VISUALIZING QUANTITATIVE ASPECTS OF COMMUNICATIVE AND COMMERCIAL INTERACTION — MORE POSSIBILITIES WITHIN 2D

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ABSTRACT

A combination of techniques is proposed for visualizing the multidimensional interaction within communication involving many agents. The principal steps are the preparation of data, cluster analysis, smoothly transient shading or partial dimming of the cluster configurations, and, finally, the indication of the major vectors of the matrix underlying the visualization. The techniques do not require 3D simulations / projections but could well be incorporated with these to enhance their visualization power. The method is illustrated with data from spoken interaction and business transactions.

Keywords: data exploration and visualization, cluster analysis, multi-dimensionality, colouring, mapping of communicating agents.

INTRODUCTION

How could we, by using the simple 2D plane without too many details, visualize the interactivity between the participants involved in a discussion, complex trade relations, or other multi-dimensional events? A picture which gives a general idea of a highly complex scenario is often very useful when searching or classifying events and when designing nets of infrastructures. We *visualize* complex, abstract events in order to use our best perceptive instrument, *vision*, for interpreting instantly their internal relations. Not only does this improve the capacity of *human* interpretation; a well-made visualization, could, although primarily constructed for humans, as a side effect, be combined fruitfully with e.g. pattern recognition. A concrete example: somebody may search a database of historical relations between countries for a maximally close analogy to how seven persons, on a smaller scale, interact when dealing with a conflict (or the inverse analogy) — this could be useful e.g. in comparative studies of intercultural communication. By carefully reducing the complexity of high-dimensional interaction, we make the scenarios easily comparable regardless of their magnitude. To understand this procedure we will outline briefly the preparation of data required and then show how it could be efficiently visualized even within the 2D plane.

VISUALIZED INTERACTION

New methods of visualization, e.g. [Allwood & Hagman 93], [Allwood & Ahlberg 95], [Eick & Wills 93], [Ingram & Benford 95] are constantly added to the more traditional methods of modelling interaction, e.g. [Kosaka 93], [Abell 93], [Carley & Banks 93]. There are several kinds of communication networks (e.g. telephone, Internet, transports) with analogous structures visualized by the methods presented in these and similar studies. In this paper the technique proposed is illustrated by three types of data sets, taken from speech and trade relations.

The Malayan Seminar

Our first example consists of data from a transcribed discussion involving eleven participants. The setting was an academic seminar at the University of Malaya, the topic was abortion and the speakers of three different ethnic backgrounds: Malayan, Chinese, and Indian. From statistics available about this seminar *number of utterances* was chosen as a measure of *activity*. Additionally the *utterance order* was considered as an indicator of *information flow*. This is shown by Table 1.

S 2 > S 1 ∨	A	J	L	M	O	P	Q	R	S	T	W	Σ
A	—	·	1	·	1	·	·	2	2	3	3	***12***
J	·	—	·	·	·	·	·	·	1	·	1	***2***
L	1	·	—	·	·	·	1	1	2	·	1	***6***
M	1	·	·	—	·	·	·	·	1	·	·	***2***
O	3	·	·	·	—	·	·	1	2	·	1	***7***
P	·	·	1	·	·	—	·	·	·	·	·	***1***
Q	·	·	·	·	·	·	—	·	1	·	·	***1***
R	2	·	·	·	2	·	·	—	1	·	3	***8***
S	3	2	4	1	2	1	·	1	—	·	3	***17***
T	·	·	·	·	·	·	·	1	1	—	2	***4***
W	2	·	·	1	2	·	·	2	7	1	—	***15***
Σ	***12***	***2***	***6***	***2***	***7***	***1***	***1***	***8***	***18***	***4***	***14***	***75***

Table 1 A "who-follows-whom" matrix for 11 speakers, 75 *following* utterances, and 75 *followed* utterances. Note that the first utterance does not follow any and the last one is not followed. Speaker A was the co-ordinator.

The reason why speakers are active to different degrees is being studied as a phenomenon *per se*. Here we will direct special interest to how each speaker distributes his utterances (whatever their number) after those of the other speakers. Table 2 shows the expected number of utterance sequences per speaker pair. The expected value E is obtained by means of the following formula (discussed thoroughly in [Hagman 94a]):

$$E\{\alpha,\beta\} = (U_\beta - F_\beta) * (U_\alpha - L_\alpha) / (U_{tot} - U_\beta - L_\alpha)$$

When spelled out, this formula says that the expected times that speaker β follows α equals the product of non-starting β-utterances (the utterances being distributed) and non-ending α-utterances divided by the number of all utterances not uttered by β and not ending the conversation, uttered by speaker α. Table 2 shows the result of applying this formula to our example and in Table 3 we see clearly how the actual distribution differs from the expected one. The most salient case is where Q spoke his only utterance after one of speaker L's six utterances. Statistically one would have expected Q to drop his line after one of the more frequent speakers, like S, W, or A.

Spkr 2 > Spkr1 ∨	A	J	L	M	O	P	Q	R	S	T	W	Σ
A	—	.32	1.03	.32	1.22	.16	.16	1.41	3.72	.67	2.75	*11.76*
J	.38	—	.17	.05	.20	.03	.03	.24	.62	.11	.46	*2.29*
L	1.12	.16	—	.16	.61	.08	.08	.71	1.86	.33	1.38	*6.49*
M	.38	.05	.17	—	.20	.03	.03	.24	.62	.11	.46	*2.29*
O	1.31	.19	.60	.19	—	.09	.09	.83	2.17	.39	1.61	*7.47*
P	.19	.03	.09	.03	.10	—	.01	.12	.31	.06	.23	*1.17*
Q	.19	.03	.09	.03	.10	.01	—	.12	.31	.06	.23	*1.17*
R	1.50	.22	.69	.22	.81	.11	.11	—	2.48	.44	1.84	*8.42*
S	3.24	.47	1.48	.47	1.75	.23	.23	2.03	—	.96	3.97	*14.83*
T	.75	.11	.34	.11	.41	.05	.05	.47	1.24	—	.92	*4.45*
W	2.81	.41	1.29	.41	1.52	.20	.20	1.76	4.66	.83	—	*14.09*
Σ	*11.87*	*1.99*	*5.95*	*1.99*	*6.92*	*.99*	*.99*	*7.93*	*17.99*	*3.96*	*13.85*	*74.43*

Table 2 A "who-follows-whom" matrix indicating the expected number of utterances

Spkr2> Spkr1∕	A	J	L	M	O	P	Q	R	S	T	W
A	—	·	97	·	82	·	·	142	54	450	109
J	·	—	·	·	·	·	·	·	161	·	218
L	89	·	—	·	·	·	1,250	142	107	·	73
M	267	·	·	—	·	·	·	·	161	·	·
O	229	·	·	·	—	·	·	121	92	·	62
P	·	·	1,167	·	·	—	·	·	·	·	·
Q	·	·	·	·	·	·	—	·	322	·	·
R	133	·	·	·	246	·	·	—	40	·	163
S	93	429	271	215	114	435	·	49	—	·	76
T	·	·	·	·	·	·	·	213	81	—	218
W	71	·	·	247	131	·	·	113	150	120	—

Table 3 A "who-follows-whom" matrix showing the ratio (%) of the actual number (Table 1) divided by the expected number (Table 2) of utterances.

Let us return to Table 1. In order to visualize all its 110 (11^2-11) speaker/speaker relations, we treat it as a *similarity matrix* and calculate its corresponding *cluster configuration. Cluster analysis* is a "cousin" of *factor analysis*; both are statistical techniques for reducing a high number of dimensions to be projected (often) onto two dimensions. See e.g. [Jain & Dubes 88] for a description of this technique. Figure 1 is the output of a cluster analysis[1] of Table 1.

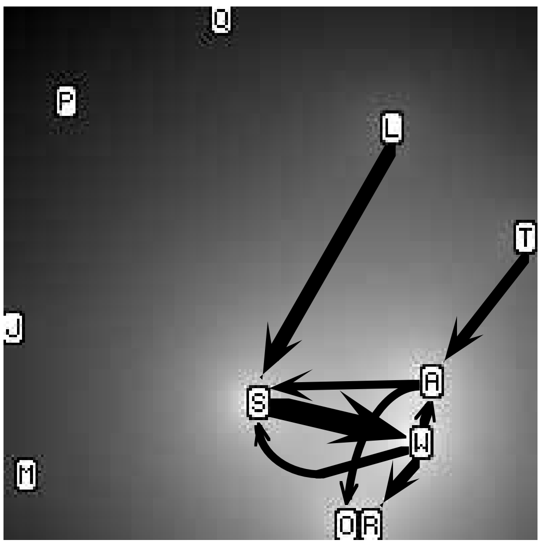

Figure 1 A cluster configuration based on the absolute values in Table 1 and thus showing the "centrality" of the speakers. The background shading reflects the total amount of utterances made by the nearest speakers. The arrows show the values greater than 2. Note that the arrow sequence L→S is read as "L follows S". Often a following speaker *directs* his interest to the preceding one.

Note that the orientation of the constellation has no importance; there are no fixed axes referring to any dimensions here — just like in outer space. The configuration may thus be rotated around any fictive point or line without changing the internal spatial relations between the projected entities. The background has been used to indicate the total values for each single speaker; the lighter, the higher the value in Table 1 and the most frequent speaker sequences have been indicated with arrows. The clustering tendency among the speakers shows the "centrality" of each speaker in terms of number of utterances.

In order to visualize the content of Table 3, which describes the relative distribution of each speaker's utterances, we treat it in the same way as Table 1 and this will yield Figure 2. We note that the clustering tendency is altered so as to visualize the *relative* speaker order during the seminar (and not the *absolute* one as in Figure 1).

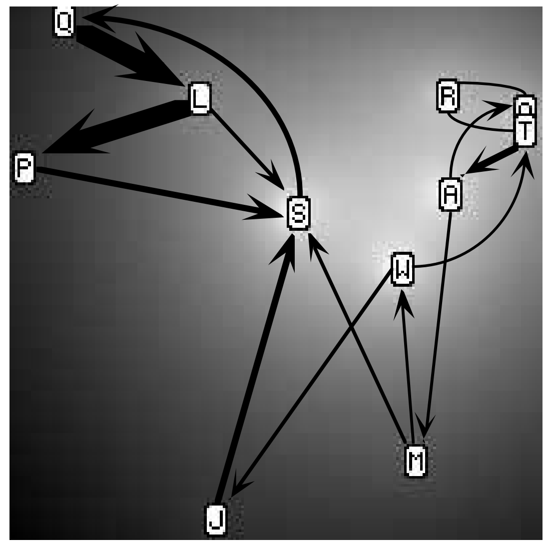

Figure 2 Cluster configuration based on the (absolute/expected) values in Table 3 which gives an idea of the most typical relative directionality of each speaker. The background shading reflects the total amount of utterances made by the nearest speakers and the arrows show the values > 200. L→S is read as "L follows S" as in Figure 1.

When closely examinating the instances of speaker sequences, we discover that there are at least three "syntactic" types:

- i Speaker 1 finishes his turn and there is felt to be a "natural pause" before Speaker 2 starts;
- ii Speaker 2 "latches" his contribution to that of Speaker 1, i.e. he smoothly takes the turn in the middle of a phrase and continues from there;
- iii Speaker 2 does not await his turn but starts speaking simultaneously with Speaker 1 and this 'overlap' may result in interrupting Speaker 1.

A rough but plausible hypothesis is that these three degrees of sequence "intensity" correlate with the degree of mutual interest in the current

[1] In [Hagman 94b] it is shown how the leaves of a dendrogram (based on single linkage, agglomerative clustering) are lined up diagonally on the display. Subsequently an iterative 2D projecting algorithm optimizes the re-representation of the underlying proximity matrix by moving the leaves / item labels on the display until a configuration with a satifactorily low stress has been reached.

topic as shown by Speaker 2 when listening to Speaker 1. Assuming this and operationalizing the degrees of intensity simply as the integers 1, 2, and 3, respectively, we elaborate Table 3 by multiplying the values of the former with the following speaker's "average intensity". The strong relative association of L to P, caused by L overlapping with P's single utterance, now becomes even more evident both in Table 4 and Figure 3.

Spkr2> Spkr1∨	A	J	L	M	O	P	Q	R	S	T	W
A	—	·	106	·	82	·	·	142	81	450	254
J	·	—	·	·	·	·	·	·	161	·	218
L	178	·	—	·	·	·	1,250	142	107	·	73
M	801	·	·	—	·	·	·	·	161	·	·
O	611	·	·	·	—	·	·	242	92	·	124
P	·	·	3,501	·	·	—	·	·	·	·	·
Q	·	·	·	·	·	·	—	·	966	·	·
R	200	·	·	·	492	·	·	—	40	·	217
S	217	429	271	215	114	435	·	49	—	·	101
T	·	·	·	·	·	·	·	213	81	—	327
W	142	·	·	741	131	·	·	113	236	120	—

Table 4 Matrix of "speaker sequence intensity" or "mutual interest".

Spkr2> Spkr1∨	A	J	L	M	O	P	Q	R	S	T	W
A	—	·	·	·	·	·	·	·	50	·	67
J	·	—	·	·	·	·	·	·	·	·	·
L	100	·	—	·	·	·	·	·	·	·	·
M	100	·	·	—	·	·	·	·	·	·	·
O	·	·	·	·	—	·	·	100	·	·	100
P	·	·	-100	·	·	—	·	·	·	·	·
Q	·	·	·	·	·	·	—	·	100	·	·
R	50	·	·	·	50	·	·	—	·	·	33
S	33	·	·	·	·	·	·	·	—	·	33
T	·	·	·	·	·	·	·	·	·	—	50
W	-50	·	·	100	·	·	·	50	14	·	—

Table 5 A so-called "agreement matrix" stating as percentages the number of times Speaker 2 agrees (positive value) or disagrees (negative value) with the preceding Speaker 1.

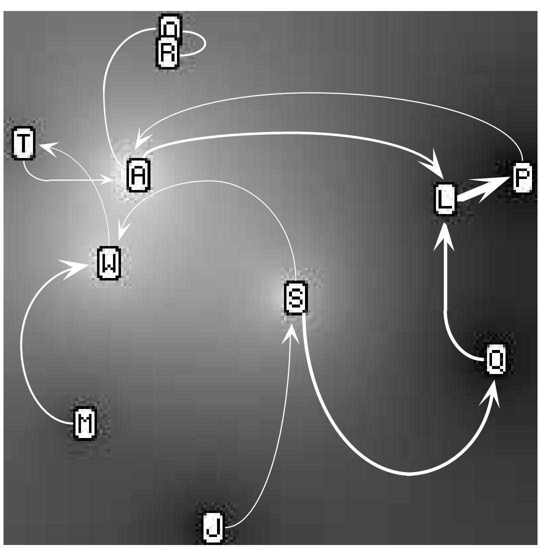

Figure 3 Cluster configuration based on the values of Table 4, showing the "speaker sequence intensity" or the degree of "mutual interest". The background shading indicates roughly the total amount of utterances, overlapping, and latching. L→P is read as "L follows P".

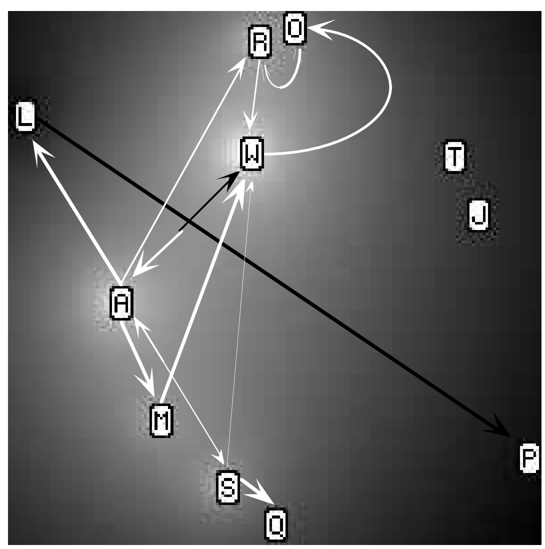

Figure 4 Configuration based on the values of Table 5. The background shading shows whether the nearest speaker mostly supports (light shade/ arrow) or objects to (dark shade/arrow) what the previous speaker just said.

While examining the intensities of the speaker sequences we also check whether Speaker 2 approves, disagrees, or expresses no standpoint with respect to what Speaker 1 has just stated. Operationalizing agreement as 1, and disagreement as -1, we get Table 5 and, from that, Figure 4. Agreement and disagreement are visualized by using the contrasting white and black arrows.

The Italian Dinners

Our second set of data is from a study of how Italian children learn the art of arguing [Pontecorvo & Fasulo 93]. One of the relations considered in these transcriptions of dinner discussions is *who problematizes whom*. Table 6 shows the situation in the Nacchi family (‘Target’ is the child in focus):

↓Proble-mtzs→	Father	Mother	Target	Siblings	Others	Σ
Father	—	·	·	·	·	*0*
Mother	·	—	1	2	·	*3*
Target	·	15	—	·	·	*15*
Siblings	2	2	·	—	·	*4*
Others	·	·	·	·	—	*0*
Σ	*2*	*17*	*1*	*2*	*0*	***22***

Table 6 Data of the Nacchi family, showing the number of times somebody in the left-hand column problematizes other family members.

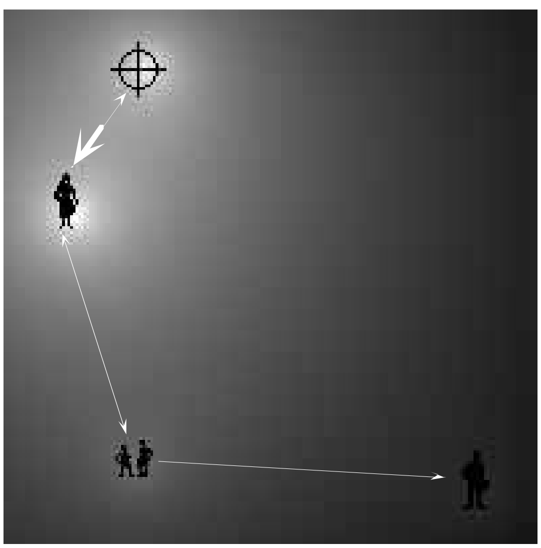

Figure 5 Configuration based on Table 6. Background shading is given by the combined number of times problematizing and being problematized.

At this dinner *la mamma* is obviously a central figure. This also shows up in the corresponding cluster configuration in Figure 5, which was calculated in the same way as the configuration in the Malayan material with the exception that the text lables have been replaced by icons.

The more peripheral presence of the siblings and, especially, of the father is evident. Note that the background shading of Figure 5 is analogous to the *temperature* of the universe; the further away from the stars, the colder and darker. Compare this with Figure 6 which exemplifies another shading. Here, the shading is analogous to the *light* of the universe; high values in the table correspond to suns whereas low values correspond to black holes.

Figure 6 Same configuration as Figure 6 but the dominant background shading is set to the mean value of the persons. The value variation in Table 6 is shown with deviations from the gray shade representing this mean value.

In another family, the Soldano’s, *il padre* was very much in the centre, together with the target of the research. As can be seen in Table 7, there were also ‘Others’ indirectly involved in the discussion who represented both problematizers and problematizees:

↓Proble-mtzs→	Father	Mother	Target	Siblings	Others	Σ
Father	—	4	21	6	2	*33*
Mother	4	—	5	4	4	*17*
Target	21	11	—	·	2	*34*
Siblings	12	16	4	—	2	*34*
Others	4	4	·	·	—	*8*
Σ	*41*	*35*	*30*	*10*	*10*	***126***

Table 7 Data of the Soldano family, showing how people are problematized within and outside the family.

Even in this case, the configuration was shaded in two different ways:

Figure 7 Configuration based on the Soldano family data in Table 7. The background shading is analogous to that of Figure 5.

... and this time the underlying forces are visualized by arrows drawn in the second variant:

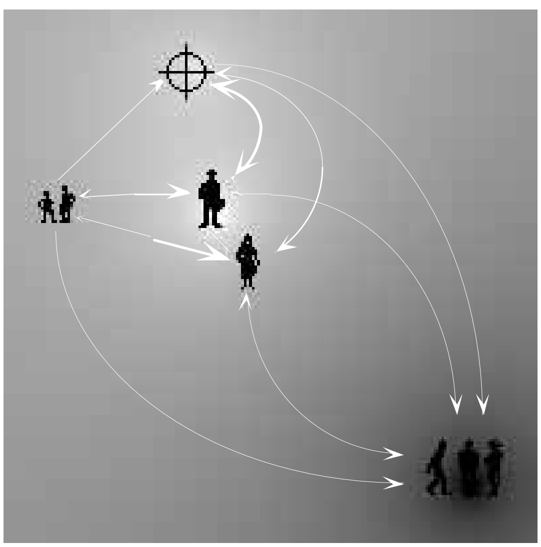

Figure 8 Configuration based on Table 7 and with the same background shading as in Figure 6.

European Trade Relations

Our third data set exemplifying quantifiable aspects of interaction is taken from the world of international trade and has more features in common with the foregoing examples of spoken interaction than might be expected. Both types have a set of agents with certain interests and (in-)dependencies and in both cases there is some kind of exchange taking place. Table 8 is taken from [SCB 95] and contains the most important trading partners of Sweden, listed in (originally Swedish) alphabethical order, starting with the Nordic countries, then Europe, and then the rest of the world. This table is incomplete and therefore the row 'Other' refers to the countries left out. The table reflects world trade as seen from the perspective of a medium-sized Western European country. This table, which reports the figures for 1992, was subject to cluster analysis, loaded as a similarity matrix which was then symmetricized. The result is seen in Figure 12, p. 86, where the background shading of green (the colour of US $) is determined by the total annual import volume of the nearest foreground country; the lighter the shade, the larger the total. In this way each country's "centrality" or "quantitative importance" is represented. In the cases of POL and YUG, however, no figures were reported from the trade with other countries and that is why their background has been "dimmed". In the configuration, closely situated countries in a cluster are either strongly related to each other or similarly related to other entities or both. The recurring cluster containing GER, FRA, and GBR in all the four configurations is mainly held together by the strong (commercial) attraction of the countries to each other. The presence of BRA in the cluster NOR, DEN, BRA, and FIN, is due only to similar relations with the more central, "heavy" countries, whereas the presence of NOR, DEN, and FIN in the same cluster is both the effect of similar trade relations to other countries and the effect of strong internal attraction. How can we know for which of the two reasons some countries are near to each other? One way is to indicate for each country the *n* countries it is most strongly related to. This has been done for SPA and SWE in Figures 9 through 12. We see that these countries have similar but not reciprocal interests. This would however have been the case if we had indicated the major interests of anyone of NOR, DEN, BRA, and FIN together with SWE. As SWE gradually loses its (quantitative) importance throughout the years 1962-92, it also gradually qualifies (geometrically, when visionally interpreting the picture) as a member of this cluster. This also happens for the same reasons to NOR, DEN, and FIN. The countries BRA, SAF, and GRE were left out in the 1972 statistics due to their marginality in European trade and POL, JAP, and IND were included for the opposite reason. These changes probably made AUT move to another quadrant in 1972.

E/I	SWE	DEN	FIN	NOR	BLX	FRA	ITA	YUG	NET	POL	SWI	USR	SPA	GBR	GER	AUT	CAN	USA	IND	JAP	AUS
SWE	–	3637	2485	4020	2521	3542	2412	134	2768	375	1142	569	1328	5763	9025	979	643	4877	175	1207	705
DEN	3878	–	713	1952	850	2255	1897	100	1749	506	724	425	838	4186	9214	430	202	1736	112	1436	188
FIN	3082	904	–	921	638	1943	1205	50	1196	365	447	1113	740	2943	4186	379	196	1266	99	354	259
NOR	3414	1815	854	–	1524	3083	832	31	1655	314	334	102	474	6778	5844	167	1215	2063	63	713	90
BLX	1760	1095	600	624	–	20573	9110	188	19039	515	2539	573	3520	10077	28696	1629	343	4850	1555	1295	345
FRA	2551	1884	978	1059	20600	–	27199	814	10360	823	7138	2292	15838	21440	48886	2396	2217	15262	738	5416	1083
ITA	1911	1397	764	875	5665	25403	–	2757	4839	1137	6577	4470	9807	11881	37532	4672	1443	12843	532	4161	958
YUG	99	54	29	82	152	889	2808	–	220	217	117	2954	99	216	3657	463	47	494	64	47	31
NET	2136	1851	772	1027	21882	12123	11140	371	–	963	2916	908	3466	17391	39174	1467	419	5532	313	1317	429
POL	414	449	282	118	337	658	888	111	496	–	71	1981	187	625	4795	461	48	400	87	159	19
SWI	949	654	411	388	2127	5387	2412	209	1835	298	–	249	1526	6878	16263	2170	540	5776	274	3186	503
USR	795	0	1704	416	1240	3563	5882	2752	1160	2412	244	–	900	1342	8291	899	218	921	572	2507	20
SPA	698	423	261	315	1988	12906	6330	63	2102	155	897	470	–	5307	11008	680	359	3188	158	769	156
GBR	4291	2756	1834	2409	9623	18402	10757	281	11442	1054	3738	920	7282	–	27982	1470	3407	20694	1834	4901	2422
GER	9221	7767	3591	3759	29869	44594	40655	3520	33586	4688	22034	9704	14897	33407	–	23231	2897	29596	1998	10746	2358
AUT	673	408	259	311	893	2064	4117	918	1238	644	2571	937	749	1665	1372	–	248	1353	114	748	164
CAN	266	184	137	470	584	1541	1469	21	714	46	258	1169	572	3330	2739	275	–	101292	428	7647	662
USA	4358	1901	1294	2224	5402	20103	9892	342	9927	637	4227	4103	7357	2246	27096	2142	79294	–	2106	52693	9269
IND	135	98	48	78	633	721	767	44	341	78	218	1987	312	1513	1723	132	230	4066	–	2035	235
JAP	2517	1391	1161	1638	2776	9766	4401	47	4788	238	2835	1280	4655	13064	24377	2556	8914	99481	1637	–	7373
AUS	144	84	120	88	421	950	883	28	396	9	113	74	250	1779	1372	33	604	3971	661	12409	–
σ (G$)	43	29	18	23	110	190	145	13	110	15	59	36	75	152	313	47	103	320	14	114	27
Other (G$)	7	5	3	3	15	49	43	?	24	?	3	12	25	70	89	8	23	234	10	119	13
Σ (G$)	50	34	21	26	125	240	189	?	134	?	62	48	100	222	402	54	127	554	24	233	41
σ/Σ (%)	87	85	86	88	88	79	77	?	82	?	96	76	75	69	78	86	82	58	57	49	67

Table 8 Table of export (rows) and import (columns) reported for 21 countries 1992. To the table sums (σ), import from other countries is added which gives a total sum (Σ). The percentage of the import from these countries with respect to the total import is also indicated for each country on the bottom row.

SUMMARY AND FUTURE WORK

Visualization can never amend badly prepared data. Too often the attitude is encountered that just applying some fancy statistics or visualization program to one's data will do the whole job. Careful data preparation is the first important step towards a high quality visualization of the phenomenon of interest. The value distribution of the data represented as a cluster configuration can be indicated by transient isosurface colouring or shading (which between the items could either tend towards the minimum or the mean value). If not all, at least the major internal forces between the items could also be shown by arrows. This type of visualization is grasped mentally more quickly than ordinary tables and is a valuable complement to more detailed but less surveyable tables. One further possibilitiy regarding the kind of interaction illustrated in the last example (which is often interesting to make prognoses of) is to first calculate expected configurations for the intermediate years by interpolating the positions and then either compare these with the actual ones or to use them to sketch future trends. Interpolation of these configurations also makes possible the animation of a scenario.

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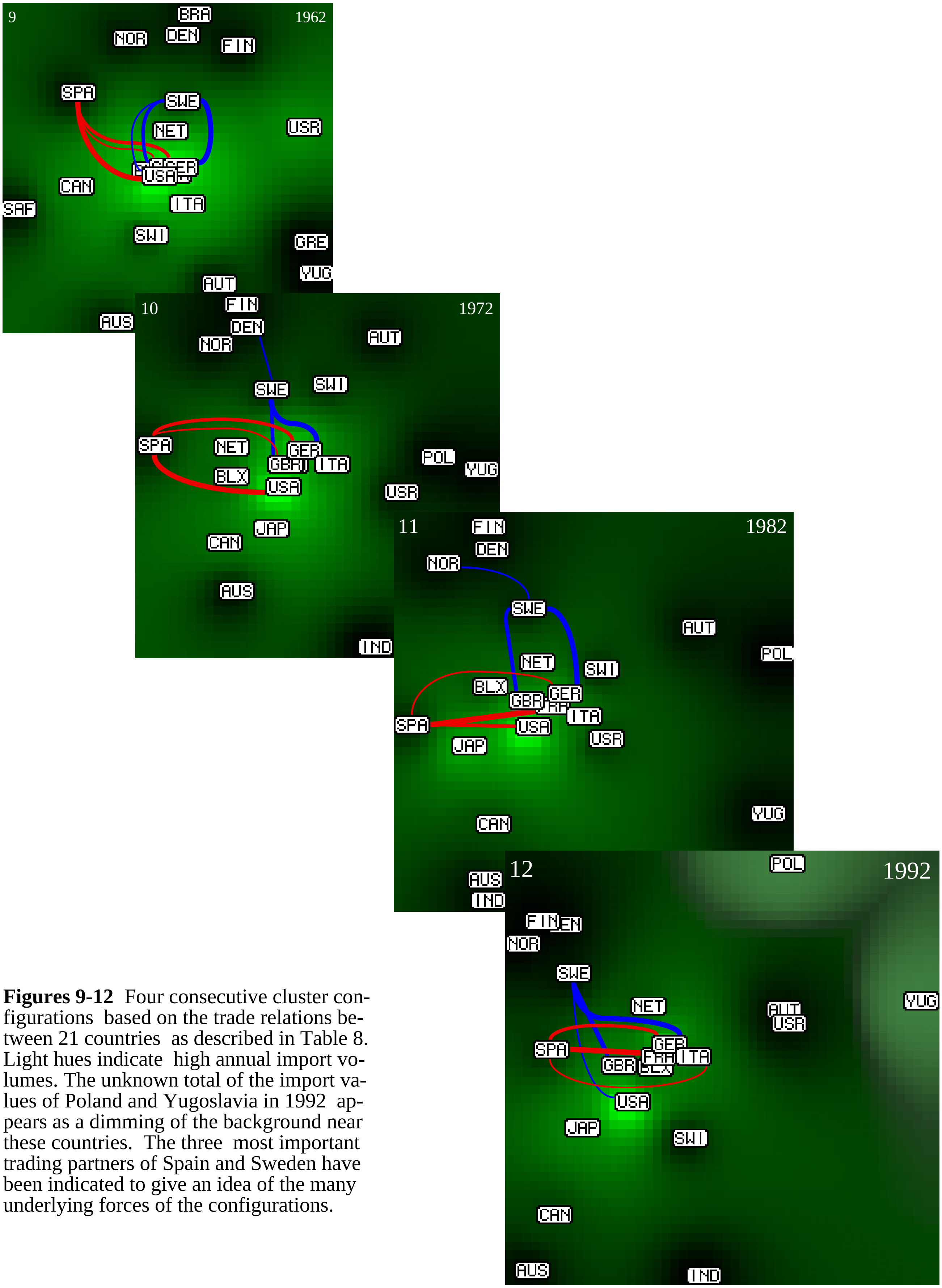

Figures 9-12 Four consecutive cluster configurations based on the trade relations between 21 countries as described in Table 8. Light hues indicate high annual import volumes. The unknown total of the import values of Poland and Yugoslavia in 1992 appears as a dimming of the background near these countries. The three most important trading partners of Spain and Sweden have been indicated to give an idea of the many underlying forces of the configurations.