Bibliometric field delineation with heat maps of bibliographically coupled publications using core documents and a cluster approach - the case of multiscale simulation and modelling (research in progress)

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Contribution at the ECOST-MEETING-TD1210-290816-077233 "Identification, location and temporal evolution of topics - data and algorithm - comparison of approaches" 2016 08 29 – 2016 08 30

Keywords: field delineation, bibliometrics, science mapping, cluster analysis , core documents, multiscale simulation and modelling

Acknowledgement: This work was funded by the Austrian COMET-Program (Project K2 XTribology, Grant No. 849109), and has been carried out within the Excellence Centre of Tribology.

A remarkable advance has been made in the development of bibliometric approaches for the identification and delineation of research topics, see for example Shibata, N., Kajikawa, Y., Takeda, Y. and Matsushima, K. (2009), Boyack, K. & Klavans, R. (2010), Glänzel, W. (2012). In recent years traditional bibliometric concepts like co-citation analysis, bibliographic coupling (Price, D.D., (1965), Persson, O., (1994), Kessler, M.M. (1963)), have been enriched with text and semantic similarities, topic modelling (Yau, C.,K., Porter, A., Newman, N., Suominen, A. (2014)) as well as hybrid methods, (Janssens, F., Glänzel, W., & Moor, B. (2008)). Additionally visualization tools for networks and the representation of agglomerations of similar documents in a two dimensional space (Van Eck, N.J. and Waltman, L. (2010), Chen, C (2006), Kopcsa, A. & Schiebel, E. (1998)), dendrograms of hierarchies but also word clouds are helpful instruments that have been applied or developed. Well known algorithms are cluster analysis, multidimensional scaling with spring models. Recently latent Dirichlet allocation for topic modeling has been added.

However the identification of thematic issues or fields from thousands of publications is still a challenge. A reason is that some issues and after all emerging research topics very often do not have sharp borders to others. The reason is that publications that are thought to build delineated communities in a network of similar documents tend to be more or less strong connected to other communities that are located nearby. For example, in the case of bibliographic coupling often cited pioneering, influential and fundamental publications are responsible for cross linkages.

In this contribution a semi-automated graphically assisted procedure for the delineation of subfields is suggested. It is an attempt to combine several bibliometric approaches. The idea is to work with a reduced number of publications that are core documents having been selected by a minimum of the sum of the similarity to all other objects (Glänzel, W., & Thijs, B. (2011))., to map these documents in a two dimensional space with a spring model (Kopcsa, A., Schiebel, E., (1998)), to select documents with a high centrality in a hot zone of an agglomeration of similar documents and to enlarge this core set with documents that have a minimum similarity to each element of the core. That way, documents have been agglomerated to a hot zone by the so called second order similarity but the selection of subsets is done with the help individual similarities (Colliander & Ahlgreen, 2012; Thijs, B., Schiebel, E. & Glänzel, W., 2013). In a next step the coupling elements of a these selected subsets (cited references) are visualized on the map and demonstrate the spreading of the underlying knowledge base of a selected and delineated research front (Schiebel, E. (2015)).

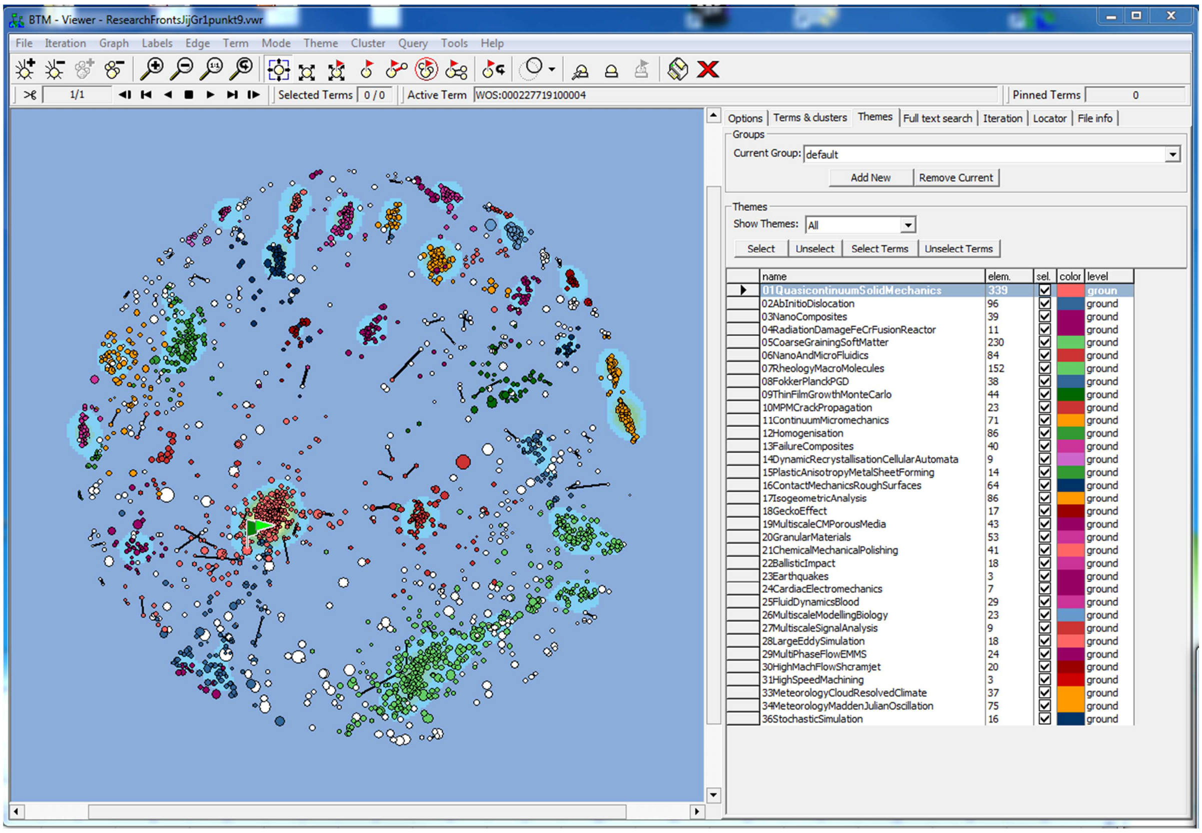
The names of the research fronts are inspired by the most relevant keywords, the content of the cited documents and the content of the documents of the research front.

The resulting research fronts are compared with the results of a cluster analysis in a concordance matrix. The comparison of the clusters with the research fronts gives an additionally view on the subfields to be delineated. Subsets of documents that form a strong and delineated community can be identified identically as a research front from the map but also as a well separated cluster. Other research fronts can be subdivided in compact sub fields.

The following procedure is proposed and presented for discussion in the workshop:

- Collection of a set of publications of research on multiscale simulation and modeling (MSSM) downloaded from Web of Science.
- Calculation of sum similarities (Jaccard index) of bibliographically coupled publications
- Selection of a subset of publications with a threshold of the sum similarity
- Calculation and visualization of a two dimensional map of the subset of bibliographically coupled publications with a spring model.
- Filter and visualize the local density of the number of publications weighted with the similarity to draw agglomerations of publications with a heat map.
- Graphically assisted selection of documents in the center of a red heat zone
- Selection of additional elements of the community by thresholds of similarity (Jaccard index, number of common references)
- Visualization of the coupling elements (cited references) to examine the compactness of the selected community
- Providing lists of TFIDF ranked keywords, authors, organizations, cited references and abstracts of the publications of the community to name the research fronts
- Calculation of a cluster analysis (Pearson, Ward or other similarities and linkage methods) of the subset of bibliographically coupled publications. Visualization with a circular dendrogram.
- Visualization of selected clusters in the heat map
- Comparison of the identified communities of both approaches (Concordance matrix)
- Conclusions (exclusion of cited reviews, highly cited fundamental publications, preprocessing of the set of publications by excluding publications with weak second order sum similarities, workload,…)

Exemplary results:



BTM - Viewer - ResearchFrontsJijGr1punkt9.vwr
File Iteration Graph Labels Edge Term Mode Theme Cluster Query Tools Help
1/1
Options | Terms & clusters | Themes | Full text search | Iteration | Locator | File info
Groups
Add New | Remove Current
Themes
Select | Unselect | Select Terms | Unselect Terms

Selected Terms 0 / 0

Active Term WOS:000227719100004

Pinned Terms 0

Current Group: default

Show Themes: All

	name	elem.	sel.	color	level
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	02AbInitioDislocation	96	☑	🟦	ground
	03NanoComposites	39	☑	🟪	ground
	04RadiationDamageFeCrFusionReactor	11	☑	🟪	ground
	05CoarseGrainingSoftMatter	230	☑	🟩	ground
	06NanoAndMicroFluidics	84	☑	🟥	ground
	07RheologyMacroMolecules	152	☑	🟩	ground
	08FokkerPlanckPGD	38	☑	🟦	ground
	09ThinFilmGrowthMonteCarlo	44	☑	🟩	ground
	10MPMCrackPropagation	23	☑	🟥	ground
	11ContinuumMicromechanics	71	☑	🟧	ground
	12Homogenisation	86	☑	🟩	ground
	13FailureComposites	40	☑	🟪	ground
	14DynamicRecrystallisationCellularAutomata	9	☑	🟪	ground
	15PlasticAnisotropyMetalSheetForming	14	☑	🟩	ground
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	18GeckoEffect	17	☑	🟥	ground
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	21ChemicalMechanicalPolishing	41	☑	🟥	ground
	22BallisticImpact	18	☑	🟪	ground
	23Earthquakes	3	☑	🟪	ground
	24CardiacElectromechanics	7	☑	🟪	ground
	25FluidDynamicsBlood	29	☑	🟪	ground
	26MultiscaleModellingBiology	23	☑	🟦	ground
	27MultiscaleSignalAnalysis	9	☑	🟥	ground
	28LargeEddySimulation	18	☑	🟥	ground
	29MultiPhaseFlowEMMS	24	☑	🟪	ground
	30HighMachFlowShcramjet	20	☑	🟥	ground
	31HighSpeedMachining	3	☑	🟥	ground
	33MeteorologyCloudResolvedClimate	37	☑	🟧	ground
	34MeteorologyMaddenJulianOscillation	75	☑	🟧	ground
	36StochasticSimulation	16	☑	🟦	ground

Figure 1: Heat map of the agglomeration of bibliographically coupled MSSM publications (bubbles), spring model, colored red heat zones (local density of documents weighted by sum similarity), reduced number of publications (2325 out of 8145, threshold for the sum of Jaccardindices for each node: 1.9), publications of a research fronts are marked with the color of the research front, data retrieved October 20, 2014

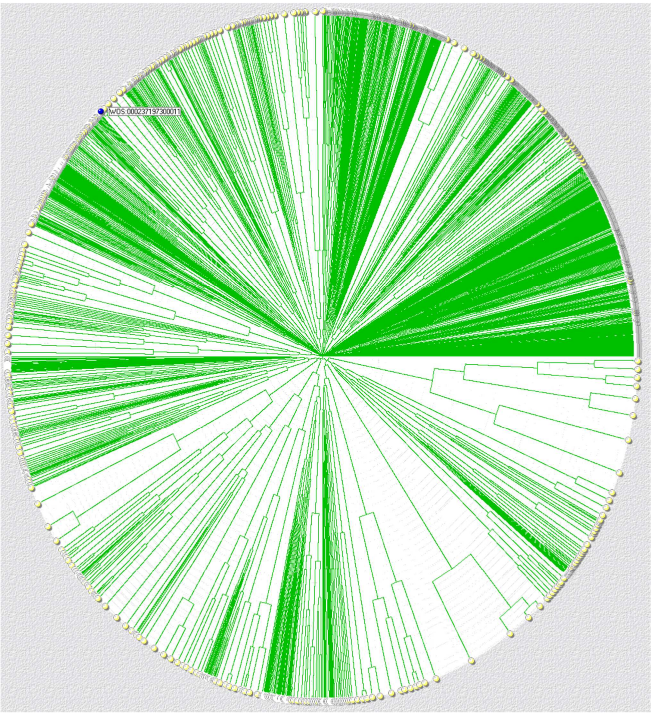
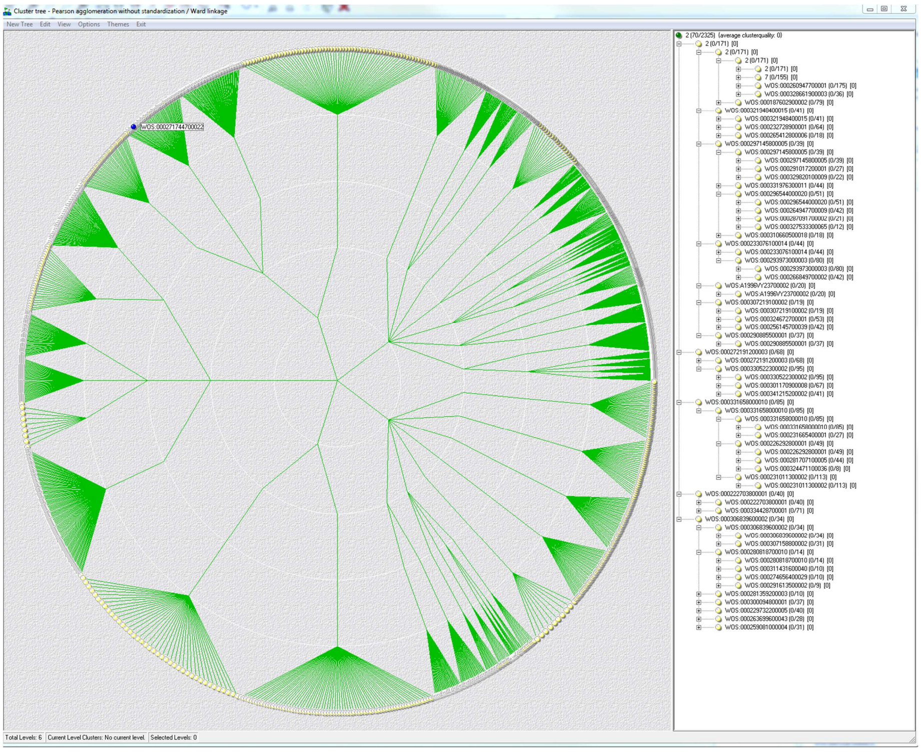


Figure 2: Cluster tree of bibliographically coupled publications: Pearson Correlation of second order Jaccard similarity, Ward Linkage



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View
Options
Themes
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        ⊞ WOS:000233076100014 (0/44) [0]
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    ⊟ WOS:000307219100002 (0/19) [0]
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        ⊞ WOS:000256145700039 (0/42) [0]
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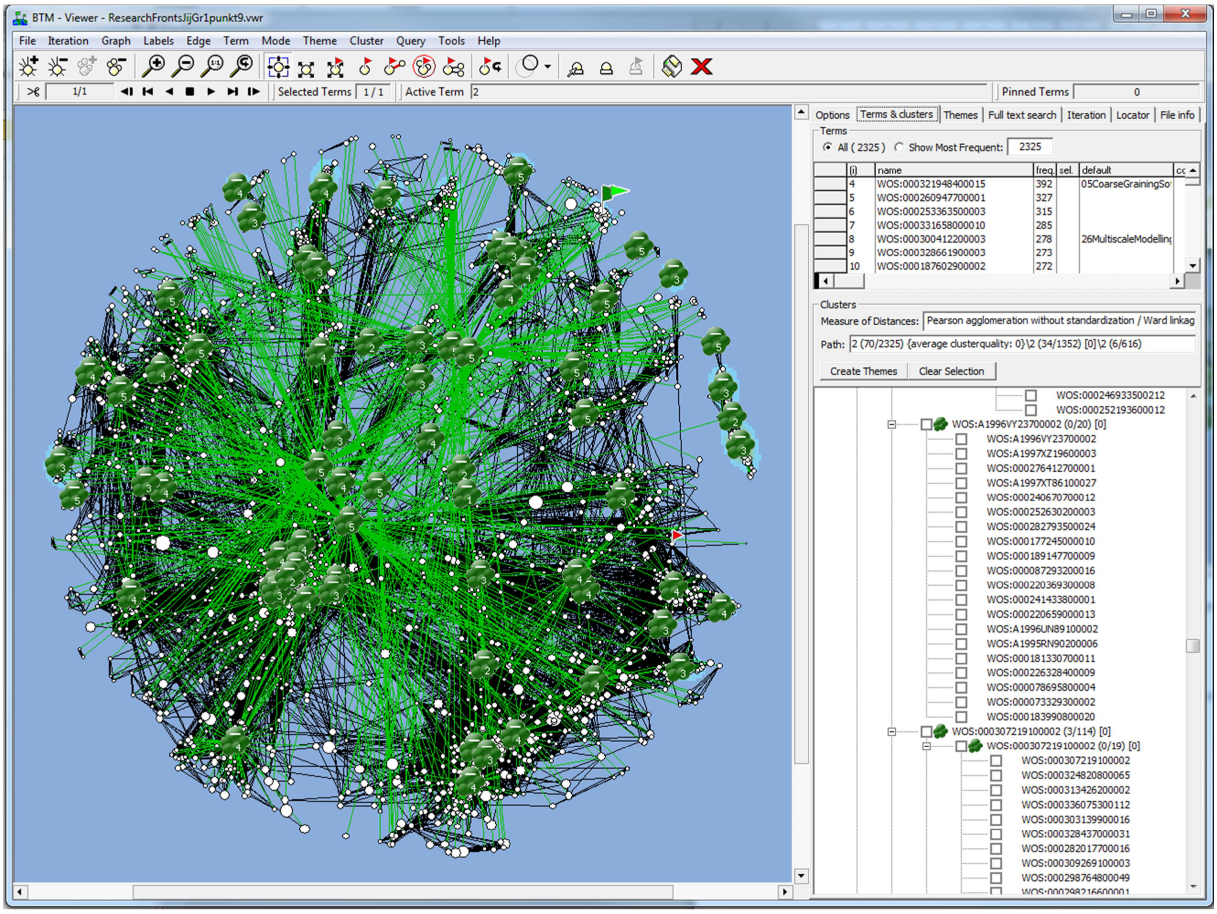
Total Levels: 6 | Current Level Clusters: No current level. | Selected Levels: 0

Figure 3: Cut circular cluster tree of research fronts with 5 equidistant clusters levels with 5/19/36/50 clusters



Selected Terms 1 / 1 | Active Term 2 | Pinned Terms 0

Terms

● All (2325) ○ Show Most Frequent: 2325

(i)	name	freq.	sel.	default	cc
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5	WOS:000260947700001	327			
6	WOS:000253363500003	315			
7	WOS:000331658000010	285			
8	WOS:000300412200003	278		26MultiscaleModelling	
9	WOS:000328661900003	273			
10	WOS:000187602900002	272			

Clusters

Measure of Distances: Pearson agglomeration without standardization / Ward linkag

Path: 2 (70/2325) {average clusterquality: 0}\2 (34/1352) [0]\2 (6/616)

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        □ WOS:000246933500212
        □ WOS:000252193600012
⊟ □ WOS:A1996VY23700002 (0/20) [0]
    □ WOS:A1996VY23700002
    □ WOS:A1997XZ19600003
    □ WOS:000276412700001
    □ WOS:A1997XT86100027
    □ WOS:000240670700012
    □ WOS:000252630200003
    □ WOS:000282793500024
    □ WOS:000177245000010
    □ WOS:000189147700009
    □ WOS:000087293200016
    □ WOS:000220369300008
    □ WOS:000241433800001
    □ WOS:000220659000013
    □ WOS:A1996UN89100002
    □ WOS:A1995RN90200006
    □ WOS:000181330700011
    □ WOS:000226328400009
    □ WOS:000078695800004
    □ WOS:000073329300002
    □ WOS:000183990800020
⊟ □ WOS:000307219100002 (3/114) [0]
    ⊟ □ WOS:000307219100002 (0/19) [0]
        □ WOS:000307219100002
        □ WOS:000324820800065
        □ WOS:000313426200002
        □ WOS:000336075300112
        □ WOS:000303139900016
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        □ WOS:000309269100003
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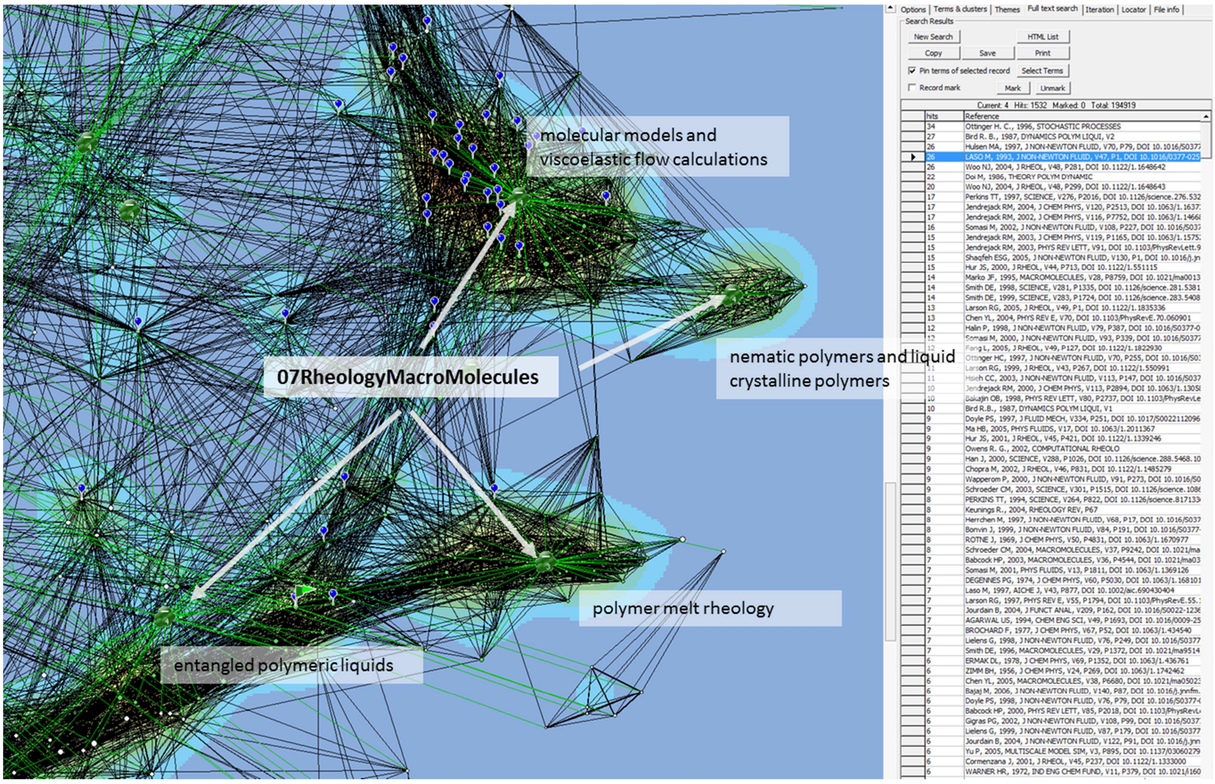
Figure 4: Visualization of the Cluster structure in the heat map of Figure 1, black lines are edges of the similarities and green lines indicate the cluster category



☑ Pin terms of selected record

□ Record mark

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hits	Reference
34	Ottinger H. C., 1996, STOCHASTIC PROCESSES
27	Bird R. B., 1987, DYNAMICS POLYM LIQUI, V2
26	Hulsen MA, 1997, J NON-NEWTON FLUID, V70, P79, DOI 10.1016/S037
26	LASO M, 1993, J NON-NEWTON FLUID, V47, P1, DOI 10.1016/0377-025
26	Woo NJ, 2004, J RHEOL, V48, P281, DOI 10.1122/1.1648642
22	Doi M, 1986, THEORY POLYM DYNAMIC
20	Woo NJ, 2004, J RHEOL, V48, P299, DOI 10.1122/1.1648643
17	Perkins TT, 1997, SCIENCE, V276, P2016, DOI 10.1126/science.276.532
17	Jendrejack RM, 2004, J CHEM PHYS, V120, P2513, DOI 10.1063/1.1637
17	Jendrejack RM, 2002, J CHEM PHYS, V116, P7752, DOI 10.1063/1.1466
16	Somasi M, 2002, J NON-NEWTON FLUID, V108, P227, DOI 10.1016/S037
15	Jendrejack RM, 2003, J CHEM PHYS, V119, P1165, DOI 10.1063/1.1575
15	Jendrejack RM, 2003, PHYS REV LETT, V91, DOI 10.1103/PhysRevLett.9
15	Shaqfeh ESG, 2005, J NON-NEWTON FLUID, V130, P1, DOI 10.1016/j.jn
15	Hur JS, 2000, J RHEOL, V44, P713, DOI 10.1122/1.551115
14	Marko JF, 1995, MACROMOLECULES, V28, P8759, DOI 10.1021/ma0013
14	Smith DE, 1998, SCIENCE, V281, P1335, DOI 10.1126/science.281.5381
14	Smith DE, 1999, SCIENCE, V283, P1724, DOI 10.1126/science.283.5408
13	Larson RG, 2005, J RHEOL, V49, P1, DOI 10.1122/1.1835336
13	Chen YL, 2004, PHYS REV E, V70, DOI 10.1103/PhysRevE.70.060901
12	Halin P, 1998, J NON-NEWTON FLUID, V79, P387, DOI 10.1016/S0377-0
12	Somasi M, 2000, J NON-NEWTON FLUID, V93, P339, DOI 10.1016/S0377
12	Fang L, 2005, J RHEOL, V49, P127, DOI 10.1122/1.1822930
[illegible]	Ottinger HC, 1997, J NON-NEWTON FLUID, V70, P255, DOI 10.1016/S0
11	Larson RG, 1999, J RHEOL, V43, P267, DOI 10.1122/1.550991
11	Hsieh CC, 2003, J NON-NEWTON FLUID, V113, P147, DOI 10.1016/S037
10	Jendrejack RM, 2000, J CHEM PHYS, V113, P2894, DOI 10.1063/1.1305
10	Bakajin OB, 1998, PHYS REV LETT, V80, P2737, DOI 10.1103/PhysRevLe
10	Bird R.B., 1987, DYNAMICS POLYM LIQUI, V1
9	Doyle PS, 1997, J FLUID MECH, V334, P251, DOI 10.1017/S0022112096
9	Ma HB, 2005, PHYS FLUIDS, V17, DOI 10.1063/1.2011367
9	Hur JS, 2001, J RHEOL, V45, P421, DOI 10.1122/1.1339246
9	Owens R. G., 2002, COMPUTATIONAL RHEOLO
9	Han J, 2000, SCIENCE, V288, P1026, DOI 10.1126/science.288.5468.10
9	Chopra M, 2002, J RHEOL, V46, P831, DOI 10.1122/1.1485279
9	Wapperom P, 2000, J NON-NEWTON FLUID, V91, P273, DOI 10.1016/S0
9	Schroeder CM, 2003, SCIENCE, V301, P1515, DOI 10.1126/science.108
8	PERKINS TT, 1994, SCIENCE, V264, P822, DOI 10.1126/science.817133
8	Keunings R., 2004, RHEOLOGY REV, P67
8	Herrchen M, 1997, J NON-NEWTON FLUID, V68, P17, DOI 10.1016/S037
8	Bonvin J, 1999, J NON-NEWTON FLUID, V84, P191, DOI 10.1016/S0377-
8	ROTNE J, 1969, J CHEM PHYS, V50, P4831, DOI 10.1063/1.1670977
8	Schroeder CM, 2004, MACROMOLECULES, V37, P9242, DOI 10.1021/ma
7	Babcock HP, 2003, MACROMOLECULES, V36, P4544, DOI 10.1021/ma03
7	Somasi M, 2001, PHYS FLUIDS, V13, P1811, DOI 10.1063/1.1369126
7	DEGENNES PG, 1974, J CHEM PHYS, V60, P5030, DOI 10.1063/1.168101
7	Laso M, 1997, AICHE J, V43, P877, DOI 10.1002/aic.690430404
7	Larson RG, 1997, PHYS REV E, V55, P1794, DOI 10.1103/PhysRevE.55.
7	Jourdain B, 2004, J FUNCT ANAL, V209, P162, DOI 10.1016/S0022-123
7	AGARWAL US, 1994, CHEM ENG SCI, V49, P1693, DOI 10.1016/0009-25
7	BROCHARD F, 1977, J CHEM PHYS, V67, P52, DOI 10.1063/1.434540
7	Lielens G, 1998, J NON-NEWTON FLUID, V76, P249, DOI 10.1016/S0377
7	Smith DE, 1996, MACROMOLECULES, V29, P1372, DOI 10.1021/ma9514
6	ERMAK DL, 1978, J CHEM PHYS, V69, P1352, DOI 10.1063/1.436761
6	ZIMM BH, 1956, J CHEM PHYS, V24, P269, DOI 10.1063/1.1742462
6	Chen YL, 2005, MACROMOLECULES, V38, P6680, DOI 10.1021/ma0502
6	Bajaj M, 2006, J NON-NEWTON FLUID, V140, P87, DOI 10.1016/j.jnnfm.
6	Doyle PS, 1998, J NON-NEWTON FLUID, V76, P79, DOI 10.1016/S0377-
6	Babcock HP, 2000, PHYS REV LETT, V85, P2018, DOI 10.1103/PhysRevL
6	Gigras PG, 2002, J NON-NEWTON FLUID, V108, P99, DOI 10.1016/S037
6	Lielens G, 1999, J NON-NEWTON FLUID, V87, P179, DOI 10.1016/S0377
6	Jourdain B, 2004, J NON-NEWTON FLUID, V122, P91, DOI 10.1016/j.jnn
6	Yu P, 2005, MULTISCALE MODEL SIM, V3, P895, DOI 10.1137/03060279
6	Cormenzana J, 2001, J RHEOL, V45, P237, DOI 10.1122/1.1333000
6	WARNER HR, 1972, IND ENG CHEM FUND, V11, P379, DOI 10.1021/i160

Figure 5: Cluster structure in the heat map of Figure 1 for the research front 07Rheology MacroMolecules

Table 1: Concordance of research fronts from the heat map and clusters at level 5, value: number of documents, clusters named by the document with the highest number of references – in most cases a review, marked values indicate corresponding agglomerations

Clusters Level 5	Sum	non zero columns	<>	01QuasicontinuumSolidMechanics	02AbInitioDislocation	03NanoComposites	04RadiationDamageFeCrFusionReactor	05CoarseGrainingSoftMatter	06NanoAndMicroFluidics	07RheologyMacroMolecules	08FokkerPlanckPGD	09ThinFilmGrowthMonteCarlo	10MPMCrackPropagation	11ContinuumMicromechanics	12Homogenisation	13FailureComposites	14DynamicRecrystallisationCellularAutomata	15PlasticAnisotropyMetalSheetForming	16ContactMechanicsRoughSurfaces	17IsogeometricAnalysis	18GeckoEffect	19MultiscaleCMPorousMedia	20GranularMaterials	21ChemicalMechanicalPolishing	22BallisticImpact	23Earthquakes	24CardiacElectromechanics	25FluidDynamicsBlood	26MultiscaleModellingBiology	27MultiscaleSignalAnalysis	28LargeEddySimulation	29MultiPhaseFlowEMMS	30HighMachFlowShcramjet	31HighSpeedMachining	33MeteorologyCloudResolvedClimate	34MeteorologyMaddenJulianOscillation	36StochasticSimulation
Sum	***2325***		***463***	***339***	***96***	***39***	***11***	***230***	***84***	***152***	***38***	***44***	***23***	***71***	***86***	***40***	***9***	***14***	***64***	***86***	***17***	***43***	***53***	***41***	***18***	***3***	***7***	***29***	***23***	***9***	***18***	***24***	***20***	***3***	***37***	***75***	***16***
non zero rows			*37*	*17*	*8*	*2*	*2*	*10*	*9*	*8*	*2*	*2*	*5*	*6*	*5*	*5*	*1*	*2*	*4*	*5*	*1*	*5*	*2*	*2*	*1*	*1*	*1*	*2*	*2*	*1*	*3*	*2*	*1*	*1*	*3*	*2*	*1*
WOS:000272846700001	171	12	82	2				10	3					5		2						1	13						21	9	7						16
WOS:000258965800001	155	13	73	31	3	7							4	13	1	2				7		6				3			2					3			
WOS:000187602900002	79	4	6	1	70		2																														
WOS:000260947700001	175	14	76	3	6		9	10	1	8				9	21	7	9		7								7	2									
WOS:000328661900003	36	3	1						2			33																									
WOS:000233076100014	44	2	12			32																															
WOS:000266849700002	42	3	4											32	6																						
WOS:000293973000003	80	7	17	3	1								1	2	54							2															
WOS:000290885500001	37	2	1							36																											
WOS:000264947700009	42	6	15	8				8	1				7					3																			
WOS:000287091700002	21	3	9									11																			1						
WOS:000291017200001	27	1																										27									
WOS:000296544000020	51	4	32	1				11																								7					
WOS:000297145800005	39	3	12		1															26																	
WOS:000327533300065	12	2	1															11																			
WOS:000329820100009	22	3	1																	4												17					
WOS:000331976300011	44	5	30	1				1	10	2																											
WOS:000310660500018	18	1																							18												
WOS:A1996VY23700002	20	1																															20				
WOS:000256145700039	42	2																	4					38													
WOS:000307219100002	19	3	1	1																	17																
WOS:000324672700001	53	3	2																48					3													
WOS:000232728900001	64	3	1							59	4																										
WOS:000265412800006	18	2	1							17																											
WOS:000321948400015	41	3	7					6		28																											
WOS:000222703800001	40	3	1																																34	5	
WOS:000334428700001	71	2																																	1	70	
WOS:000272191200003	68	3	4	1					63																												
WOS:000301170900008	67	4	6					59	1	1																											
WOS:000341215200002	41	1						41																													
WOS:000330522300002	95	2	12					83																													
WOS:000259081000004	31	1																				31															
WOS:000263699600043	28	1														28																					
WOS:000229732200005	40	1																					40														
WOS:000280818700010	14	3	3											10		1																					
WOS:000291613500002	9	3	7						1	1																											
WOS:000263213800010	6	2	2												4																						
WOS:000274656400026	10	1	10																																		
WOS:000291012700004	5	2	3																																2		
WOS:000311431600040x	10	1											10																								
WOS:000281359200003	10	2	5																5																		
WOS:000300094800001	37	3	1	2							34																										
WOS:000306839600002	34	2	2																	32																	
WOS:000307158800002	31	4	1																	17		3									10						
WOS:000226292800001	49	3	7	31	11																																
WOS:000281707100005	44	2	3	41																																	
WOS:000324471100036	8	1		8																																	
WOS:000231011300002	113	1		113																																	
WOS:000231665400001	27	2		24	3																																
WOS:000331658000010	85	6	12	68	1			1	2				1																								

References

Boyack, K. & Klavans, R., (2010) Co-Citation Analysis, Bibliographic Coupling, and Direct Citation: Which Citation Approach represents the Research Front Most Accurately?, *JASIST* 61(12): 2389-2404.

Chen, C., (2006) CiteSpace II: Detecting and Visualizing Emerging Trends and Transient Patterns in Scientific Literature. *JASIST*, 57(3): 359-377

Colliander, C., & Ahlgren, P., (2012) Experimental comparison of first and second-order similarities in a scientometric context. *Scientometrics, 90*(2), 675-685. doi:10.1007/s11192-011-0491-x

Glänzel, W., & Thijs, B., (2011) Using 'core documents' for the representation of clusters and topics. *Scientometrics, 88*(1), 297-309. doi:10.1007/s11192-011-0347-4

Glänzel, W., (2012) Bibliometric Methods for Detecting and Analysing Emerging Research Topics. *PROFESIONAL DE LA INFORMACION,* 21(2), 194–201. doi:10.3145/epi.2012.mar.11

Janssens, F., Glänzel, W. & Moor, B., (2008) A hybrid mapping of information science. *Scientometrics, 75*(3), 607–631. doi:10.1007/s11192-007-2002-7

Kopcsa, A. & Schiebel, E., (1998) Science and technology mapping: A new iteration model for representing multidimensional relationships*. Journal of the American Society for Information Science* 49 (1), 7–17, doi:10.1002/(SICI)1097-4571(1998)49:1<7:AID-ASI3>3.0.CO;2-W.

Persson, O., (1994) The Intellectual base and research fronts of *JASSIS* 1986-1990. JASSIS 45(1): 31-38

Price, D.D., (1965) Networks of scientific papers. *Science*, 149, 510-515

Shibata, N., Kajikawa, Y., Takeda, Y. and Matsushima, K. (2009) Comparative study on methods of detecting research fronts using different types of citation. *JASSIS*, 60: 571–580. doi:10.1002/asi.20994

Schiebel, E. (2015) Mapping the Spreading of Cited References over Research Fronts of Bibliographically Coupled Publications; in: *Proceedings of the 14th International Symposium on Information Science (ISI)*", F. Pehar, C. Schlögl, C. Wolff (ed.); Verlag Werner Hülsbusch, Glückstadt (2015), ISBN: 978-3-940317-81-0; 404 - 409.

Thijs, B., Schiebel, E., & Glänzel, W. (2013) Do second-order similarities provide added-value in a hybrid approach? *Scientometrics, 96*(3), 667-677. doi:10.1007/s11192-012-0896-1

Van Eck, N.J. and Waltman, L. (2010) Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523-538

Yau, C.,K., Porter, A., Newman, N., Suominen, A. (2014) Clustering scientific documents with topic modeling, *Scientometrics* 100: 767. doi:10.1007/s11192-014-1321-8