989 to 1993. This was done in the following way. We calculated the number of publications each sub-domain had in common with the others. The resulting co-occurrence matrix was input for multidimensional scaling (MDS). We constructed a map of the situation in 1992/1993, and another for 1989/1990. The differences between the two maps will give indications about the dynamics of the field on a 'macro scale'.

Next, we constructed 'fine-structure' maps of the sub-domains. The most frequent key-words were selected per sub-domain and used for co-word analysis. We constructed a map for the 'present' (1992/1993) and the 'past' (1989/1990). Moreover, we identified the 'hot' topics (words with a significantly higher frequency in the 'present' than in the 'past'), and the 'cooled-down' topics. Finally, we generated an overview of the most active German institutions by sub-domain.

7.3 Results

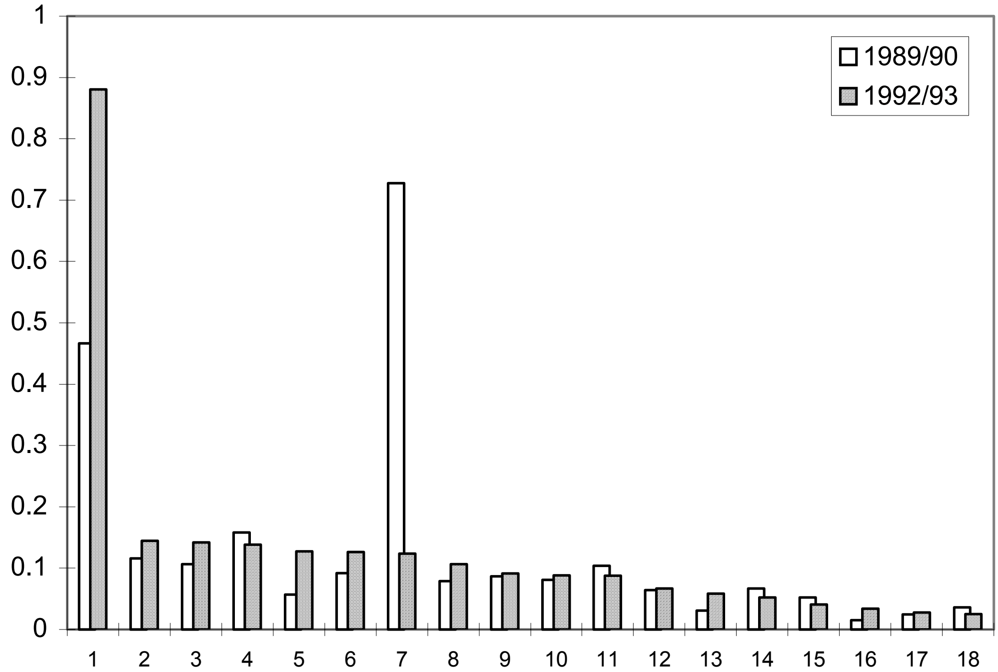
Neural network research has already been the subject of several studies (Debackere and Rappa, 1994; McCain and Whitney, 1994). This attractiveness is due to the interdisciplinary and relatively new character of the field and, most importantly, its strong growth and expanding application potentials. McCain and Whitney (1994) demonstrated what kinds of problems are encountered when exploring such a field. One of the main problems is that there are only a few accepted notions of the structure of the field: it is difficult to obtain an extensive overview of the main sub-domains.

The strength of our method is that it does not depend on these accepted notions. In fact, we let the bibliographic data generate its own structure of the field. We analyze its dynamics by the monitoring the evolution of the separate sub-domains and the relations among them.

We discuss in this paper the trends in neural network research only with respect to the size (numbers of publications) from 1989 to 1993. For other aspects (such as the

[10] Note that in the INSPEC database only the affiliation of the *first* author is included.

structural evolution of the field, that is, the relations of the sub-domains among each other) we refer to our foregoing article (Noyons and Van Raan, 1998). The 'size' of a sub-domain in a two-year period was determined by the proportion of publications included in that sub-domain in relation to the total number of publications in the same two-year period for the whole field. In Figure 7-1, these 'relative sizes' of the 18 sub-domains in 1989/1990 and in 1992/1993 are plotted.



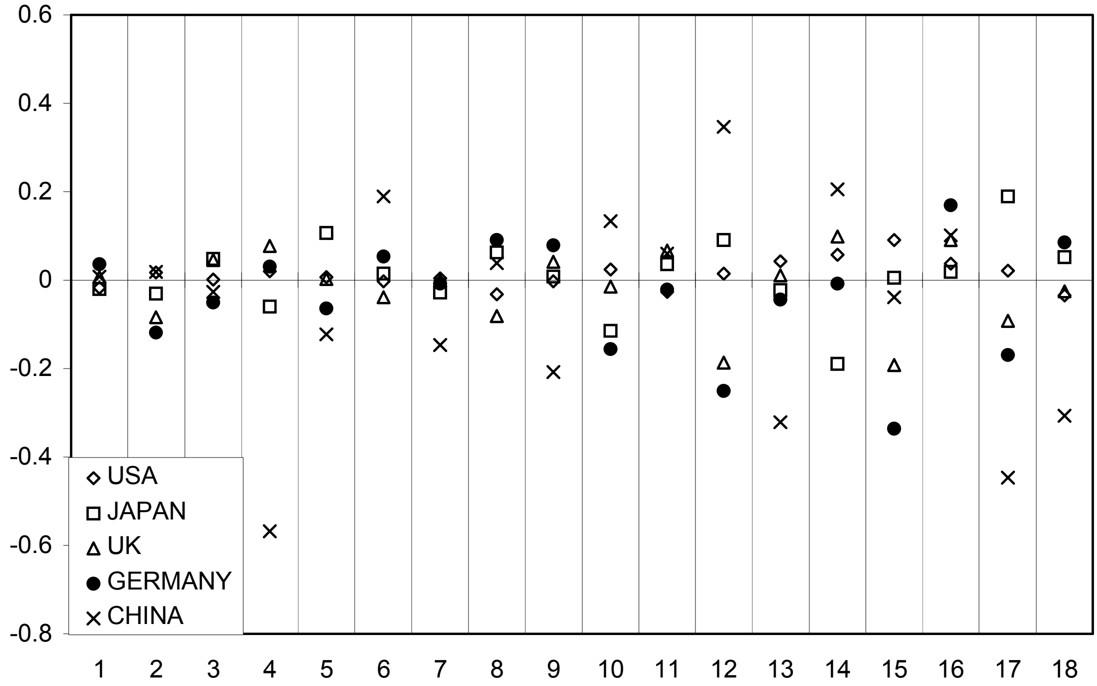
Sub-domains

1	NN-general	10	Signal Processing/Information Theory
2	Non-linear Systems	11	Self-adjusting Systems
3	Control Engineering	12	Optical Computing Techniques
4	Biology & Medicine	13	Parallel Architecture/Geophysics
5	NN devices	14	Probability & Statistics
6	Optical NN	15	Circuit Design
7	Expert Systems	16	Instrumentation
8	Optimisation	17	Character recognition
9	Robotics	18	Vision

Figure 7-1 Size of the 18 neural network research sub-domains in 1989/1990 and 1992/1993

We observed a significant *increase* of activity in sub-domain 1 (NN-general), 5 (NN devices), 13 (Parallel Architecture/Geophysics), and 16 (Instrumentation). A dramatic *decrease* of activity was observed in sub-domain 7 (Expert Systems). As pointed out in Noyons and Van Raan (1998), the 'shift of activity' from 7 to 1 and 5, is merely due to adjustments in the classification scheme of INSPEC. So, in fact, it is an artifact, based on 'jargon change'.

First, we give an overview of the activity profile of the most active countries in neural network research. For the most recent period of time in our study (1992/1993), the results for the five most active countries are given in Figure 7-2.



Sub-domains

1	NN-general	10	Signal Processing/Information Theory
2	Non-linear Systems	11	Self-adjusting Systems
3	Control Engineering	12	Optical Computing Techniques
4	Biology & Medicine	13	Parallel Architecture/Geophysics
5	NN devices	14	Probability & Statistics
6	Optical NN	15	Circuit Design
7	Expert Systems	16	Instrumentation
8	Optimisation	17	Character recognition
9	Robotics	18	Vision

Figure 7-2 Activity Index in 1992/1993 for 5 most active countries in neural network research

We found that Germany was in this 'top' five in the whole period studied. The figure illustrates where a country puts its emphases, in relation to the activity of all other countries. Of course, the calculated activity indices are subject to (statistical) error.

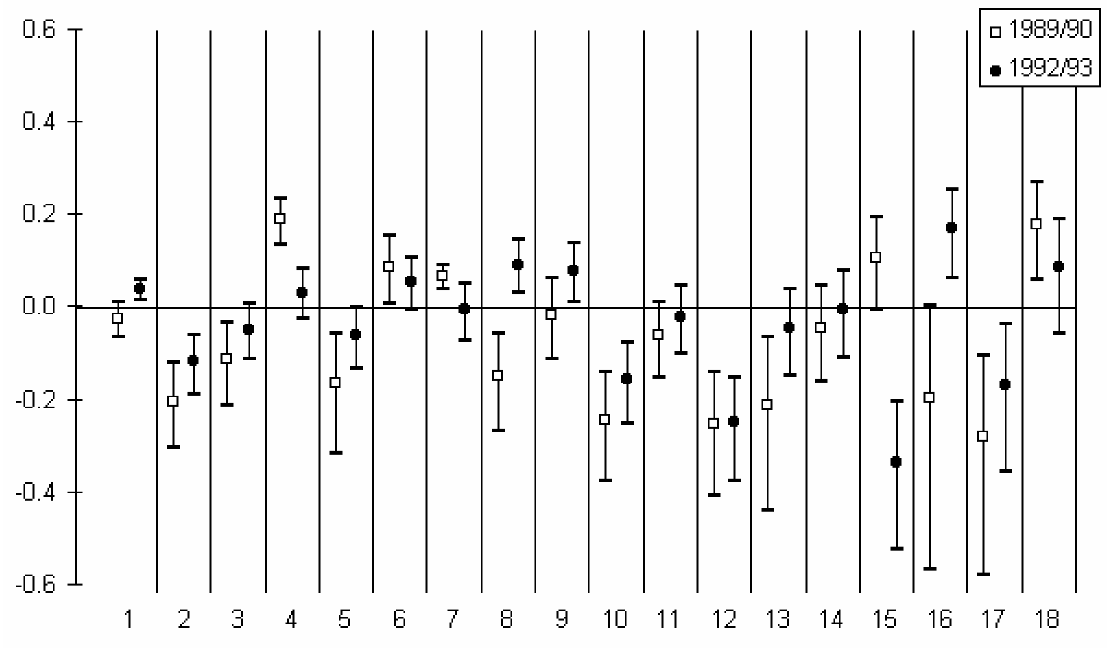
For the sake of clarity, we leave error-bars out of this figure (they will, however, be used in the other figures).

China has an activity profile that differs substantially from that of the other countries. For instance, in sub-domain 4 (Biology & Medicine) the Chinese activity is far below (worldwide) the average, whereas the activity in this sub-domain of the other four countries is around average. In sub-domain 12 (Optical computing techniques), China's activity is well above average, while for the United Kingdom and, more significantly, for Germany it is below.

For Germany, we found an activity around average in almost all sub-domains. This is to be expected for a country with a large scientific production. The activity profile of a country is calculated in relation to the worldwide activity profile. Obviously, countries with a large publication output determine to a great extent the worldwide profile. Only in sub-domain 12 (Optical computing techniques), and even more clearly in 15 (Circuit design), the German activity was below world average.

In Figure 7-3, the activity profile of Germany is monitored for two periods: 1989/1990 and 1992/1993. This shows how German neural network researchers adjusted their scope during the period under study. The numerical values for Germany in 1989/1990 and 1992/1993 are presented with error bars. They were calculated under the assumption of a Poisson-distribution in order to have a first, but reasonable approximation of the statistics[11]. Only if the two data points of a sub-domain have no overlap in error range, they are considered significant.

[11] See also Engelsman and Van Raan (1990) A standard error for the absolute number of publications for Germany in both years was calculated by a relatively simple approximation: the square root of n, divided by n; n is the number of publications by Germany in a sub-domain. For the two extremes the activity index was determined and added to the figure.



Sub-domains			
1	NN-general	10	Signal Processing/Information Theory
2	Non-linear Systems	11	Self-adjusting Systems
3	Control Engineering	12	Optical Computing Techniques
4	Biology & Medicine	13	Parallel Architecture/Geophysics
5	NN devices	14	Probability & Statistics
6	Optical NN	15	Circuit Design
7	Expert Systems	16	Instrumentation
8	Optimisation	17	Character recognition
9	Robotics	18	Vision

Figure 7-3 Neural network research profile for Germany in 1989/1990 and 1992/1993

The figure shows striking changes in German activity characteristics. Particularly in sub-domain 16 (Instrumentation), the activity increased from below to above average. In absolute numbers the German activity increased from 3 to 21 publications, while the overall activity in this sub-domain increases from 90 to 353. As a result, we found that the Germany activity in this sub-domain has caught up with the overall (worldwide) trend. In sub-domain 15 (Circuit design), the trend was in the reversed direction. The worldwide declining activity in this sub-domain (see Figure 7-1), was also observed in the German activity (from 20 to 8 publications). We observe an increase of German activity in 8 (Optimisation), again similar to the overall trend of increasing activity. Finally, the unchanged low German activity in 12 (Optical computing techniques) is in contrast with the strikingly high Chinese activity in this sub-domain.

Optimisation

As an example of a more detailed actor-activity analysis, we 'zoomed' into sub-domain 8 (Optimisation). The map is constructed on the basis of co-occurrences of the most important (frequent) keywords (descriptors, controlled terms) in the publications belonging to this sub-domain in 1992/1993. For details, we refer to our foregoing paper Noyons and Van Raan (1998). The keywords were plotted into two dimensions by multidimensional scaling (MDS). Within these two dimensions, MDS yields a position for each mapped word, taking into account all relations (number of co-occurrences) this word has with all other words, as well as all relations the other words have with each other. The lines indicate relations between two individual words with a strong pair-wise relation (Salton index > 0.3).

Furthermore, we added 'map-external' information about the words which was not covered by the co-occurrence structure (that is, the position of the words in the map). Three kinds of information were added:

- *Central* topics in the sub-domain (words occurring in more than 10% of the publications) are printed in uppercase and bold face;
- Topics that show a *growing* interest of researchers in 1992/1993 compared with 1989/1990 (that is, the proportion of publications on the topic increased by more than 2%) appear with a '(+)' in the map, and topics showing a *decreasing* interest (of 2% or more) appear with a '(-)';
- Topics for which we found *no German activity* (no German publications) are underlined.

Looking for general trends in the sub-domain 'optimisation', we find two patterns on the map: the central/left side covering topics with a stable or decreasing interest, and the right/upper side covering topics with an increasing interest. It appears that more recent mathematical techniques (fuzzy logic, genetic algorithms) took over the leading position of older techniques (combinatorial mathematics). It should also be noted that some of the trends are in fact 'artificial' because the 'jargon' of the indexed terms was extended. For instance, the topic 'Neural Net' in the center of the map did not, of course, really become less interesting, but this term has been 'replaced' to a substantial extent by other, more specific terms (such as Hopfield NN, Recurrent NN).

Germany was active in almost all topics in this sub-domain. Still, there are four topics with an increasing worldwide interest, all in the same area (central right-hand side) of the map, for which no German activity was found: control system synthesis, non-linear control systems, machine control, and power system stability.

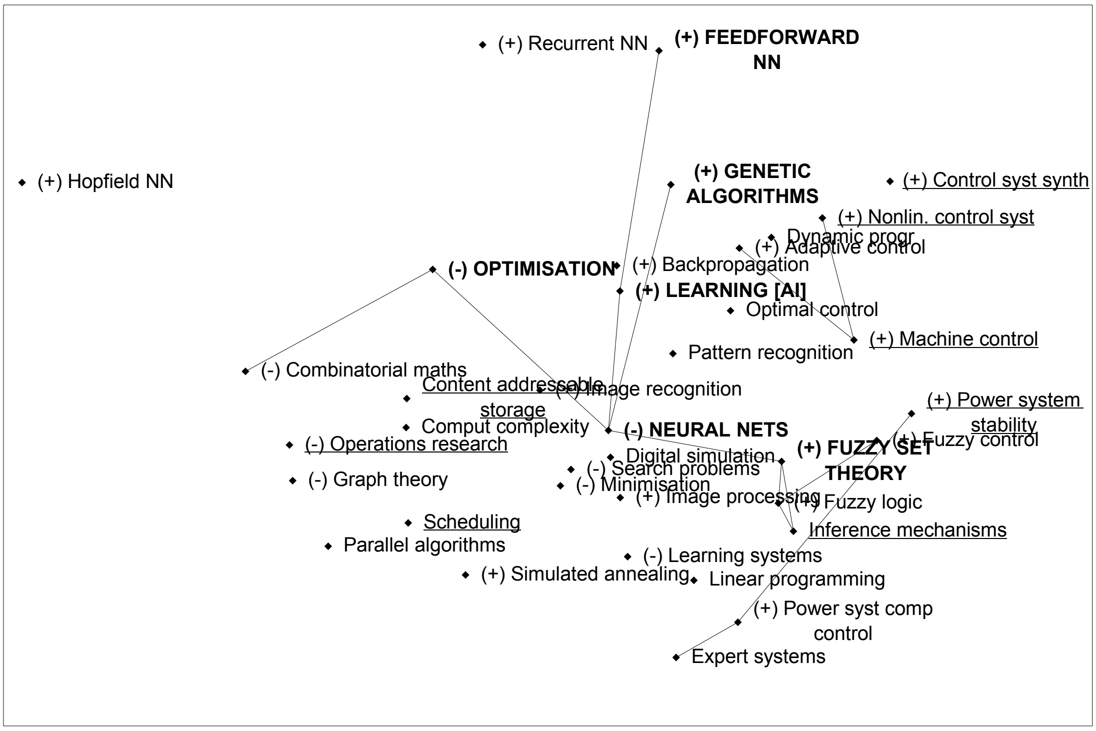


Figure 7-4 Fine structure map of sub-domain 8 (Optimisation) in 1992/1993

German actors' frequency of publication

In Table 7–3, the most frequently publishing German actors (with more than 2%) are listed by sub-domain. The number of publications in 1992/1993 are given, and their share related to all German publications in that particular sub-domain.

Table 7–3 Most important German actors by sub-domain in neural network research (1992/1992)

Subd.	*German actor*	*Publs in 92/93*	*% Actor-Germany*
1	TECH-UNIV-MUNICH, MUNICH	33	8.07
1	SIEMENS-AG, MUNICH	25	6.11
1	TECH-UNIV-DARMSTADT, DARMSTADT	21	5.13
1	DORTMUND-UNIV, DORTMUND	17	4.16
1	ERLANGEN-NURNBERG-UNIV, ERLANGEN	17	4.16
1	GER-NAT-RES-CTR-COMP-SCI, ST-AUGUSTIN	16	3.91
1	RUHR-UNIV-BOCHUM, BOCHUM	16	3.91
1	STUTTGART-UNIV, STUTTGART	14	3.42
1	GOTTINGEN-UNIV, GOTTINGEN	13	3.18

Subd.	*German actor*	*Publs in 92/93*	*% Actor-Germany*
1	WURZBURG-UNIV, WURZBURG	13	3.18
1	KARLSRUHE-UNIV, KARLSRUHE	12	2.93
1	PADERBORN-UNIV, PADERBORN	12	2.93
2	GOTTINGEN-UNIV, GOTTINGEN	4	8.51
2	TECH-UNIV-MUNICH, MUNICH	4	8.51
2	TECH-UNIV-DARMSTADT, DARMSTADT	3	6.38
3	SIEMENS-AG, MUNICH	6	11.54
3	DORTMUND-UNIV, DORTMUND	4	7.69
3	TECH-UNIV-DARMSTADT, DARMSTADT	4	7.69
4	TECH-UNIV-MUNICH, MUNICH	10	15.87
4	BIELEFELD-UNIV, BIELEFELD	5	7.94
4	PADERBORN-UNIV, PADERBORN	4	6.35
4	RUHR-UNIV-BOCHUM, BOCHUM	4	6.35
4	MAX-PLANCK-INST-BIOL-CYBERN, TUBINGEN	3	4.76
4	SIEMENS-AG, MUNICH	3	4.76
4	TECH-UNIV-BERLIN, BERLIN	3	4.76
5	TECH-UNIV-MUNICH, MUNICH	10	21.74
5	SIEMENS-AG, MUNICH	7	15.22
5	ERLANGEN-NURNBERG-UNIV, ERLANGEN	3	6.52
5	INST-MICROELECTRON, STUTTGART	3	6.52
5	TECH-UNIV-BERLIN, BERLIN	3	6.52
6	TECH-UNIV-DARMSTADT, DARMSTADT	5	8.20
6	HEIDELBERG-UNIV, HEIDELBERG	4	6.56
6	LEIPZIG-UNIV, LEIPZIG	4	6.56
6	DUSSELDORF-UNIV, DUSSELDORF	3	4.92
6	PADERBORN-UNIV, PADERBORN	3	4.92
6	TECH-UNIV-MUNICH, MUNICH	3	4.92
6	WURZBURG-UNIV, WURZBURG	3	4.92
7	TECH-UNIV-DARMSTADT, DARMSTADT	6	12.50
7	DORTMUND-UNIV, DORTMUND	5	10.42
7	TECH-UNIV-MUNICH, MUNICH	4	8.33
7	GER-NAT-RES-CTR-COMP-SCI, ST-AUGUSTIN	3	6.25
7	INST-MICROELECTRON, STUTTGART	3	6.25
8	TECH-UNIV-MUNICH, MUNICH	8	14.29
8	DORTMUND-UNIV, DORTMUND	4	7.14
8	ERLANGEN-NURNBERG-UNIV, ERLANGEN	4	7.14
8	GER-NAT-RES-CTR-COMP-SCI, ST-AUGUSTIN	3	5.36
8	HEIDELBERG-UNIV, HEIDELBERG	3	5.36
8	KARLSRUHE-UNIV, KARLSRUHE	3	5.36
9	WUPPERTAL-UNIV, WUPPERTAL	4	8.89
9	BIELEFELD-UNIV, BIELEFELD	3	6.67
9	GERMAN-AEROSP-RES-ESTABL, OBERPFAFFENHOFEN	3	6.67
9	KARLSRUHE-UNIV, KARLSRUHE	3	6.67
9	SIEMENS-AG, MUNICH	3	6.67
9	STUTTGART-UNIV, STUTTGART	3	6.67

Subd.	*German actor*	*Publs in 92/93*	*% Actor-Germany*
9	TECH-UNIV-DARMSTADT, DARMSTADT	3	6.67
10	SIEMENS-AG, MUNICH	4	15.38
10	DAIMLER-BENZ-AG, STUTTGART	2	7.69
10	DUSSELDORF-UNIV, DUSSELDORF	2	7.69
10	ERLANGEN-NURNBERG-UNIV, ERLANGEN	2	7.69
10	FRANKFURT-UNIV, FRANKFURT	2	7.69
10	GERMAN-AEROSP-RES-ESTABL, OBERPFAFFENHOFEN	2	7.69
11	KARLSRUHE-UNIV, KARLSRUHE	5	13.89
11	FRANKFURT-UNIV, FRANKFURT	3	8.33
11	PADERBORN-UNIV, PADERBORN	3	8.33
11	STUTTGART-UNIV, STUTTGART	3	8.33
11	GER-NAT-RES-CTR-COMP-SCI, ST-AUGUSTIN	2	5.56
12	DUISBURG-UNIV, DUISBURG	3	18.75
12	ESSEN-UNIV, ESSEN	2	12.50
12	SIEGEN-UNIV, SIEGEN	2	12.50
12	STUTTGART-UNIV, STUTTGART	2	12.50
12	TECH-UNIV-BERLIN, BERLIN	2	12.50
12	TECH-UNIV-MUNICH, MUNICH	2	12.50
13	DORTMUND-UNIV, DORTMUND	3	13.64
13	SIEMENS-AG, MUNICH	3	13.64
13	PADERBORN-UNIV, PADERBORN	2	9.09
13	TECH-UNIV-DARMSTADT, DARMSTADT	2	9.09
13	TECH-UNIV-MUNICH, MUNICH	2	9.09
14	SIEMENS-AG, MUNICH	4	18.18
14	ERLANGEN-NURNBERG-UNIV, ERLANGEN	3	13.64
15	DORTMUND-UNIV, DORTMUND	2	25.00
16	ERLANGEN-NURNBERG-UNIV, ERLANGEN	2	9.52
16	GER-NAT-RES-CTR-COMP-SCI, ST-AUGUSTIN	2	9.52
16	PADERBORN-UNIV, PADERBORN	2	9.52
17	KARLSRUHE-UNIV, KARLSRUHE	2	25.00
18	MARBURG-UNIV, MARBURG	2	15.38
18	PADERBORN-UNIV, PADERBORN	2	15.38
18	RUHR-UNIV-BOCHUM, BOCHUM	2	15.38

The Technical University of Munich can be found at the top of the list for nine subdomains. Siemens AG appeared in eight lists, Paderborn University and the Technical University Darmstadt in seven lists. Moreover, for the central and most important subdomain 1 (NN general) all these actors can be found near the top. As a result, we conclude that these are the most prominent actors, as far as neural network (engineering) research in Germany is concerned.

7.4 Concluding remarks and discussion

In this study, we have outlined an extensive procedure to evaluate the activity of a country, or an actor within a country, from the perspective of the international developments in a rather new and rapidly growing field like neural network research. The procedure is applied to the scientific output data of Germany in this field. The field is defined by, and therefore restricted to, publications covered by INSPEC, an international database on physics, electrical/electronic engineering and computer engineering.
We find that throughout the whole period 1989-1993, Germany is one of the leading countries in the field, with an activity around average in all sub-domains. In sub-domains with an increasing worldwide activity (NN-general; NN devices; optimisation; parallel architecture; and instrumentation), the share of German publications increased during the studied period. For circuit design we observe a significant decrease of German activity. But the worldwide activity in this sub-domain also decreases.

As an example, we also investigated the German activity in one specific sub-domain, optimisation, in more detail. This sub-domain shows an increasing worldwide interest from 1989 to 1993. In spite of this sharp increase, the German share of publication activity increases from below to somewhat above average. In the fine-structure map of this sub-domain, information about the evolution of topics, and about the German activity is integrated. In the map we observed a particular area with an increasing worldwide activity, in which, however, hardly any German activity was measured.

The most important German 'actors' in the field are the Technical University of Munich, Siemens AG, the Paderborn University, and the Technical University Darmstadt. They appear in the lists of achieving the most publications German organizations for one third to half of all 18 sub-domains. Moreover, they appear in the top-list of the central, and most important, sub-domain (NN general).

With the help of a combination of detailed mapping and actor analysis as described in this paper, we are able to disclose such detailed information. Moreover, by allowing the data itself to generate the structure of the field, we keep track of the evolving structure of science. For a rapidly developing field, like neural network research, this seems more appropriate than to force it into a structure based on aged notions and classifications. As a result, maps of science and technology offer a better evaluation tool than tables with numerical values only.

An important point of criticism of one of the two neural network experts consulted concerns time lags. According to this expert, our results, in particular for the fine-structure maps, will be influenced by the time lag of the classification scheme and the thesaurus of indexed words. Particularly in a new and rapidly developing field like neural network research, new, more specific, terms are introduced rather frequently.

To cope with this important problem, we are developing procedures to use abstract and title words to determine the structure of a research field. Once this is established, we will not depend on classification codes and indexed terms any more. As a result, the maps will come closer to the 'real world' of the researchers, because we will not have to wait for new terms and classifications to be included in the lists of database producers.

References

Debackere, K. and M.A. Rappa (1994). Institutional Variations in Problem Choice and Persistence among Scientists in an Emerging Field. *Research Policy*, 23, 425-441.

Engelsman, E.C. and A.F.J. van Raan (1990). *The Netherlands in Modern Technology: a Patent-based Assessment*. Beleidsstudies Technologie/Economie, The Hague, No. 5A.

Engelsman, E.C. and A.F.J. van Raan (1993). International comparison of technological activities and specializations: A patent-based monitoring system. *Technology Analysis & Strategic Management*, 5, 113-136.

Katz, J.S. and D. Hicks (1995). The Classification of Interdisciplinary Journals: A New Approach. *Proceedings of the 5th Biennial Conference of the International Society for Scientometrics and Informetrics* (Learned Information, Medford). 245-254.

McCain, K.W. and P.J. Whitney (1994). Contrasting assessments of interdisciplinarity in emerging specialties: The case of neural networks research. *Knowledge: Creation, Diffusion, Utilization*, 15, 285-306.

Noyons, E.C.M., M. Luwel, and H.F. Moed (1994). Informatie technologie in Vlaanderen (Information technology in Flanders). CWTS Report 94-01, Leiden.

Noyons, E.C.M., and A.F.J. van Raan (1998). Monitoring scientific developments from a dynamic perspective: Self-organized structuring to map neural network research. *Journal of the American Society for Information Science*, 49, 68-81.