



Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

# Temporal bibliographic analysis

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**SDA workshop:**

**Advances in data science for big and complex data**

University Paris-Dauphine, January 10-11, 2019

# Outline

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

- 1 Web of science
- 2 WoS networks
- 3 Cited works
- 4 Temporal networks
- 5 Network multiplication
- 6 Examples
  - Authors
  - Citations
  - Journals
  - Keywords
- 7 Bibliography



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**Current version of slides (January 10, 2019 at 13:54):** [slides PDF](#)

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

To the Web of Science (WoS), Clarivate Analytics's multidisciplinary databases of bibliographic information, we put the query

"social network\*"

Additionally, all the articles from the following journals were collected:

Social Networks, Network Science,  
Social Network Analysis and Mining,  
Journal of Complex Networks

Other network-related journals are **not considered** in WoS:

Computational Social Networks, Applied Network Science,  
Online Social Networks and Media, Connections,  
Journal of Social Structure

We limited the search to the Web of Science Core Collection because for other data bases from WoS the CR-fields (containing citation information) can not be exported. The first data set was collected in 2007, second – in June, 2018.

# WoS record

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

PT J  
AU GRANOVET.MS  
TI STRENGTH OF WEAK TIES  
SO AMERICAN JOURNAL OF SOCIOLOGY  
LA English  
DT Article  
C1 JOHNS HOPKINS UNIV, BALTIMORE, MD 21218 USA.  
CR BARNES JA, 1969, SOCIAL NETWORKS URBA  
BECKER MH, 1970, AM SOCIOL REV, V35, P267  
BERSCHEID E, 1969, INTERPERSONAL ATTRAC  
BOISSEVAIN J, 1968, MAN, V3, P542  
BOTT E, 1957, FAMILY SOCIAL NETWOR  
NR 61  
TC 2156  
PU UNIV CHICAGO PRESS  
PI CHICAGO  
PA 5720 S WOODLAWN AVE, CHICAGO, IL 60637  
SN 0002-9602  
J9 AMER J SOCIOl  
JI Am. J. Sociol.  
PY 1973  
VL 78  
IS 6  
BP 1360  
EP 1380  
PG 21  
SC Sociology  
GA P7726  
UT ISI:A1973P772600003  
ER  
SK IP

# Converting WoS data into networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

We applied the program WoS2Pajek 1.5 to the collected data.

The following networks were constructed:

- ① the authorship network  $WA$  on works  $\times$  authors (from the field AU),
- ② the journalship network  $WJ$  on works  $\times$  journals (from the field CR or J9),
- ③ the keywordship network  $WK$  on works  $\times$  keywords (from the field ID or DE or TI),
- ④ the citation network  $Cite$  on works (from the field CR).

We obtained also the following node properties:

- ① the partition  $year$  of works by publication year,
- ② the  $DC$  partition distinguishing between works with complete description ( $DC=1$ ) and the cited only works ( $DC=0$ ),
- ③ the vector of number of pages  $NP$ .

We call a *terminal* node a node without a description in the collected data set – it appears only in the WoS CR field as a reference.

We additionally collected on WoS and Google data for terminal nodes with large indegree in the citation network – highly cited works without description in the collected data set.

If a description of a node was not available in WoS we **manually** constructed a corresponding description **without** CR data (using RIS bibliographic format and converting it to WoS).

As the data set of 2007 was already completed, we made this additional search only for works 2008-\* in July 2018.

# Sizes of Original cleaned and Reduced networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

	# nodes (sum)	# nodes 1	# nodes 2	# arcs
CiteN	1,297,133			2,753,633
<b>CiteR</b>	<b>70,792</b>			398,199
WAn	1,693,104	1,297,133	395,971	1,442,240
<b>WAr</b>	<b>163,803</b>	<b>70,792</b>	<b>93,011</b>	215,901
WKn	1,329,542	1,297,133	32,409	1,167,670
<b>WKr</b>	<b>103,201</b>	<b>70,792</b>	<b>32,409</b>	1,167,666
WJn	1,366,279	1,297,133	69,146	720,044
<b>WJr</b>	<b>79,735</b>	<b>70,792</b>	<b>8,943</b>	61,741

An important property of all these networks is that they share as the first node set the same set of works (papers, reports, books, etc.) – they are *linked*.

## The most cited works - indegree

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

i	freq	id	i	freq	id
1	5348	<b>WASSERMAN_S(1994):</b>	31	734	*NEWMAN_M(2001)98:404
2	4471	<b>GRANOVET_M(1973)78:1360</b>	32	719	*NEWMAN_M(2010):
3	2906	*WATTS_D(1998)393:440	33	701	PORTES_A(1998)24:1
4	2614	*BARABASI_A(1999)286:509	34	687	BLEI_D(2003)3:993
5	2561	<b>FREEMAN_L(1979)1:215</b>	35	670	<b>BURT_R(2004)110:349</b>
6	2447	BOYD_D(2007)13:210	36	654	HANSEN_M(1999)44:82
7	2429	MCPHERSON_M(2001)27:415	37	639	PALLA_G(2005)435:814
8	2330	<b>BURT_R(1992):</b>	38	634	*CLAUSET_A(2004)70:066111
9	1886	<b>COLEMAN_J(1988)94:95</b>	39	629	*BONACICH_P(1987)92:1170
10	1572	*NEWMAN_M(2003)45:167	40	628	ERDOS_P(1959)6:290
11	1520	*GIRVAN_M(2002)99:7821	41	628	UZZI_B(1997)42:35
12	1510	<b>PUTNAM_R(2000):</b>	42	628	<b>ROGERS_E(2003):</b>
13	1285	*ALBERT_R(2002)74:47	43	613	<b>PUTNAM_R(1993):</b>
14	1240	<b>GRANOVET_M(1985)91:481</b>	44	593	BERKMAN_L(1979)109:186
15	1192	SCOTT_J(2000):	45	583	ZACHARY_W(1977)33:452
16	1171	<b>EVERETT_M(2002):</b>	46	572	<b>BORGATTI_S(2009)323:892</b>
17	1166	NEWMAN_M(2004)69:026113	47	569	*NEWMAN_M(2001)64:025102
18	1093	<b>COLEMAN_J(1990):</b>	48	565	<b>BURT_R(2005):</b>
19	1058	STEINFELD_C(2007)12:1143	49	561	ADLER_P(2002)27:17
20	1034	FORTUNATO_S(2010)486:75	50	559	<b>CHRISTAK_N(2008)358:2249</b>
21	999	<b>BORGATTI_S(2002):</b>	51	555	<b>ROGERS_E(1995):</b>
22	945	<b>CHRISTAK_N(2007)357:370</b>	52	554	MILGRAM_S(1967)1:61
23	867	<b>FREEMAN_L(1977)40:35</b>	53	553	BARON_R(1986)51:1173
24	854	<b>HANNEMAN_R(2005):</b>	54	550	<b>GRANOVET_M(1978)83:1420</b>
25	800	<b>LIN_N(2001):</b>	55	539	<b>FISCHER_C(1982):</b>
26	757	KAPLAN_A(2010)53:59	56	537	BRIN_S(1998)30:107
27	756	*BLONDEL_V(2008):P10008	57	524	<b>MARSDEN_P(1990)16:435</b>
28	742	NAHAPIET_J(1998)23:242	58	523	KEMP_D(2003):137
29	740	FORNELL_C(1981)18:39	59	523	KLEINBERG_J(1999)46:604
30	740	*NEWMAN_M(2006)103:8577	60	517	*BOCCALET_S(2006)424:175

Labels ending with : represent books



# Temporal networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

A *temporal network*  $\mathcal{N}_T = (\mathcal{V}, \mathcal{L}, \mathcal{T}, \mathcal{P}, \mathcal{W})$  is obtained by attaching the *time*,  $\mathcal{T}$ , to an ordinary network where  $\mathcal{T}$  is a set of *time points*,  $t \in \mathcal{T}$ .

In a temporal network, nodes  $v \in \mathcal{V}$  and links  $l \in \mathcal{L}$  are not necessarily present or active in all time points. Let  $T(v)$ ,  $T \in \mathcal{P}$ , be the *activity set* of time points for node  $v$  and  $T(l)$ ,  $T \in \mathcal{W}$ , the activity set of time points for link  $l$ .

Besides the presence/absence of nodes and links also their properties can change through time.

# Temporal quantities

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

We introduce a notion of a *temporal quantity*

$$a(t) = \begin{cases} a'(t) & t \in T_a \\ \text{\texttt{X}} & t \in \mathcal{T} \setminus T_a \end{cases}$$

where  $T_a$  is the *activity time set* of  $a$  and  $a'(t)$  is the value of  $a$  in an instant  $t \in T_a$ , and  $\text{\texttt{X}}$  denotes the value *undefined*.

We assume that the values of temporal quantities belong to a set  $A$  which is a *semiring*  $(A, +, \cdot, 0, 1)$  for binary operations  $+$  and  $\cdot$ .

We can extend both operations to the set  $A_{\text{\texttt{X}}} = A \cup \{\text{\texttt{X}}\}$  by requiring that for all  $a \in A_{\text{\texttt{X}}}$  it holds

$$a + \text{\texttt{X}} = \text{\texttt{X}} + a = a \quad \text{and} \quad a \cdot \text{\texttt{X}} = \text{\texttt{X}} \cdot a = \text{\texttt{X}}.$$

The structure  $(A_{\text{\texttt{X}}}, +, \cdot, \text{\texttt{X}}, 1)$  is also a semiring.

# Operations with temporal quantities

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

Let  $A_{\mathbb{R}}(\mathcal{T})$  denote the set of all temporal quantities over  $A_{\mathbb{R}}$  in time  $\mathcal{T}$ . To extend the operations to networks and their matrices we first define the *sum* (parallel links)  $a + b$  as

$$(a + b)(t) = a(t) + b(t) \quad \text{and} \quad T_{a+b} = T_a \cup T_b.$$

The *product* (sequential links)  $a \cdot b$  is defined as

$$(a \cdot b)(t) = a(t) \cdot b(t) \quad \text{and} \quad T_{a \cdot b} = T_a \cap T_b.$$

Let us define the temporal quantities **0** and **1** with requirements  $\mathbf{0}(t) = \emptyset$  and  $\mathbf{1}(t) = 1$  for all  $t \in \mathcal{T}$ . Again, the structure  $(A_{\mathbb{R}}(\mathcal{T}), +, \cdot, \mathbf{0}, \mathbf{1})$  is a semiring.

# Addition of temporal quantities

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

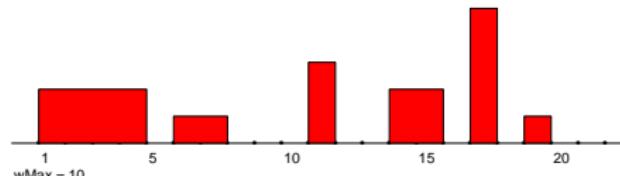
Network  
multiplication

Examples

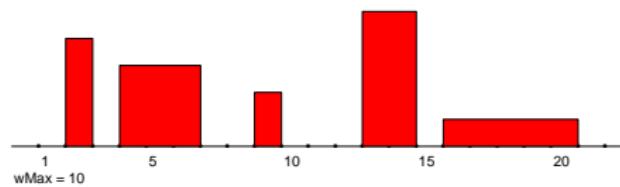
Authors  
Citations  
Journals  
Keywords

Bibliography

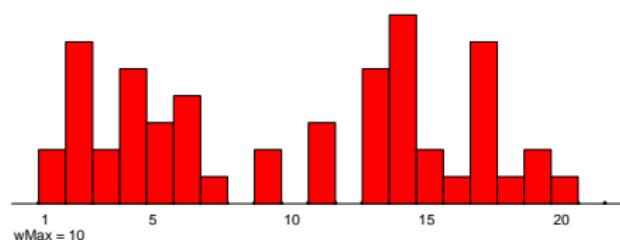
$a :$



$b :$



$a + b :$



# Multiplication of temporal quantities

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

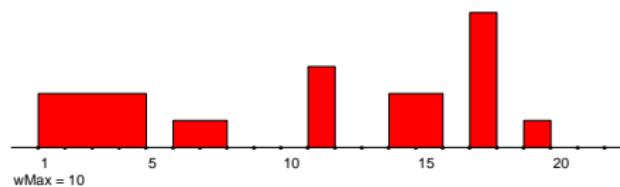
Network  
multiplication

Examples

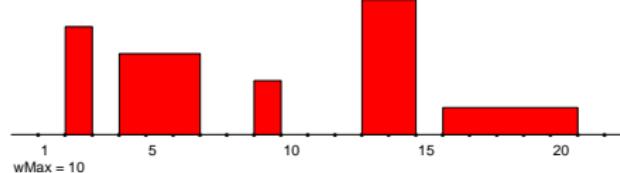
Authors  
Citations  
Journals  
Keywords

Bibliography

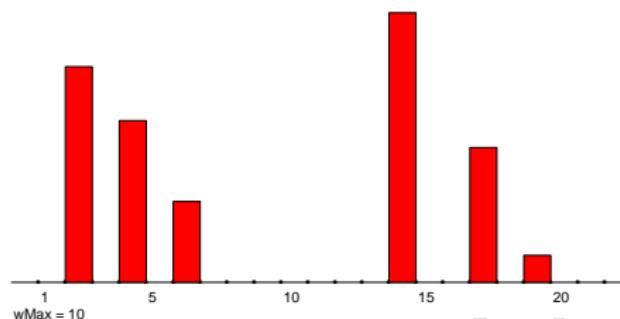
$a :$



$b :$



$a \cdot b :$



# Creating temporal networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

Let the binary matrix  $\mathbf{A} = [a_{ep}]$  describe a two-mode (or one-mode) network on the set of events  $E$  and the set of participants  $P$ :

$$a_{ep} = \begin{cases} 1 & p \text{ participated in the event } e \\ 0 & \text{otherwise} \end{cases}$$

The function  $d : E \rightarrow \mathcal{T}$  assigns to each event  $e$  the date  $d(e)$  when it happened.  $\mathcal{T} = [\text{first}, \text{last}] \subset \mathbb{N}$ . Using these data we can construct two temporal affiliation matrices:

- **instantaneous  $\mathbf{Ai} = [ai_{ep}]$** , where

$$ai_{ep} = \begin{cases} [(d(e), d(e) + 1, 1)] & a_{ep} = 1 \\ [] & \text{otherwise} \end{cases}$$

- **cumulative  $\mathbf{Ac} = [ac_{ep}]$** , where

$$ac_{ep} = \begin{cases} [(d(e), last + 1, 1)] & a_{ep} = 1 \\ [] & \text{otherwise} \end{cases}$$

# Temporal networks in Nets

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

```
>>> net = wdir+"/WAins.json"
>>> WAi = N.loadNetJSON(net)
>>> I = WAi.Index()
>>> I["ERDOS_P(1959)6:290"]
776
>>> WAi._nodes[776]
[{}, {}, {71246: [1091], 89670: [214562]},  
{'mode': 1, 'lab': 'ERDOS_P(1959)6:290', 'act': [[1959, 2019, 1]]}]
>>> WAi._nodes[71246]
[{}, {776: [1091], 11539: [25213], 11540: [25214], 15565: [33820],  
42898: [129167]}, {},  
{'mode': 2, 'lab': 'ERDOS_P', 'act': [[1894, 2019, 1]]}]
>>> WAi._nodes[89670]
[{}, {776: [214562], 15565: [215596]}, {},  
{'mode': 2, 'lab': 'RENYI_A', 'act': [[1894, 2019, 1]]}]
>>> WAi._links[1091]
[776, 71246, True, None, {'tq': [[1959, 1960, 1]]}]
>>> WAi._links[214562]
[776, 89670, True, None, {'tq': [[1959, 1960, 1]]}]
```

# Temporal citation networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

```
gdir = 'C:/Users/batagelj/work/Python/graph/Nets'
wdir = "C:/Users/batagelj/work/Python/WoS/SocNet/2018/Time/cite"
cdir = "C:/Users/batagelj/work/Python/WoS/SocNet/2018/Time/work/chart"
import sys, os, re, datetime, json
sys.path = [gdir]+sys.path; os.chdir(wdir)
from TQ import *
from Nets import Network as N
Ci = N.loadNetJSON(wdir+"/CiteIns.json")
Cu = N.loadNetJSON(wdir+"/CiteCum.json")
L = [ "#WASSERMA_S(1994):", "#GRANOVET_M(1973)78:1360", "WATTS_D(1998)393:440",
      "BARABASI_A(1999)286:509", "FREEMAN_L(1979)1:215", "#BOYD_D(2007)13:210",
      "MCPHERSO_M(2001)27:415", "BURT_R(1992):" ]
I = Ci.Index()
-----
>>> I["#WASSERMA_S(1994):"]
33
>>> TCin = [ (u, Ci.TQnetInDeg(I[u])) for u in L ]
>>> TCuin = [ (u, Cu.TQnetInDeg(I[u])) for u in L ]
>>> TCin[0]
('#WASSERMA_S(1994):', [(1994, 1995, 2), (1995, 1996, 7), (1996, 1997, 12), (1997, 1998, 23),
(1998, 1999, 26), (1999, 2000, 41), (2000, 2001, 31), (2001, 2002, 54), (2002, 2003, 38),
(2003, 2004, 64), (2004, 2005, 76), (2005, 2006, 85), (2006, 2007, 103), (2007, 2008, 220),
(2008, 2009, 238), (2009, 2010, 313), (2010, 2011, 364), (2011, 2012, 424), (2012, 2013, 459),
(2013, 2014, 438), (2014, 2015, 504), (2015, 2016, 579), (2016, 2017, 552), (2017, 2018, 528),
(2018, 2019, 167)])
>>> TCuin[0]
('#WASSERMA_S(1994):', [(1994, 1995, 2), (1995, 1996, 9), (1996, 1997, 21), (1997, 1998, 44),
(1998, 1999, 70), (1999, 2000, 111), (2000, 2001, 142), (2001, 2002, 196), (2002, 2003, 234),
(2003, 2004, 298), (2004, 2005, 374), (2005, 2006, 459), (2006, 2007, 562), (2007, 2008, 782),
(2008, 2009, 1020), (2009, 2010, 1333), (2010, 2011, 1697), (2011, 2012, 2121),
(2012, 2013, 2580), (2013, 2014, 3018), (2014, 2015, 3522), (2015, 2016, 4101),
(2016, 2017, 4653), (2017, 2018, 5181), (2018, 2019, 5348)])
>>> w = 800; h = 500
>>> p=0; (Tmin,Tmax,tt,TQmax) = TQ.TqSummary(TCin[p][1]); tit = TCin[p][0]
>>> N.TQshow(TCin[p][1],cdir,TQmax,Tmin,Tmax,w,h,tit,fill='red')
```

# Temporal citation networks

Citations to “weak ties” through time

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

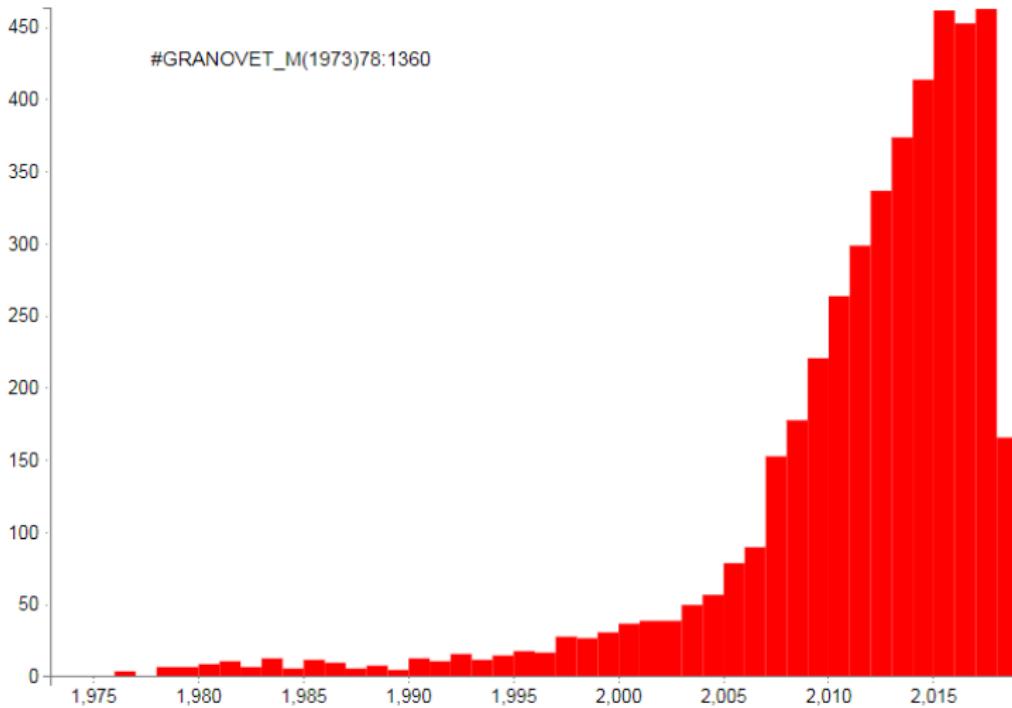
Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography



# Authors Collaboration

## Network Co

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

$$\mathbf{Co} = \mathbf{WA}^T * \mathbf{WA}$$

The weight of the edges between the nodes  $i$  and  $j$  is equal to total number of works author  $i$  and  $j$  wrote together.

The values of loops in **Co** are equal to the total number of works that each author have (which is also equal to the indegree values of the **WA** network).

The proposed approach has some *limitations*, such as the overrating of the contribution of works with many authors. To make the contribution of each work equal we have to use the normalized version  $n(\mathbf{WA})$  of the network (matrix) (*fractional approach*)

$$n(\mathbf{WA})[w, a] = \frac{\mathbf{WA}[w, a]}{\max(1, \text{outdeg}[w])}$$

# Multiplication of networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

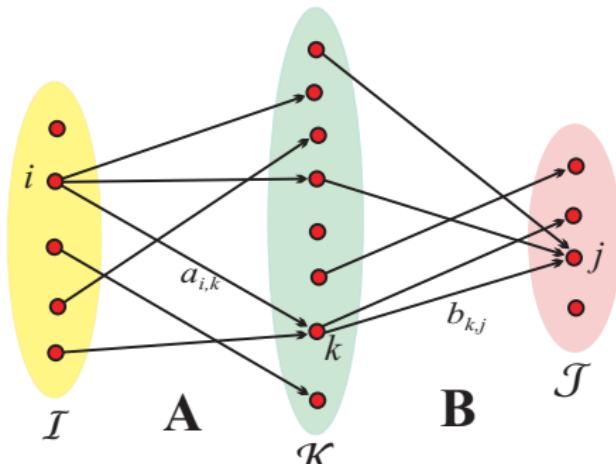
Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography



$$c_{i,j} = \sum_{k \in N_{\mathcal{A}}(i) \cap N_{\mathcal{B}}^-(j)} a_{i,k} \cdot b_{k,j}$$

If all weights in networks  $\mathcal{A}$  and  $\mathcal{B}$  are equal to 1 the value of  $c_{i,j}$  counts the number of ways we can go from  $i \in \mathcal{I}$  to  $j \in \mathcal{J}$  passing through  $\mathcal{K}$ .

# Derived networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

$$\mathbf{AK} = \mathbf{WA}^T * \mathbf{WK}$$

The weight of the arc from the node  $a$  to the node  $k$  is equal to the number of works in which the author  $a$  used the keyword  $k$ .

$$\mathbf{CiteJ} = (\mathbf{WJ})^T * \mathbf{Cite} * \mathbf{WJ}$$

the value of weight of the element  $[u,v]$  is equal to the **number of citations** from journal  $i$  to journal  $j$ .

$$\mathbf{CiteAn} = (\mathbf{WA})^T * n(\mathbf{Cite}) * \mathbf{WA}$$

The value of element  $\text{CiteAn}[u,v]$  is equal to the number of **fractional contribution** of citations from works coauthored by  $u$  to works coauthored by  $v$ .

etc.

# Multiplication of co-occurrence networks

## Instantaneous

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

Instantaneous **A** on  $P \times A$  and **B** on  $P \times B$ .  $\mathbf{C} = \mathbf{A}^T \cdot \mathbf{B}$  on  $A \times B$ .

$$c_{ij}(t) = \sum_{p \in P} a_{pi}(t)^T \cdot b_{pj}(t)$$

$a_{pi} = [(d_{pi}, d_{pi} + 1, v_{pi})]$  and  $b_{pj} = [(d_{pj}, d_{pj} + 1, v_{pj})]$   
for  $t = d$  we get

$$c_{ij} = [(d, d + 1, \sum_{p \in P: d_{pi}=d_{pj}=d} v_{pi} \cdot v_{pj})]_{d \in \mathcal{T}}$$

for  $v_{pi} = v_{pj} = 1$  we finally get

$$v_{ij}(d) = |\{p \in P : d_{pi} = d_{pj} = d\}|$$

For binary temporal two-mode networks **A** and **B** the value  $v_{ij}(d)$  of the product  $\mathbf{A}^T \cdot \mathbf{B}$  is equal to the number of different members of  $P$  with which both  $i$  and  $j$  have contact in the instant  $d$ .

# Multiplication of co-occurrence networks

## Cumulative

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples  
Authors  
Citations  
Journals  
Keywords

Bibliography

Cumulative **A** on  $P \times A$  and **B** on  $P \times B$ .  $\mathbf{C} = \mathbf{A}^T \cdot \mathbf{B}$  on  $A \times B$ .

$$c_{ij}(t) = \sum_{p \in P} a_{pi}(t)^T \cdot b_{pj}(t)$$

$a_{pi} = [(d_{pi}, \text{last} + 1, v_{pi})]$  and  $b_{pj} = [(d_{pj}, \text{last} + 1, v_{pj})]$   
for  $t = d$  we get

$$c_{ij} = [(d, d + 1, \sum_{p \in P: (d_{pi} \leq d) \wedge (d_{pj} \leq d)} v_{pi} \cdot v_{pj})]_{d \in \mathcal{T}}$$

for  $v_{pi} = v_{pj} = 1$  we finally get

$$v_{ij}(d) = |\{p \in P : (d_{pi} \leq d) \wedge (d_{pj} \leq d)\}|$$

For binary temporal two-mode networks **A** and **B** the value  $v_{ij}(d)$  of the product  $\mathbf{A}^T \cdot \mathbf{B}$  is equal to the number of different members of  $P$  with which both  $i$  and  $j$  have contact in all instants up to including the instant  $d$ .

# Temporal networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

Using the **Temporal quantities approach** [Batagelj and Praprotnik, 2016] and Python packages **Nets.py** and **TQ.py**, out of the reduced networks **WAr**, **WJr**, **WKr**, and **CiteR** we constructed the set of temporal networks of two types – *instantaneous* (with values given per each year) and *cumulative* (with cumulative values over the years) in .json format. These are the networks **WAins**, **WAcum**, **WJins**, **WJcum**, **WKrins**, **WKcum**, and **CiteIns**, **CiteCum**.

These temporal networks were used for construction of other **derived** temporal networks.

# Temporal networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

Example of node with temporal quantities - *instantaneous*:

```
['NEWMAN_M', [(1999, 2000, 2), (2000, 2001, 4), (2001, 2002, 9),  
(2002, 2003, 10), (2003, 2004, 9), (2004, 2005, 15), (2005, 2006, 7),  
(2006, 2007, 13), (2007, 2008, 4), (2008, 2009, 1), (2009, 2010, 2),  
(2010, 2011, 3), (2016, 2017, 2)]]
```

Example of node with temporal quantities - *cumulative*:

```
['NEWMAN_M', [(1999, 2000, 2), (2000, 2001, 6), (2001, 2002, 15),  
(2002, 2003, 25), (2003, 2004, 34), (2004, 2005, 49), (2005, 2006, 56),  
(2006, 2007, 69), (2007, 2008, 73), (2008, 2009, 74), (2009, 2010, 76),  
(2010, 2016, 79), (2016, 2019, 81)]]
```

# Number of publications for selected authors

## Indegree of WAins network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

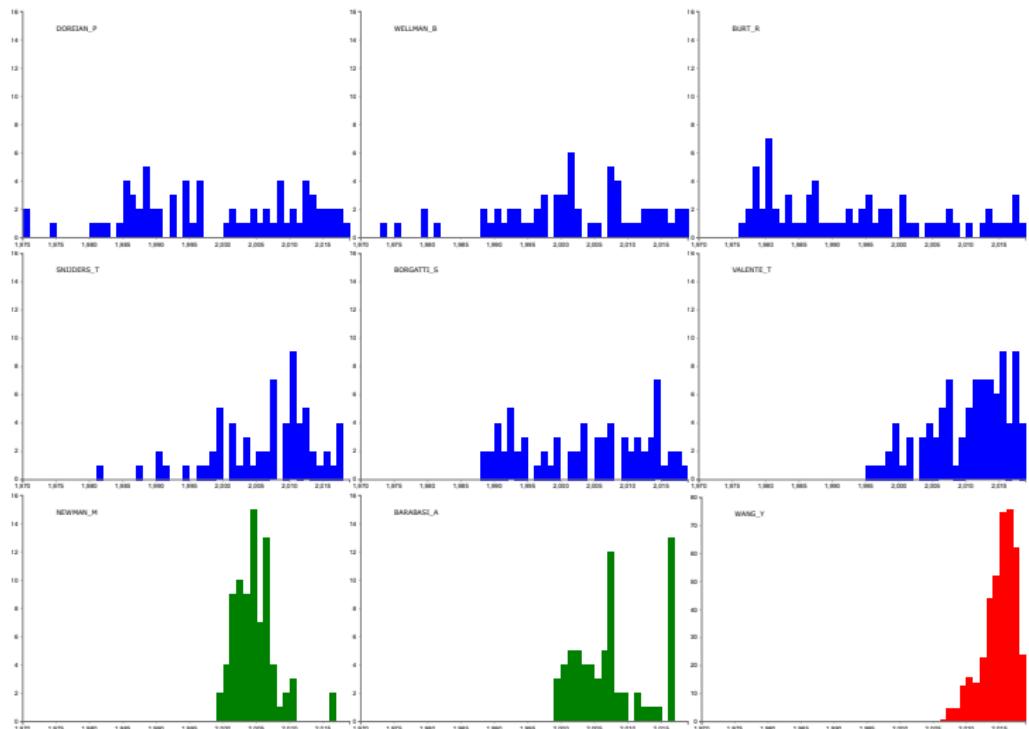
Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography



# Number of publications for selected authors

## Indegree from WAcum network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

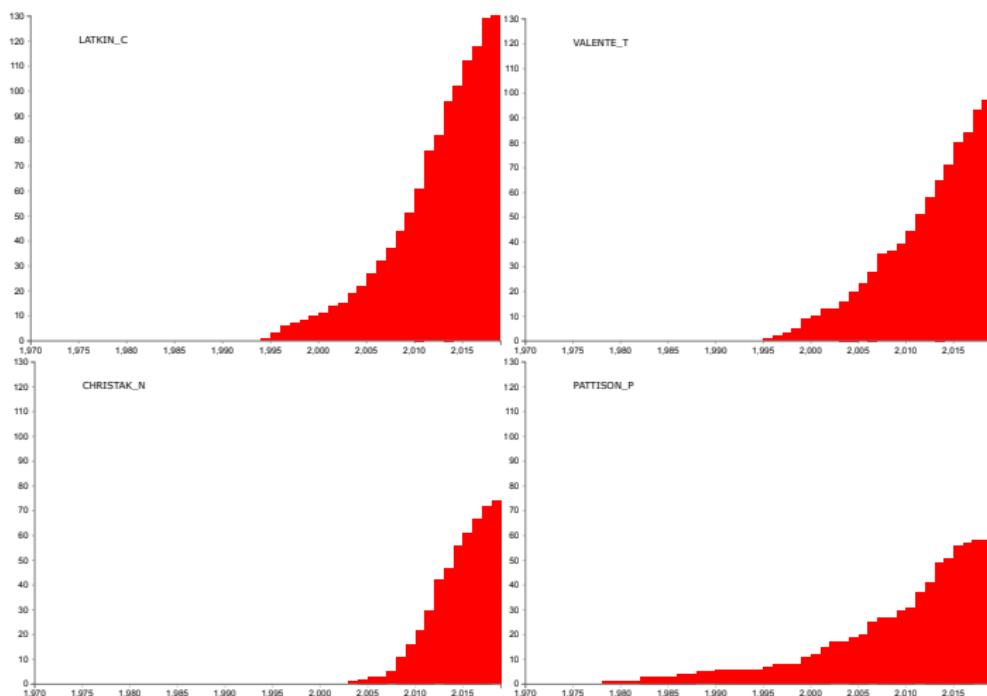
Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography



# Temporal co-authorship networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

## The matrices

$$\mathbf{Colns} = \mathbf{WAins}^T \cdot \mathbf{WAins} \quad \text{and} \quad \mathbf{CoCum} = \mathbf{WAcum}^T \cdot \mathbf{WAcum}$$

describe the instantaneous co-authorship temporal network and the cumulative co-authorship temporal network, counting the number of works two authors wrote together.

# Collaboration networks CCn and CCtt

Constructed from WAins and WAcum networks

$$n(\mathbf{WAcum})[w, a] = \frac{\mathbf{WAcum}[w, a]}{\max(1, \text{outdeg}(w))}$$

then

$$\mathbf{CCn} = (\mathbf{WAcum})^T * n(\mathbf{WAcum}),$$

The weight of the edges between the nodes (authors) is equal to the contribution of author  $i$  to works, that he or she wrote together with author  $j$ .

$$n'(\mathbf{WAins})[w, a] = \frac{\mathbf{WAins}[w, a]}{\max(1, \text{outdeg}(w) - 1)}$$

then

$$\mathbf{CCtt} = n(\mathbf{WAins})^T * n'(\mathbf{WAins}),$$

The weights of the edges between the nodes (authors) are equal to the total contribution of “strict collaboration” of authors  $i$  and  $j$  to works they wrote together.

# Temporal collaborativeness for selected authors from Collaboration network CCn

## Temporal bibliographic analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

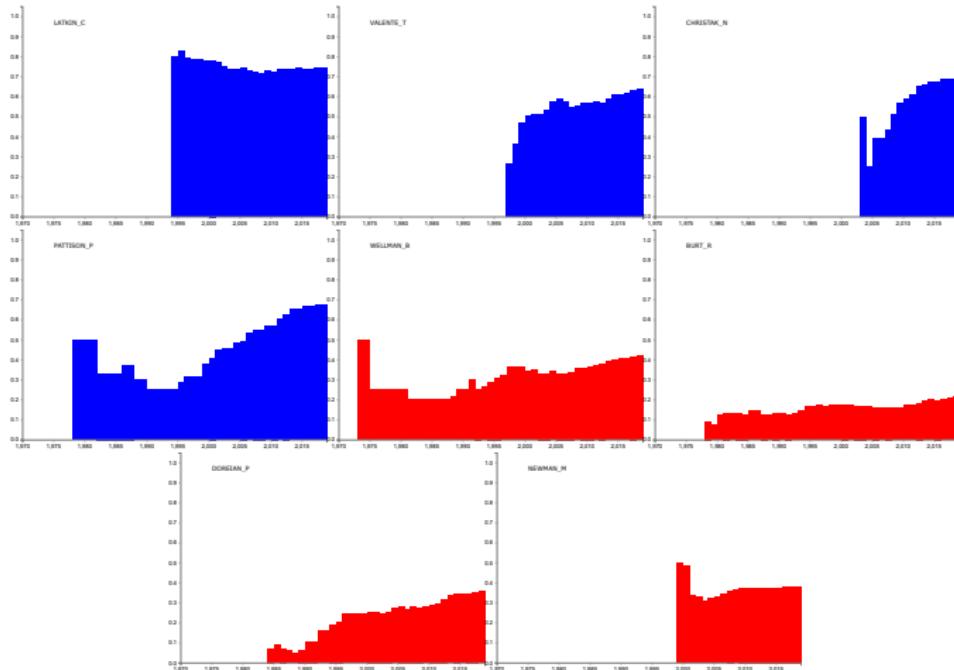
Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography



# Strict temporal collaboration for selected authors from Collaboration network CCtt

## Temporal bibliographic analysis

V. Batagelj,  
D. Maltseva

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science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

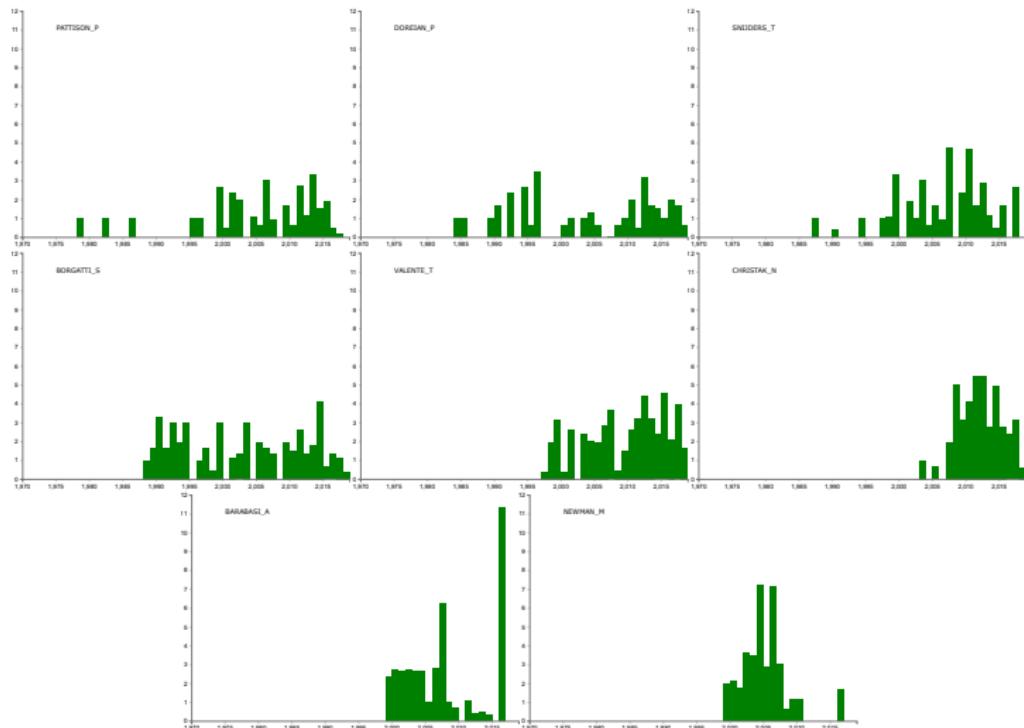
Authors

Citations

Journals

Keywords

Bibliography



# Temporal citation networks

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

A citation matrix  $\mathbf{Ci}$  describes the citation relation  $p$  cites  $q$ . Note that  $p$  cites  $q \Rightarrow d(p) \geq d(q)$ .

Then we can construct its instantaneus version  $\mathbf{Cii}$ :

$$cii_{pq} = [(d(p), d(p) + 1, 1)] \quad \text{iff} \quad ci_{pq} = 1$$

and its cumulative version  $\mathbf{Cic}$ :

$$cic_{pq} = [(d(p), last + 1, 1)] \quad \text{iff} \quad ci_{pq} = 1$$

Temporal versions of:

Bibliographic coupling  $\mathbf{biCo} = \mathbf{Ci} \cdot \mathbf{Ci}^T$ .

Co-citation  $\mathbf{coCi} = \mathbf{Ci}^T \cdot \mathbf{Ci}$ .

Citations between authors  $\mathbf{Ca} = \mathbf{WA}^T \cdot \mathbf{Ci} \cdot \mathbf{WA}$ .

$$\mathbf{ACA} = \mathbf{WAi}^T \cdot \mathbf{Cii} \cdot \mathbf{WAc}$$

# Citations among authors

ACA and ACAn nets from WAins, WAcum and CiteIns nets

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

Keywords

Bibliography

$$\mathbf{ACA} = (\mathbf{WAins})^T * \mathbf{CiteIns} * \mathbf{WAcum}$$

The value of weight of the element  $ACA[u, v]$  is equal to the **number of citations** per year from works coauthored by  $u$  to works coauthored by  $v$ .

$$\mathbf{ACAn} = (\mathbf{WAins})^T * n(\mathbf{CiteIns}) * \mathbf{WAcum}$$

where

$$n(\mathbf{CiteIns})[u, v] = \frac{\mathbf{CiteIns}[u, v]}{\max(1, \text{outdeg}(u))}$$

The value of element  $ACAn[u, v]$  is equal to the number of **fractional contribution** of citations per year from works coauthored by  $u$  to works coauthored by  $v$ .

# Self-citations for selected authors

## Loops from ACA network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

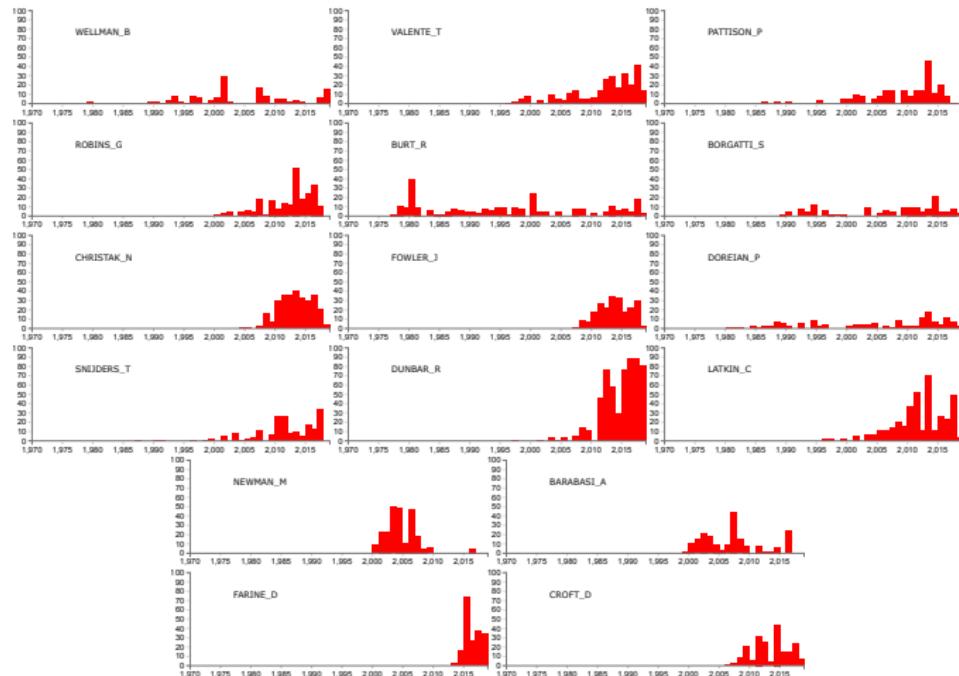
Authors

Citations

Journals

Keywords

Bibliography



# Citations between authors with largest link weights from ACA network with extracted loops

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

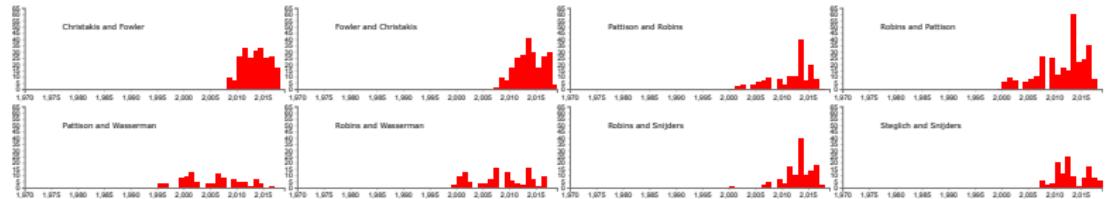
Citations

Journals

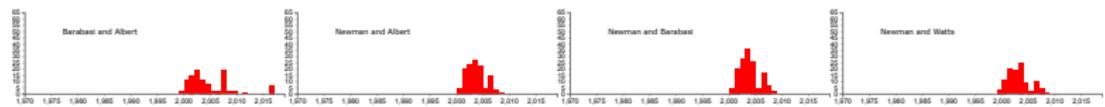
Keywords

Bibliography

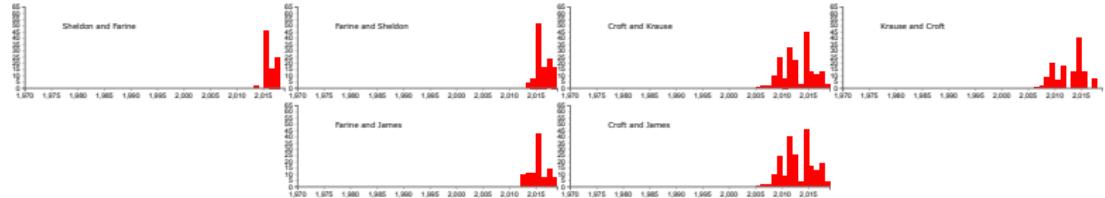
## Social Sciences



## Physics



## Animal social networks



# Outgoing citations for selected authors from ACAn network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

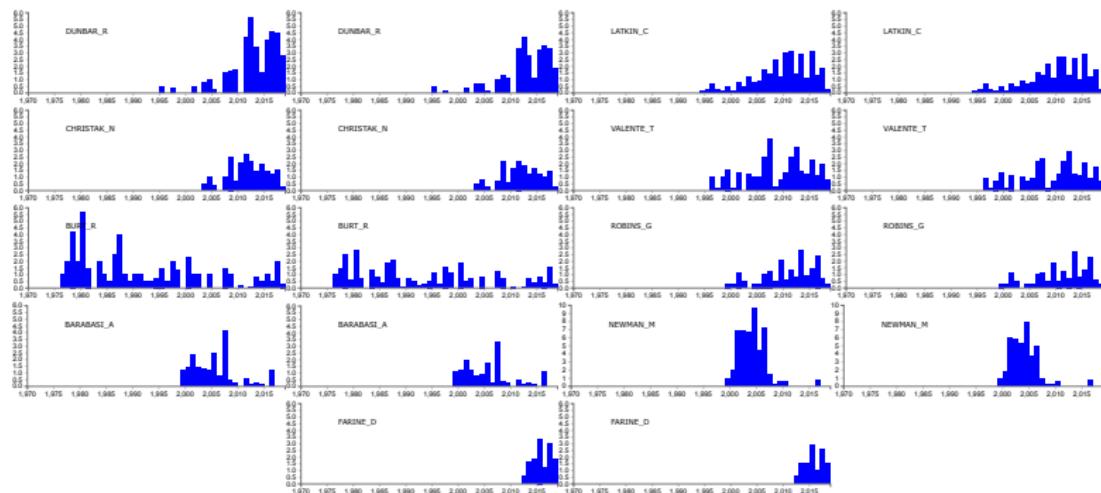
Citations

Journals

Keywords

Bibliography

## OutSum of ACAn: how much authors are cited by a selected author



# Incoming citations for selected authors from ACAn network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

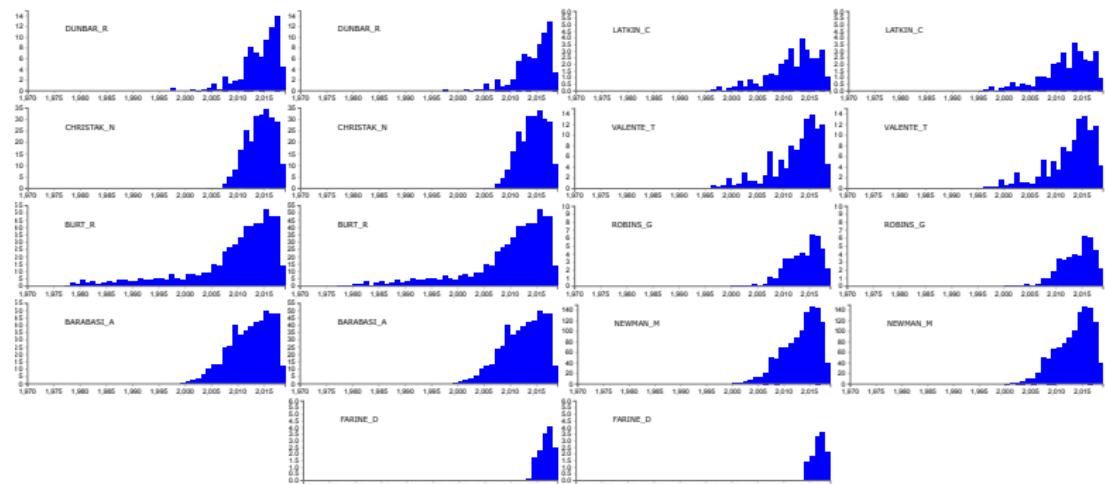
Citations

Journals

Keywords

Bibliography

InSum of ACAn: how much authors cite selected authors  
(note different scales)



# Number of journals and papers from WJins network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

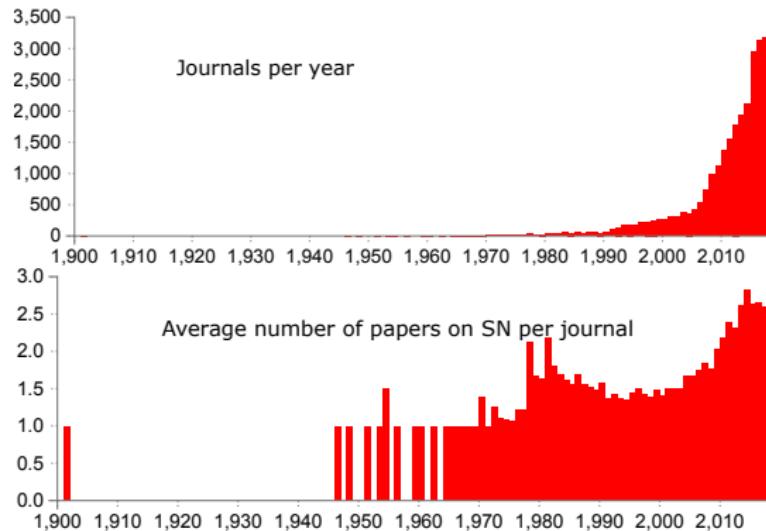
Authors

Citations

Journals

Keywords

Bibliography



We counted a proportion of the *Number of works* published in each journal in each year and the *Maximum number of papers* published per year (in any journal). This proportions aims to normalize the input of the selected journal in each year in range from 0 to 100% and shows their importance through time.

# Importance of SNA journals from WJins norm network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

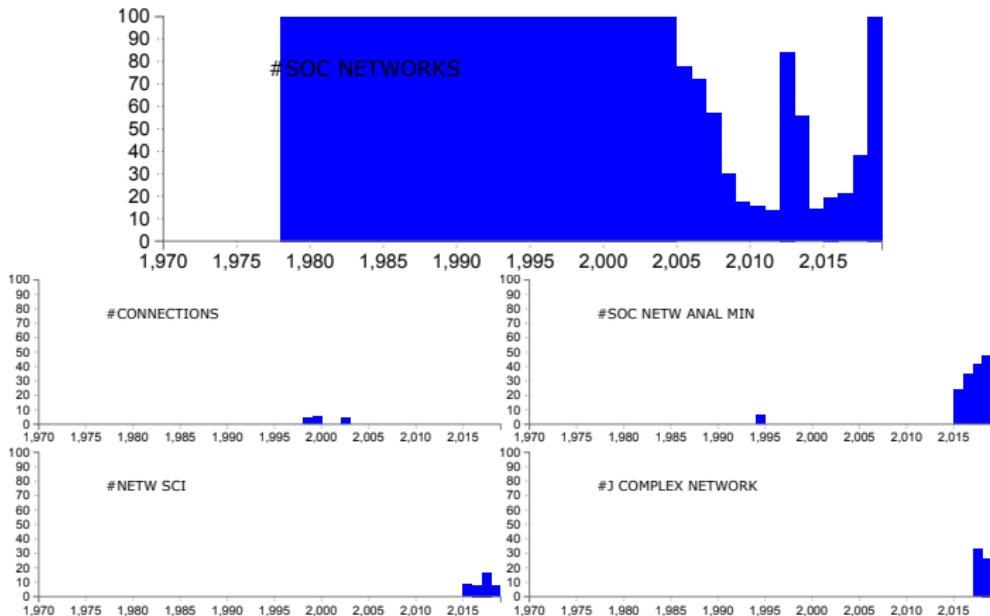
Authors

Citations

Journals

Keywords

Bibliography



# Importance of journals in Social Sciences from WJins norm network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

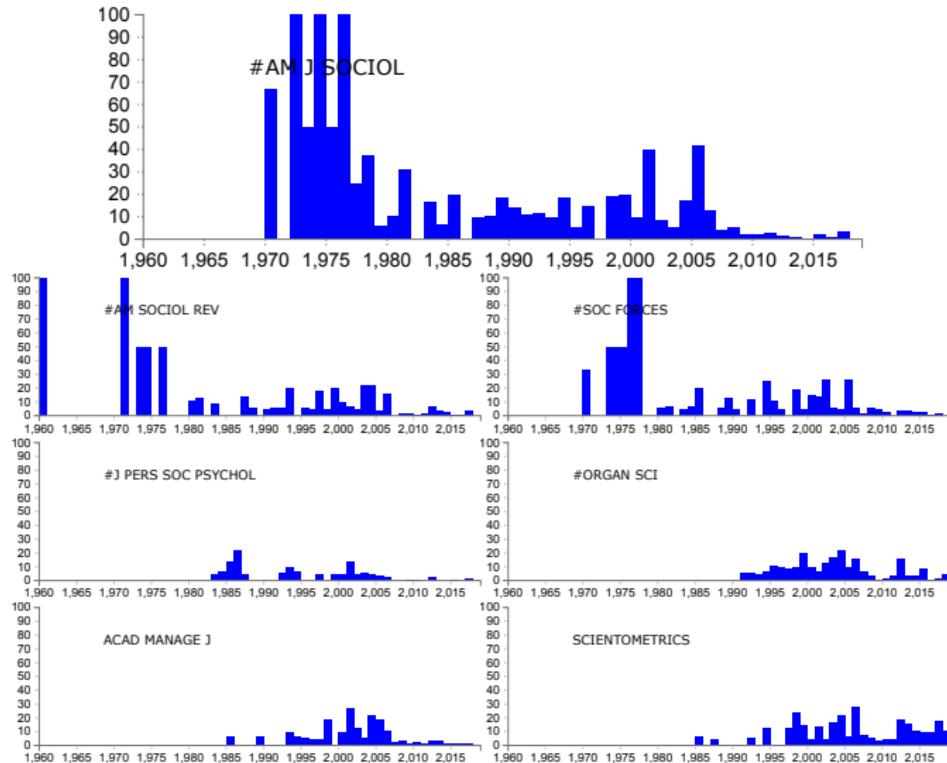
Authors

Citations

Journals

Keywords

Bibliography



# Importance of other journals from WJins norm network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

Citations

Journals

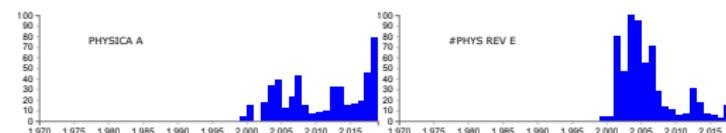
Keywords

Bibliography

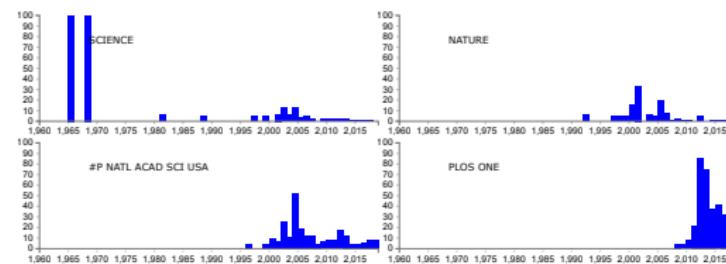
## Computer Science



## Physics



## General scientific journals



# Importance of other journals from WJins norm network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

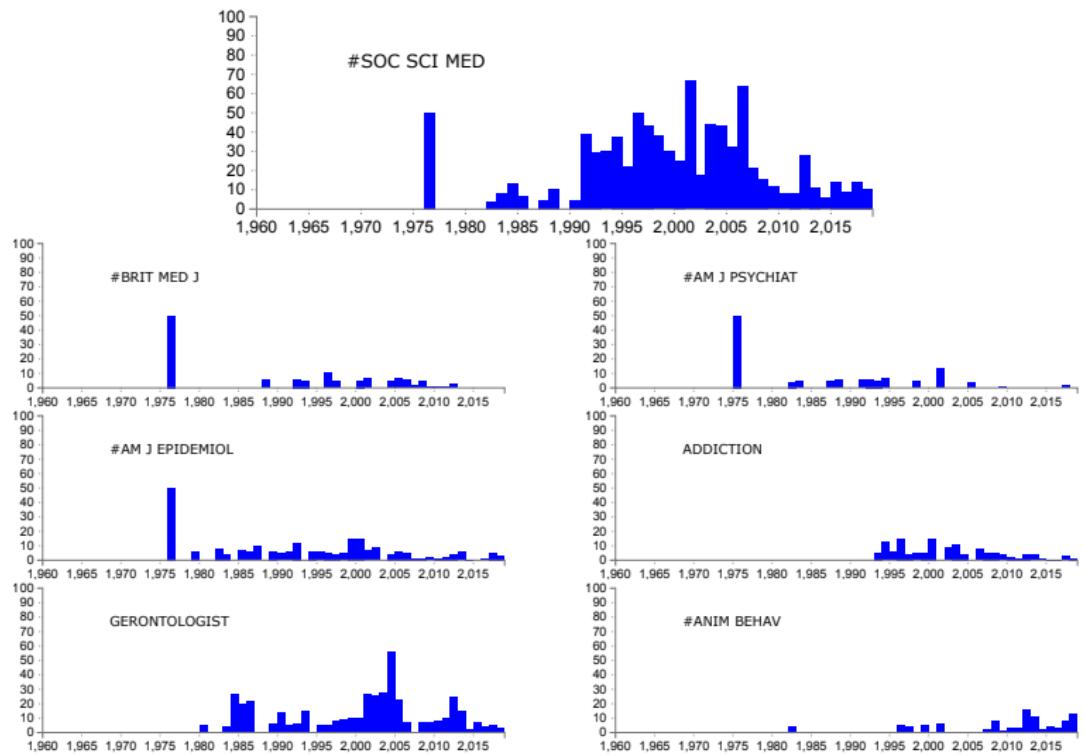
Authors

Citations

Journals

Keywords

Bibliography



# Citations among journals

JCJ and JCJn from WJins, WJcum, CiteIns nets

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography

$$\mathbf{JCJ} = (\mathbf{WJins})^T * \mathbf{CiteIns} * \mathbf{WJcum}$$

The value of weight of the element  $JCJ[i,j]$  is equal to the **number of citations** per year from journal  $i$  to journal  $j$ .

$$\mathbf{JCJn} = (\mathbf{WJins})^T * n(\mathbf{CiteIns}) * \mathbf{WJcum}$$

where

$$n(\mathbf{CiteIns})[u, v] = \frac{\mathbf{CiteIns}[u, v]}{\max(1, \text{outdeg}(u))}$$

The value of element  $JCJn[i,j]$  is equal to the number of **fractional contribution** of citations per year from journal  $i$  to journal  $j$ .

# Self-citations of journals

## Loops from JCJ network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

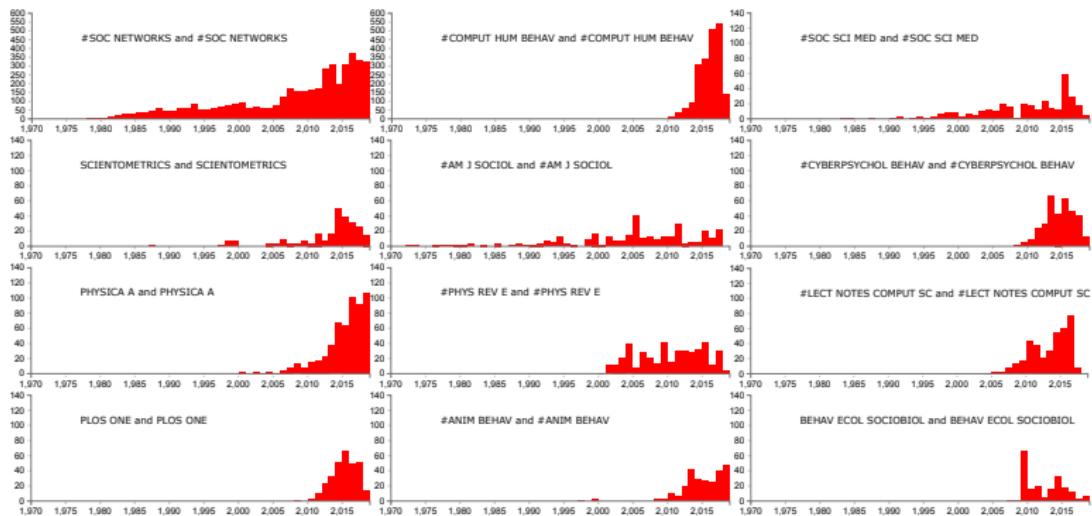
Authors

Citations

Journals

Keywords

Bibliography



# Citations of Social Networks journal InSum and OutSum of JCJ network without loops

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

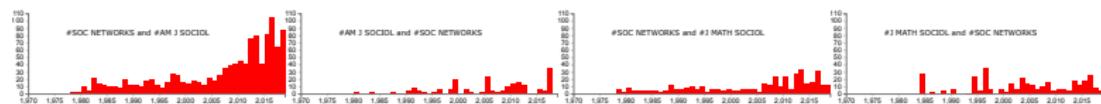
Citations

Journals

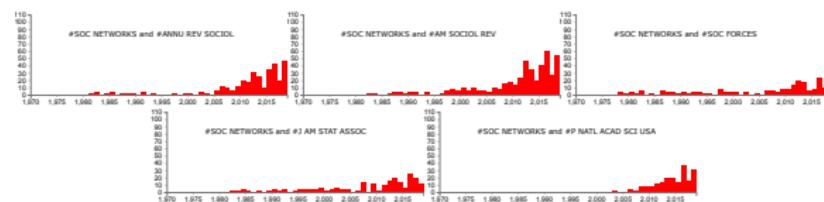
Keywords

Bibliography

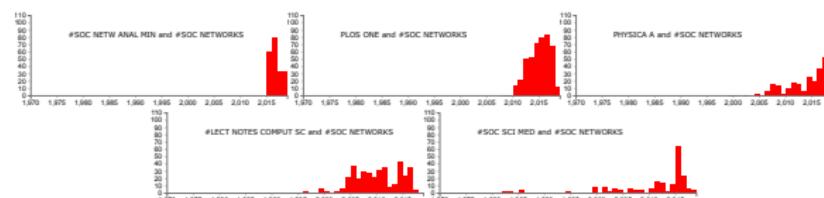
## OutSum and InSum:



## OutSum:



## InSum:



# Citation of general scientific journals from JCJ network without loops

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

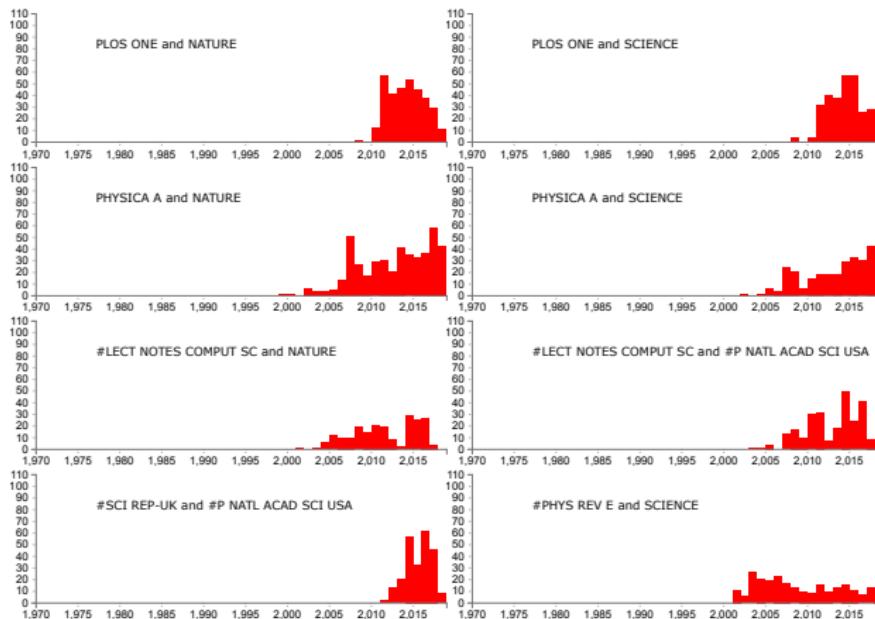
Authors

Citations

Journals

Keywords

Bibliography



# Citations of other journals from JCJ network without loops

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

Authors

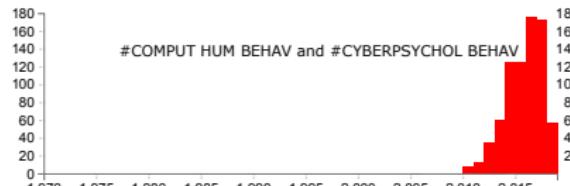
Citations

Journals

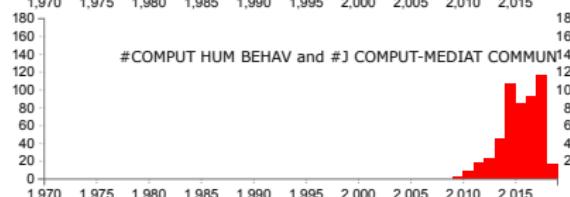
Keywords

Bibliography

## Computer Science:

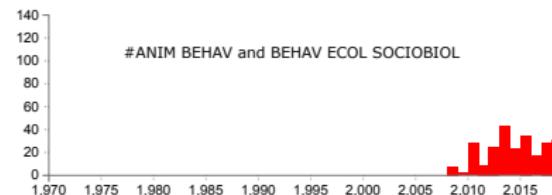


#CYBERPSYCHOL BEHAV and #COMPUT HUM BEHAV



#COMPUT HUM BEHAV and PERS INDIV DIFFER

## Animal social networks:



#ANIM BEHAV and BEHAV ECOL SOCIOBIOL

# Outgoing citations with/without loops from JCJn network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

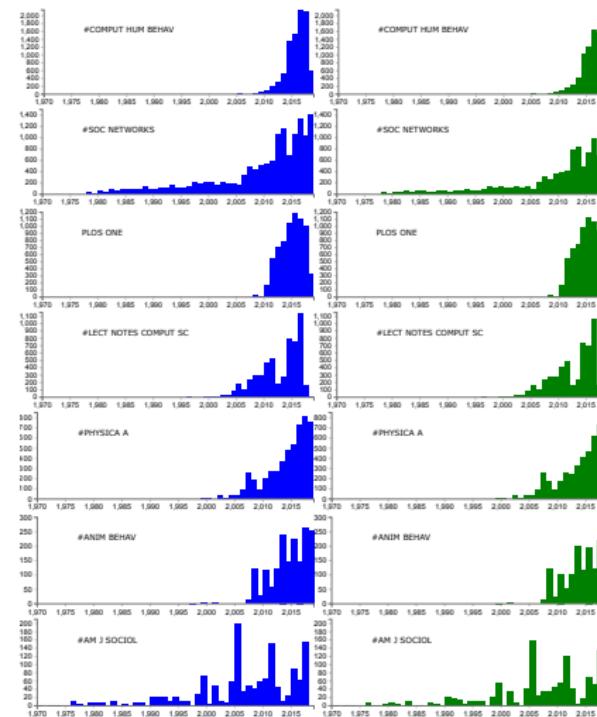
Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography



# Incoming citations with/without loops from JCJn network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

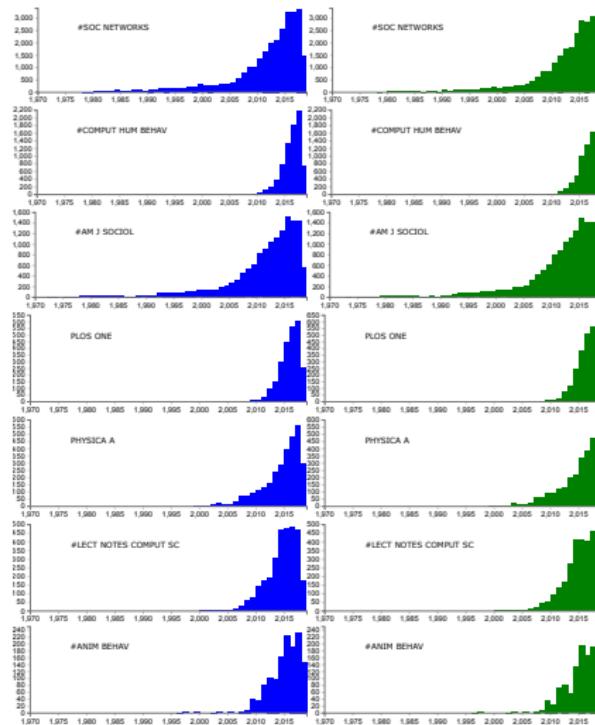
Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography



# Number of keywords from WKins network

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

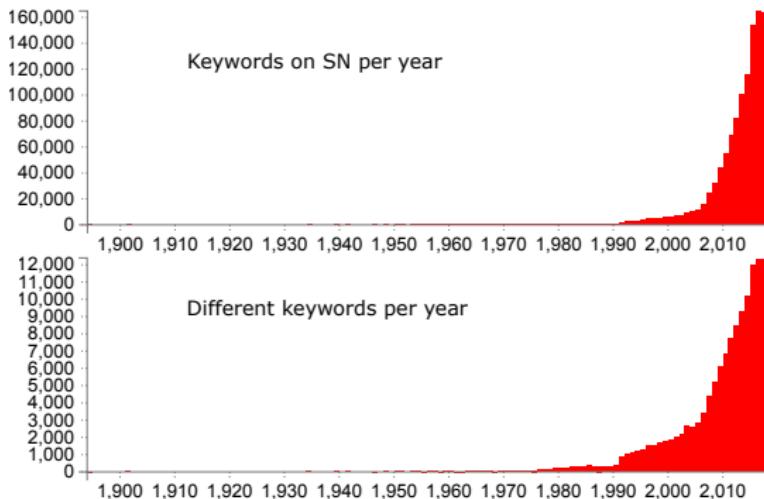
Authors

Citations

Journals

Keywords

Bibliography



Basing on **WKins** network, we counted a proportion of the *Number of each keyword* per year and the *Maximum number of keywords* for each year. This proportions aims to normalize the importance of selected keywords through time in range from 0 to 100%.

# Importance of selected keywords from WKins network [100 scale]

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

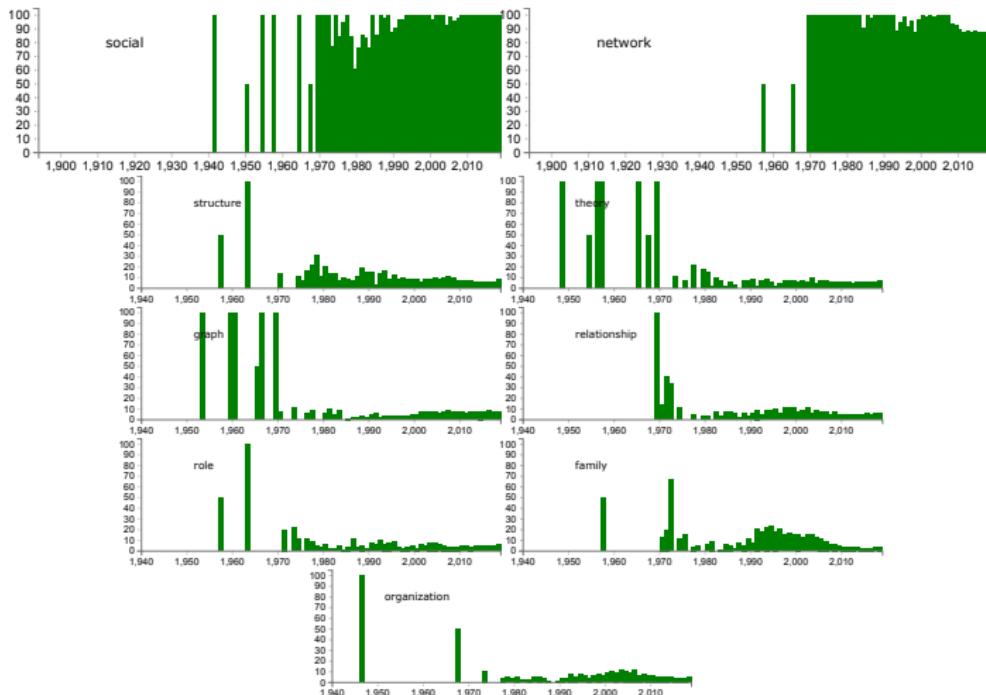
Authors

Citations

Journals

Keywords

Bibliography



# Importance of selected keywords from WKins network [50 scale]

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

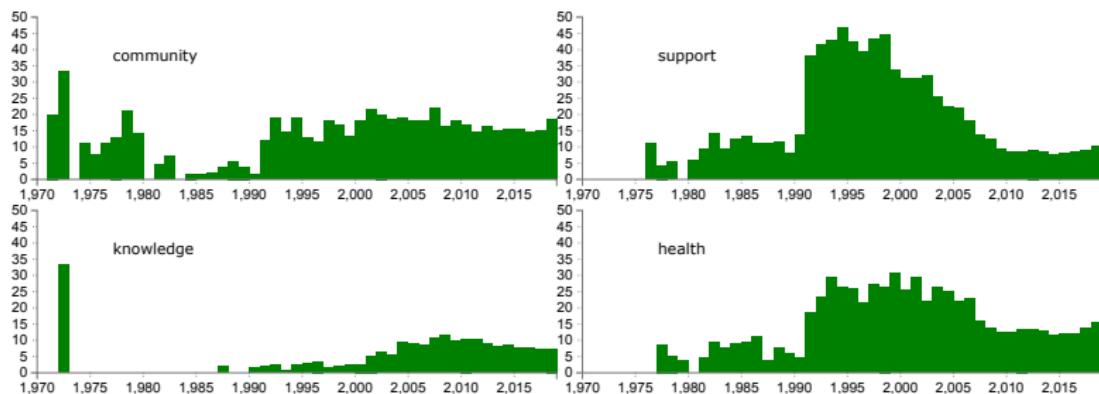
Temporal  
networks

Network  
multiplication

Examples

Authors  
Citations  
Journals  
Keywords

Bibliography



# Importance of selected keywords from WKins network [30 scale]

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

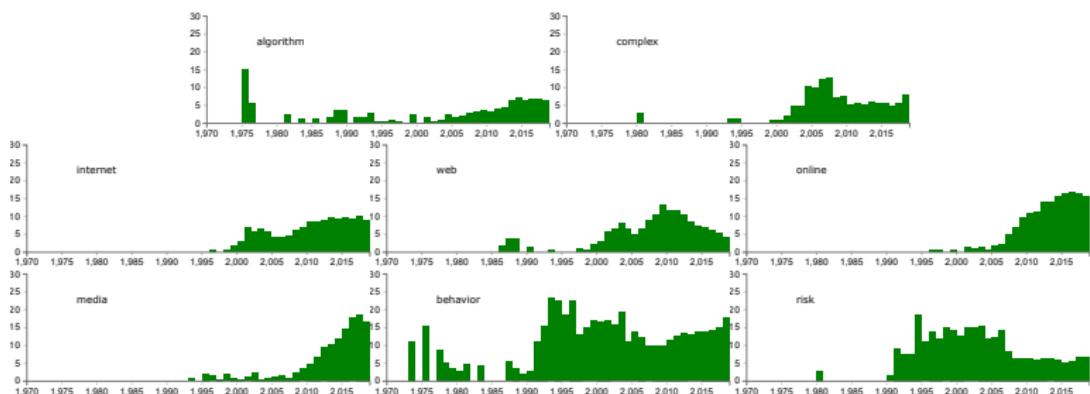
Authors

Citations

Journals

Keywords

Bibliography



# Importance of selected keywords from WKins network [14 and 10 scale]

Temporal  
bibliographic  
analysis

V. Batagelj,  
D. Maltseva

Web of  
science

WoS networks

Cited works

Temporal  
networks

Network  
multiplication

Examples

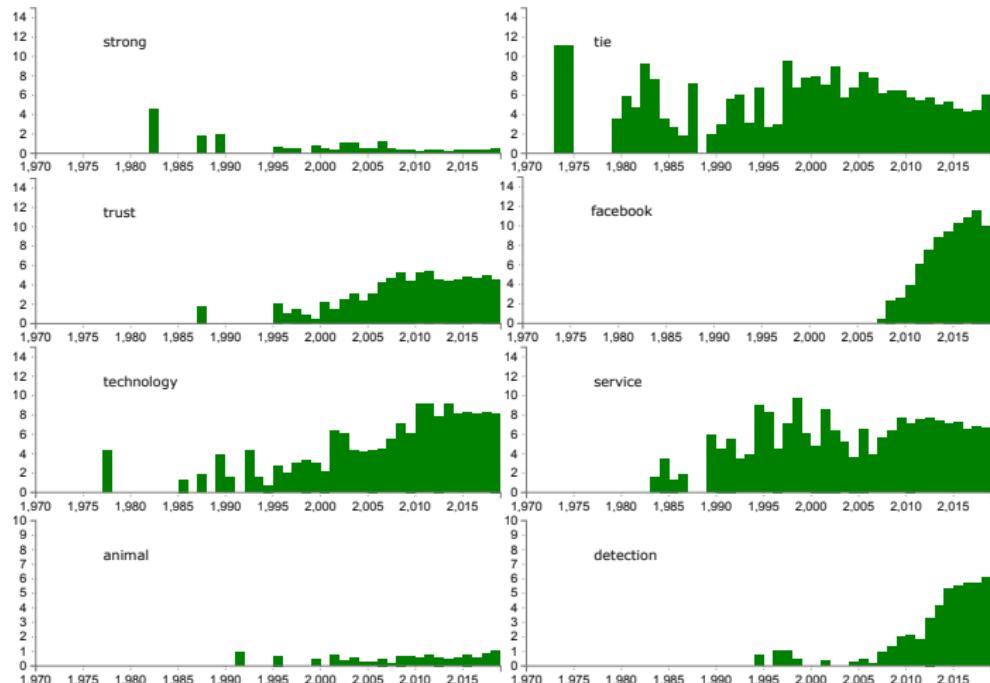
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# Bibliography I

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WoS networks

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Examples  
Authors  
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Keywords

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Temporal  
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WoS networks

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networks

Network  
multiplication

Examples  
Authors  
Citations  
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