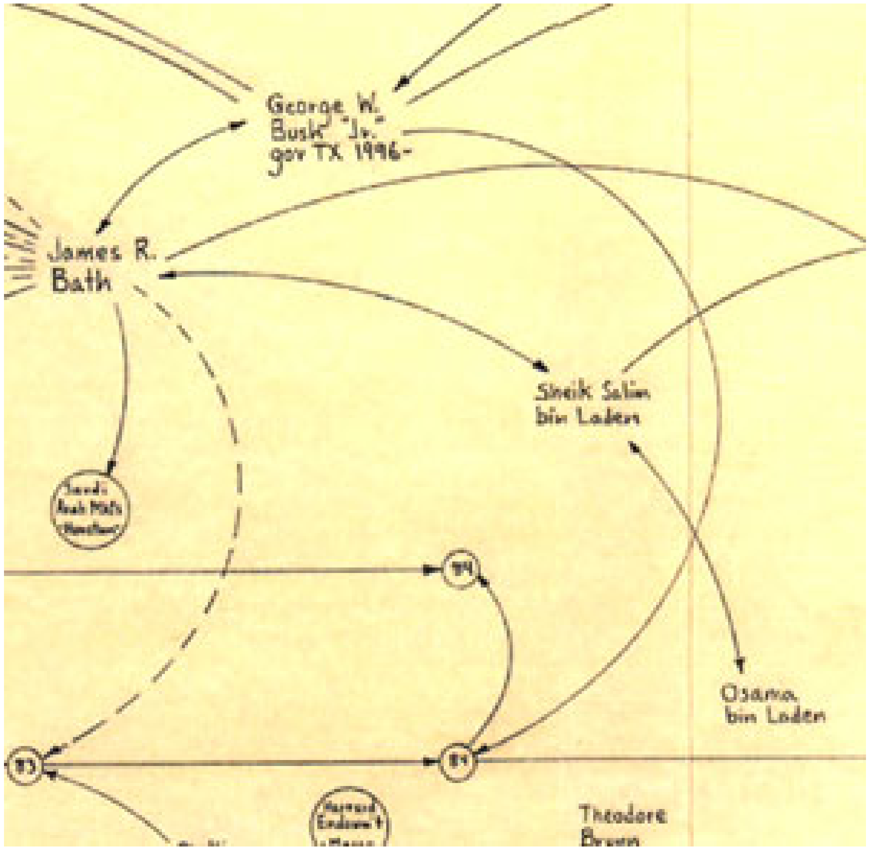

Mark Lombardi

Network Analysis
Sources of Networks

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ECPR Summer School, July 30 – August 16, 2008

Faculty of Social Sciences, University of Ljubljana

version: August 5, 2008 / 02 : 03

Outline

Sociograph

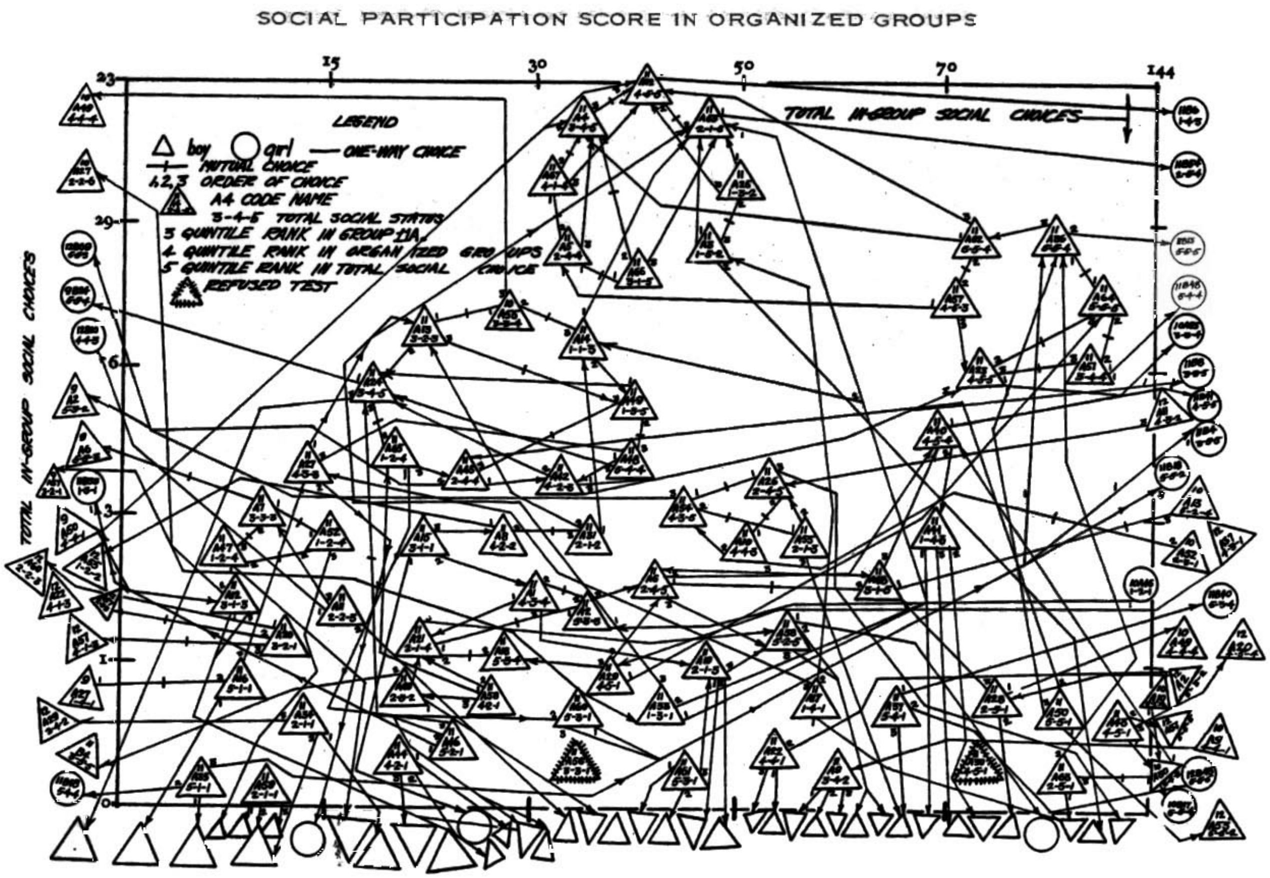
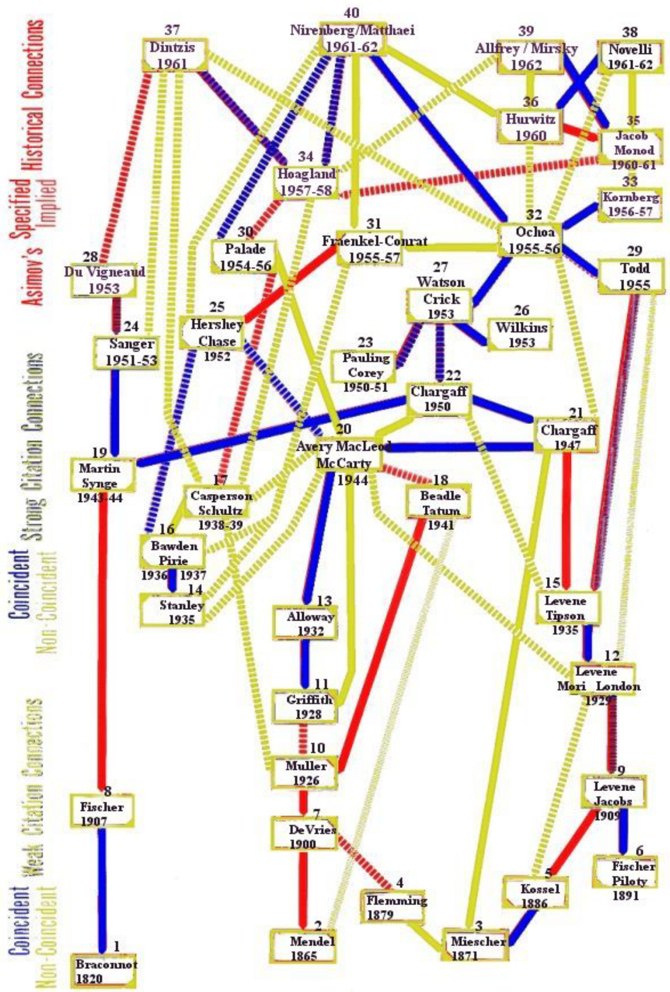


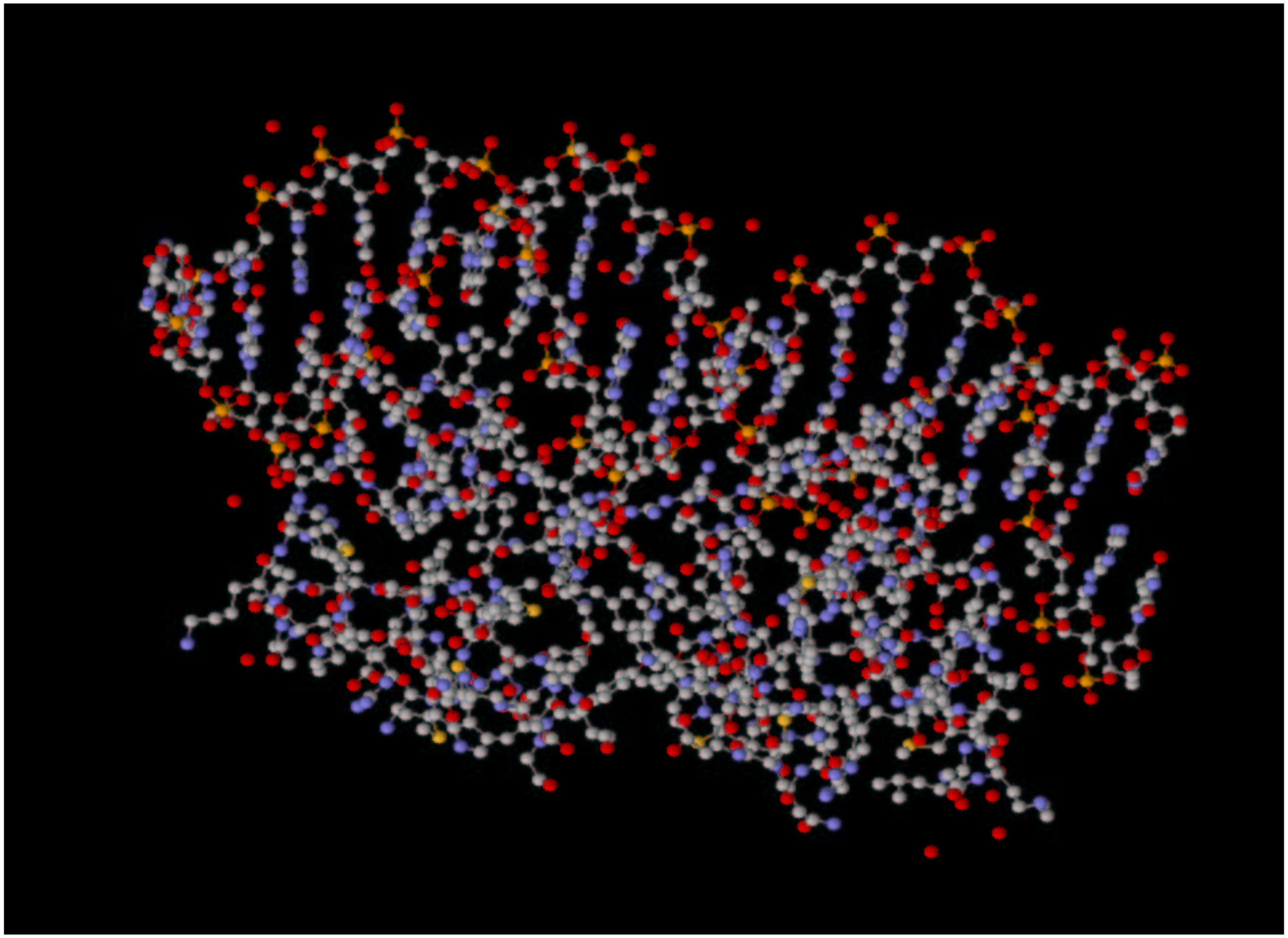
FIGURE 3. GROUP 11A. A SOCIAL STATUS SOCIOGRAPH OF THE 68 BOYS OF THE 11TH GRADE. IT SHOWS QUINTILE POSITIONS FOR: (1) GRADE AVERAGE, (2) SOCIAL PARTICIPATION SCORES IN STUDENT ORGANIZATIONS, AND (3) TOTAL FRIENDSHIP CHOICES ON A SOCIOMETRIC TEST (TOTAL CHOICES INCLUDE DIRECT AND INDIRECT CHOICES). THE STUDENT'S POSITION ON THE CHART IS THAT OF HIS CLIQUE GROUP AVERAGE FOR BOTH SOCIAL PARTICIPATION SCORES AND TOTAL FRIENDSHIP CHOICES. OUT-OF-CLASS CHOICES APPEAR IN THE SIDE MARGIN; OUT-OF-SCHOOL CHOICES IN THE LOWER MARGIN. 11

Development of DNA (Garfield)

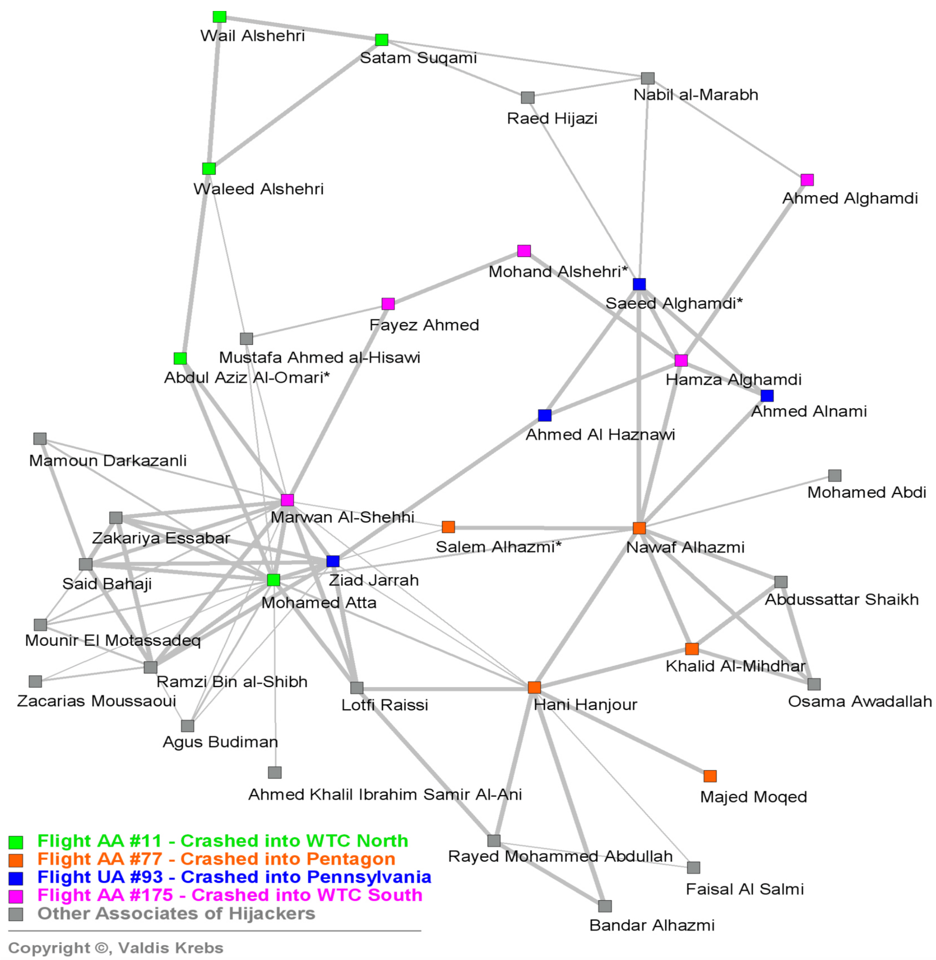


In 1964 E. Garfield with collaborators produced, on the basis of the book Asimov I.: *The Genetic Code* (1963), a corresponding 'citation' network. It was shown that the analysis '*demonstrated a high degree of coincidence between an historian's account of events and the citational relationship between these events*'.

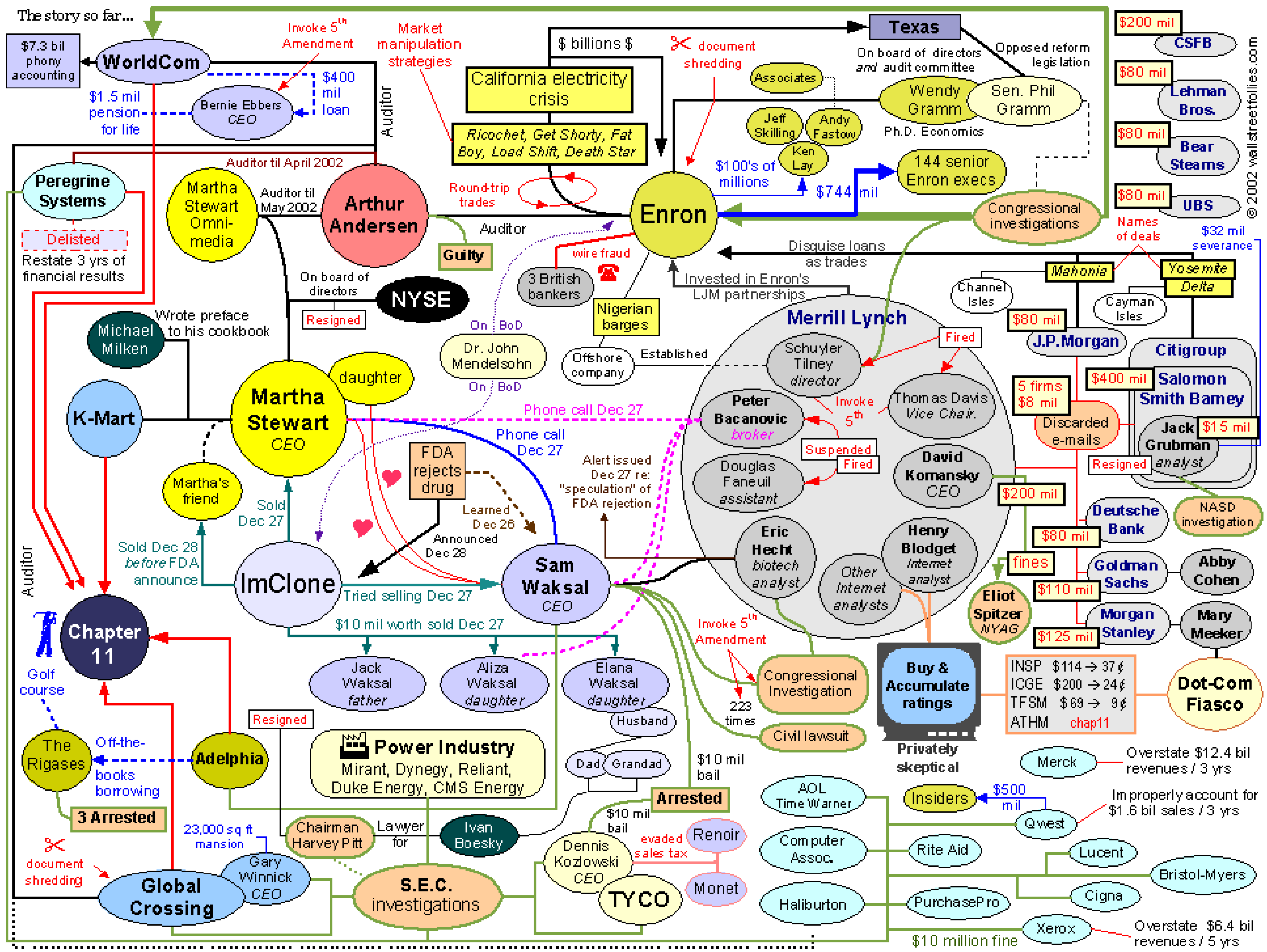
Organic molecule 3CRO



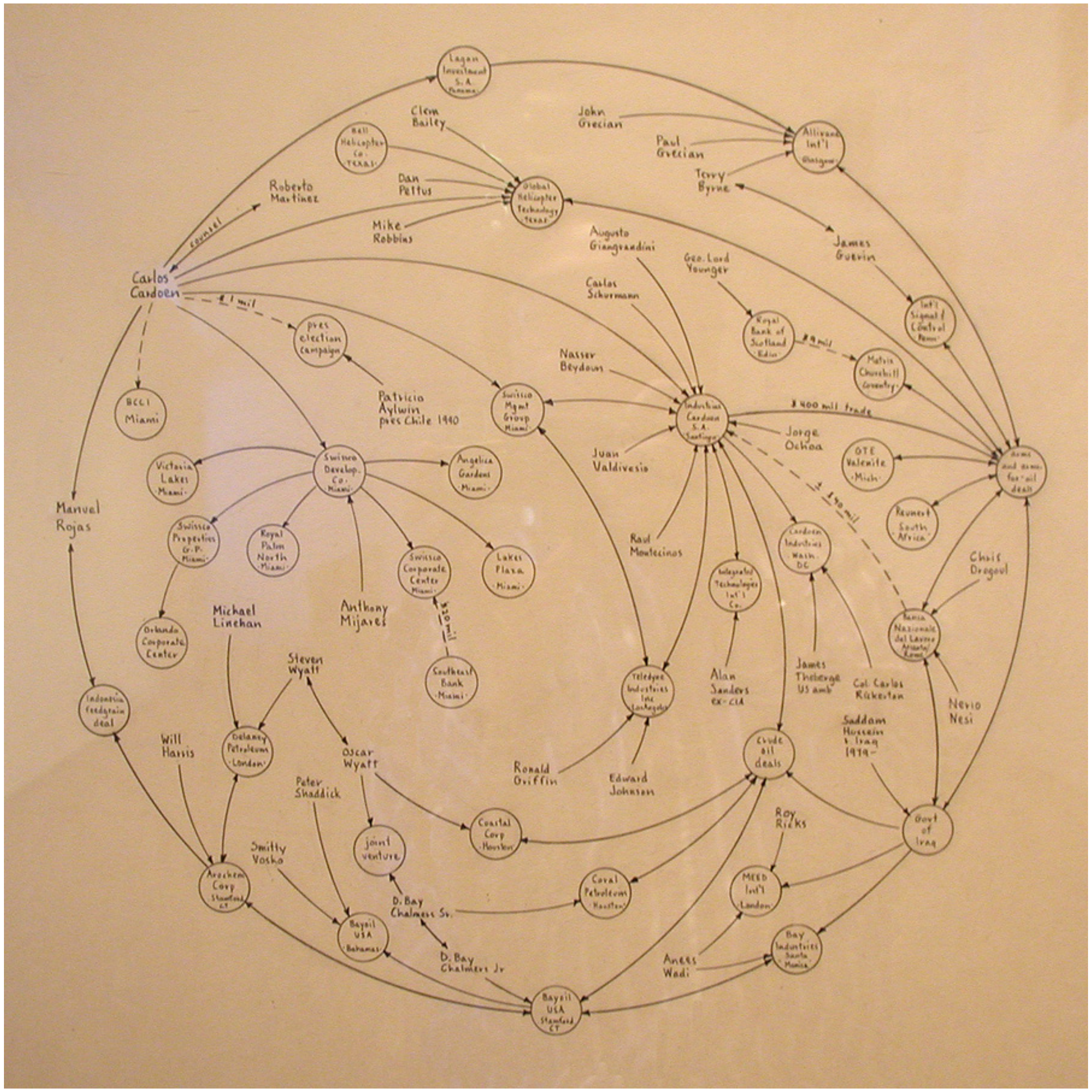
Hijackers (Krebs)



Wall Street Follies

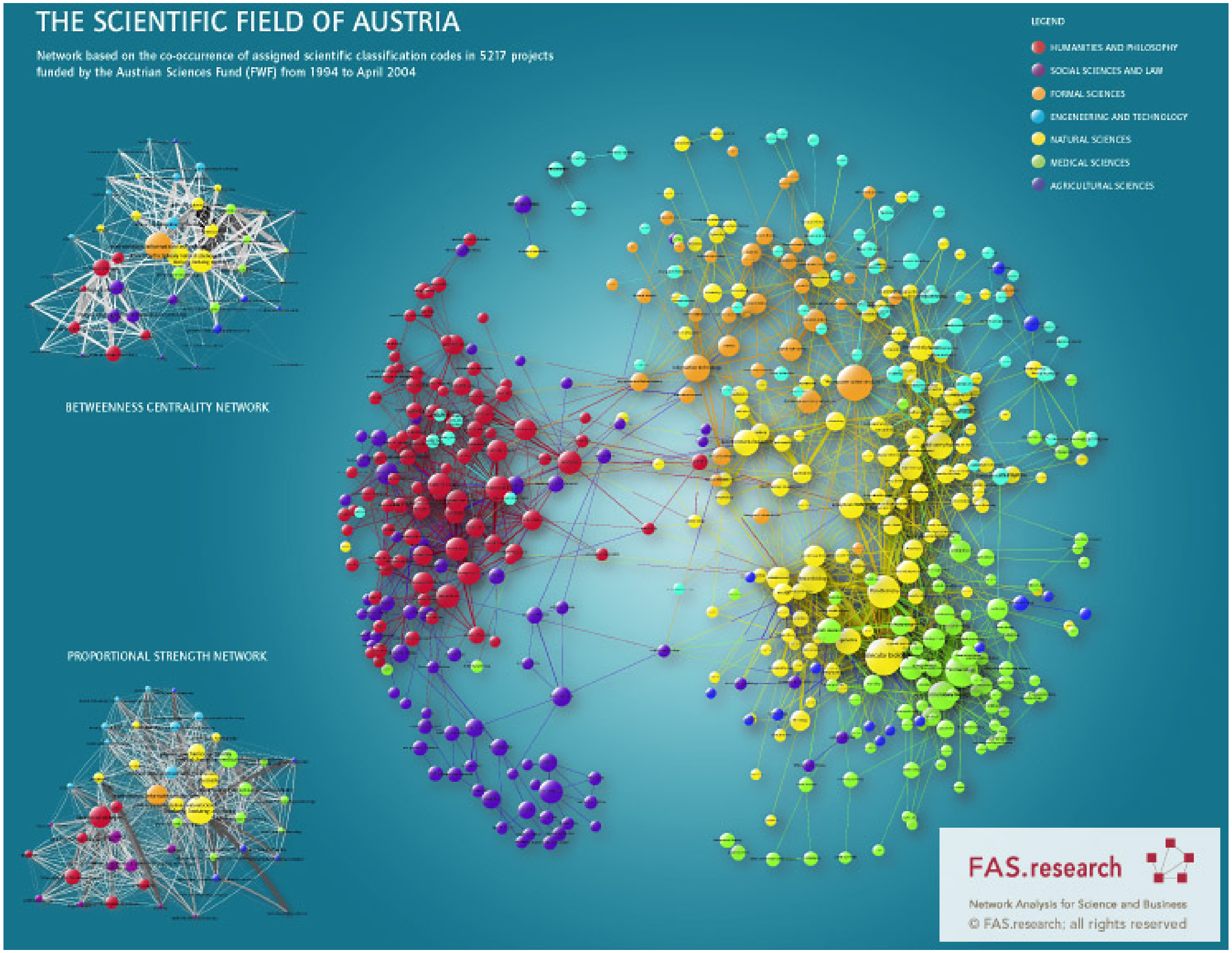


Lombardi's networks

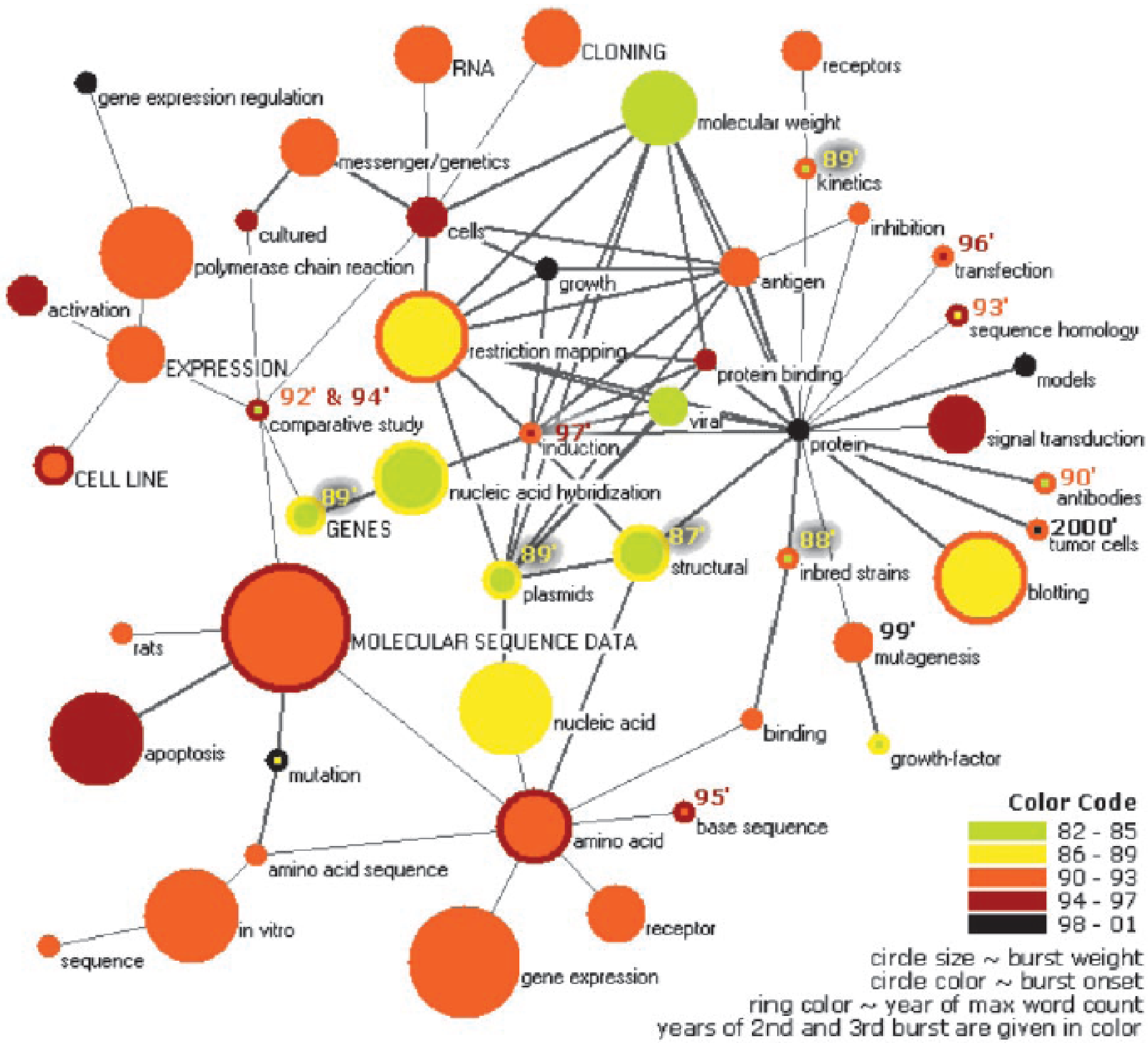


Mark Lombardi (1951-2000) transformed business relations into art.

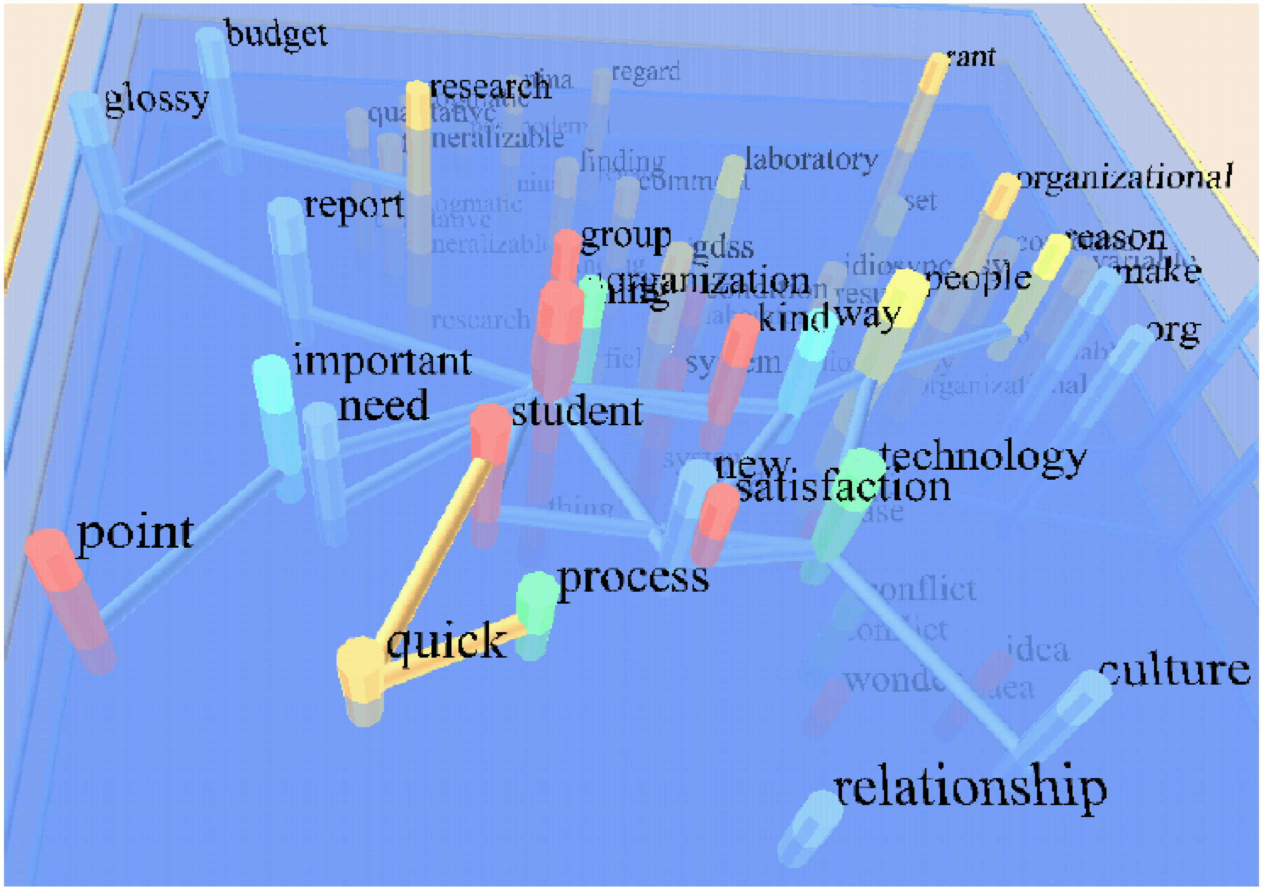
FAS: The scientific field of Austria



Katy Börner: Text analysis



Ulrik Brandes: Discourse network



How to get a network?

Collecting data about the network $\mathcal{N} = (\mathcal{V}, \mathcal{L}, \mathcal{P}, \mathcal{W})$ we have first to decide, what are the units (vertices) – *network boundaries*, when are two units related – *network completness*, and which properties of vertices/lines we shall consider.

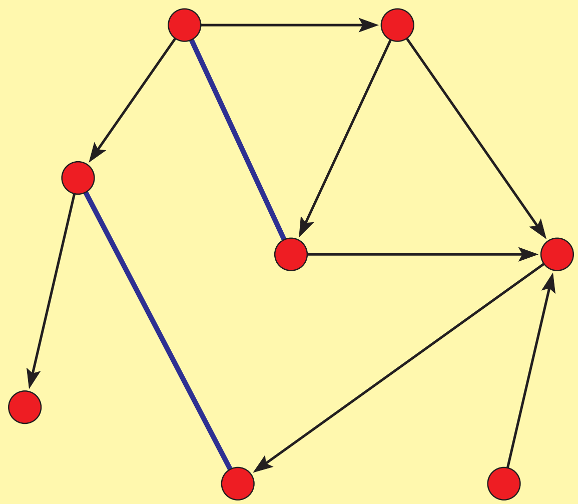
How to measure networks (questionaires, interviews, observations, archive records, experiments, $\ldots$)?

What is the quality of measured networks (reliability and validity)?

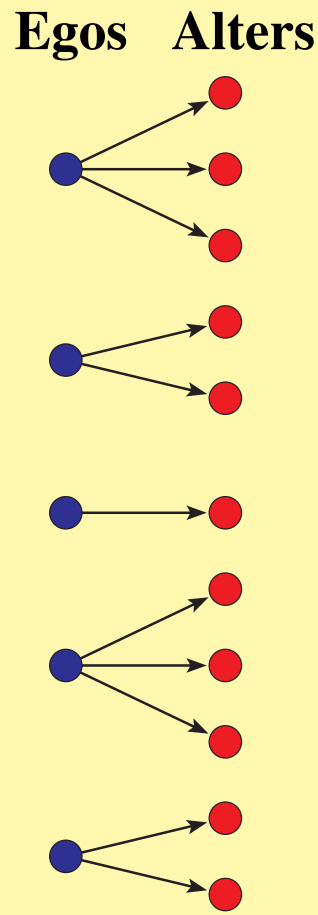
Several networks are already available in computer readable form or can be constructed from such data.

For large sets of units we often can't measure the complete network. Therefore we limit the data collection to selected units and their neighbors. We get *ego-centered networks*.

Complete and ego-centered networks



COMPLETE NETWORK



EGO-CENTERED NETWORKS

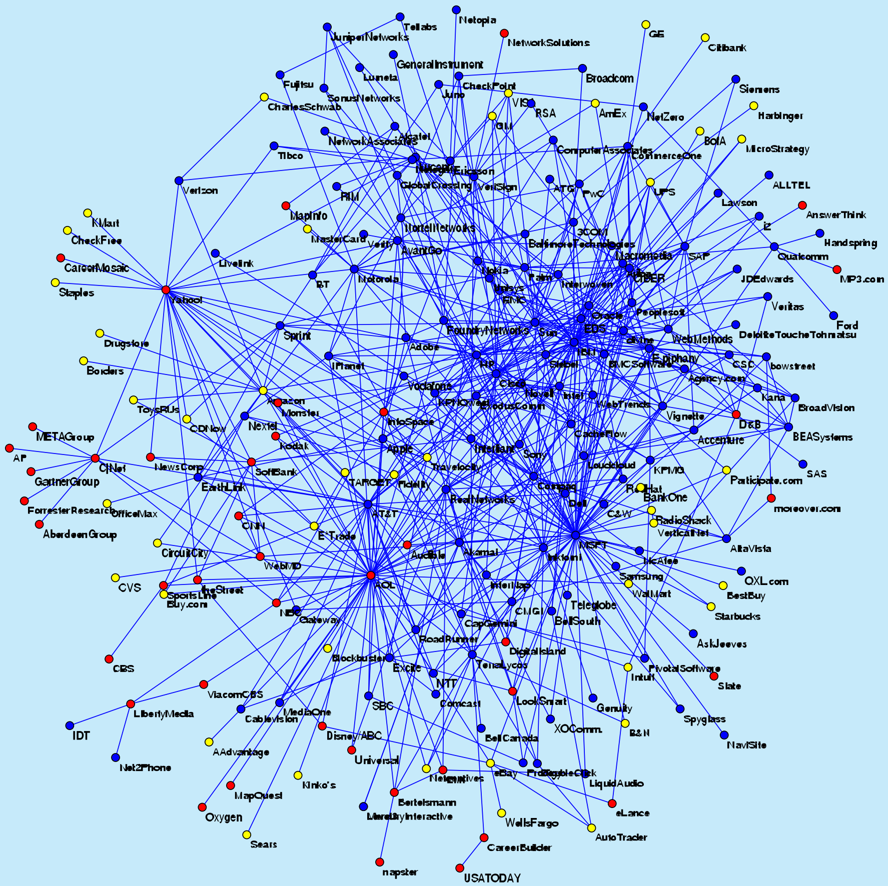
Use of existing network data

Pajek supports input of network data in several formats: UCINET's DL files, graphs from project Vega, molecules in MDLMOL, MAC, BS; genealogies in GEDCOM.

Davis.DAT, C84N24.VGR, MDL, 1CRN.BS, DNA.BS, ADF073.MAC, Bouchard.GED.

Several network data sets are already available in computer readable form and need only to be transformed into network descriptions.

Krebs Internet industries



Each node in the network represents a company that competes in the Internet industry, 1998 do 2001.

$n = 219,\ m = 631.$

red – content,

blue – infrastructure,

yellow – commerce.

Two companies are connected with an edge if they have announced a joint venture, strategic alliance or other partnership.

URL: **`http://www.orgnet.com/netindustry.html`**. *Recode*, *InfoRapid*.

Genealogies

For describing the genealogies on computer most often the GEDCOM format is used (*GEDCOM standard 5.5*).

Many such genealogies (files `*.GED`) can be found on the Web – for example *Roper's GEDCOMs* or *Isle-of-Man GEDCOMs*.

Several programs are available for preparation and maintainance of genealogies: free *GIM* and commercial *Brothers Keeper* (Slovenian version is available at *SRD*).

From the data collected in Phd. thesis:
Mahnken, Irmgard. 1960. Dubrovački patricijat u XIV veku. Beograd, Naučno delo.
the *Ragusa* network was produced.

GEDCOM

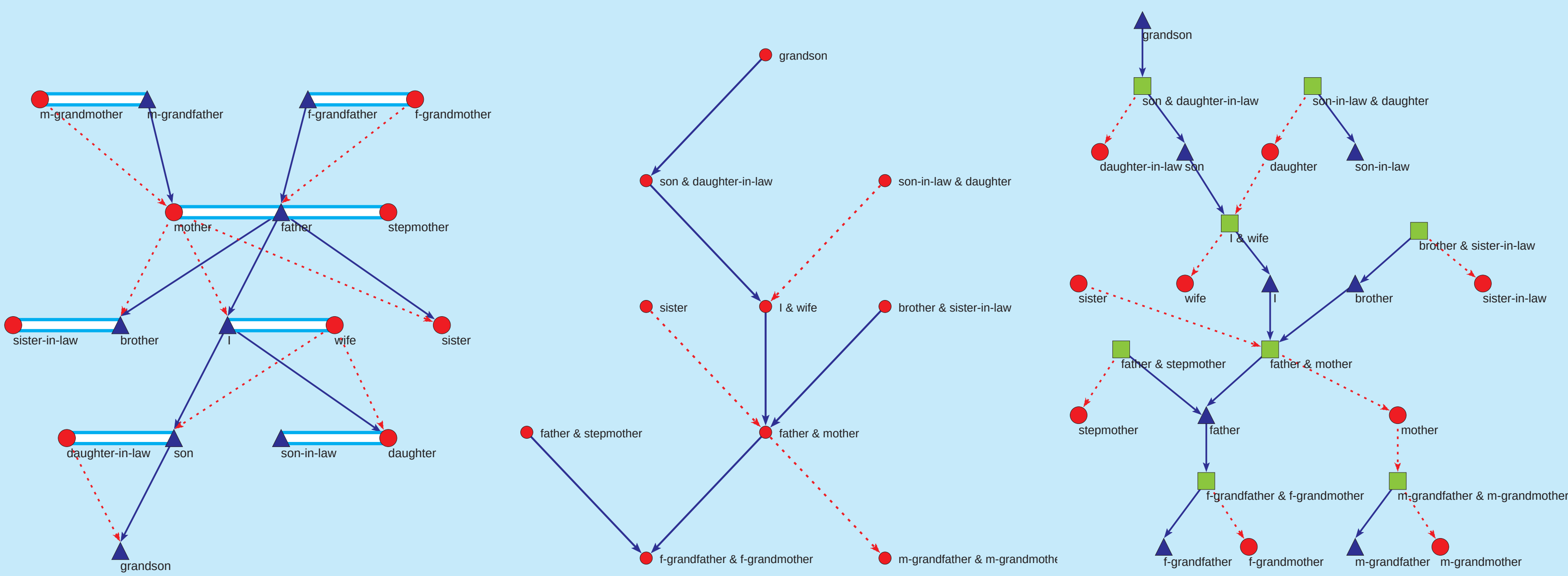
GEDCOM is a standard for storing genealogical data, which is used to interchange and combine data from different programs, which were used for entering the data.

```
0 HEAD
1 FILE ROYALS.GED
...
0 @I58@ INDI
1 NAME Charles Philip Arthur/Windsor/
1 TITL Prince
1 SEX M
1 BIRT
2 DATE 14 NOV 1948
2 PLAC Buckingham Palace, London
1 CHR
2 DATE 15 DEC 1948
2 PLAC Buckingham Palace, Music Room
1 FAMS @F16@
1 FAMC @F14@
...
...
0 @I65@ INDI
1 NAME Diana Frances /Spencer/
1 TITL Lady
1 SEX F
1 BIRT
2 DATE 1 JUL 1961
2 PLAC Park House, Sandringham
1 CHR
2 PLAC Sandringham, Church
1 FAMS @F16@
1 FAMC @F78@
...
...
0 @I115@ INDI
1 NAME William Arthur Philip/Windsor/
1 TITL Prince
1 SEX M
1 BIRT
2 DATE 21 JUN 1982
2 PLAC St.Mary's Hospital, Paddington
1 CHR
2 DATE 4 AUG 1982
2 PLAC Music Room, Buckingham Palace
1 FAMC @F16@
...
0 @I116@ INDI
1 NAME Henry Charles Albert/Windsor/
1 TITL Prince
1 SEX M
1 BIRT
2 DATE 15 SEP 1984
2 PLAC St.Mary's Hosp., Paddington
1 FAMC @F16@
...
0 @F16@ FAM
1 HUSB @I58@
1 WIFE @I65@
1 CHIL @I115@
1 CHIL @I116@
1 DIV N
1 MARR
2 DATE 29 JUL 1981
2 PLAC St.Paul's Cathedral, London
```

Network representations of genealogies

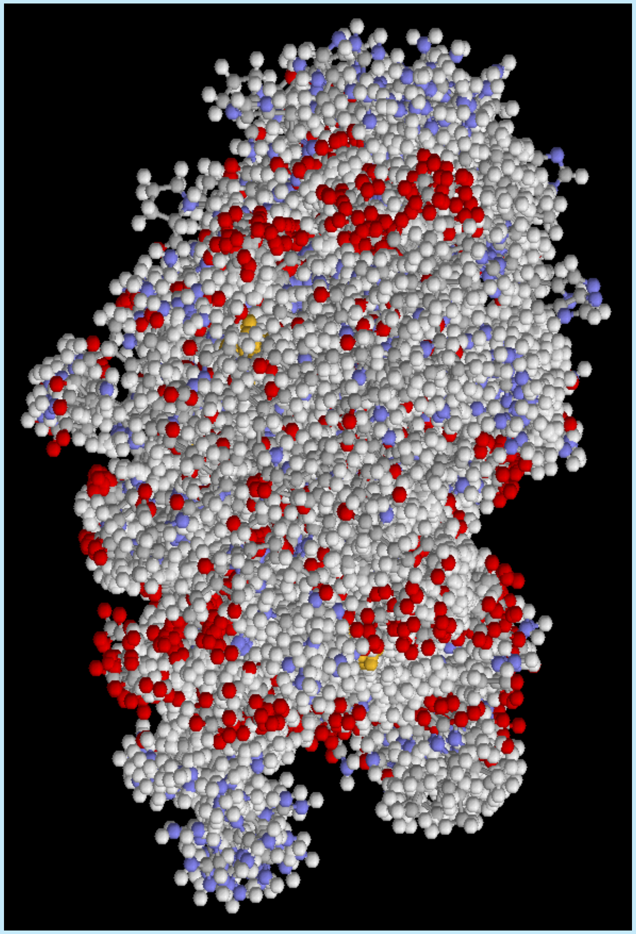
In usual *Ore* graph every person is represented with a vertex; they are linked with two relations: *are married* (blue edge) and *has child* (black arc) – partitioned into *is mother of* and *is father of*.

In *p-graph* the vertices are married couples or singles; they are linked with two relations: *is son of* (solid blue) and *is dauther of* (dotted red). More about p-graphs *D. White*.



Ore graph, p-graph, and bipartite p-graph

Molecular networks



virus 1GDY: $n = 39865$, $m = 40358$

In the Brookhaven Protein Data Bank we can find many large organic molecula (for example: `Simian / 1AZ5.pdb`) stored in PDB format.

They can be inspected in 3D using the program **Rasmol** (*RasMol*, *program*, *RasWin*) or *Protein Explorer*.

A molecule can be converted from PDB format into BS format (supported by **Pajek**) using the program *BabelWin* + *Babel16*.

GraphML

GraphML – XML format for network description.

L'Institut de Linguistique et Phonétique Générales et Appliquées (ILPGA), Paris III; Traitement Automatique du Langage (TAL): BaO4 : Des Textes Aux Graphes Plurital

LibXML, `xsltproc` download, XSLT, Xalan, Python, Sxslt.

```
xsltproc GraphML2Pajek.xsl graph.xml > graph.net
java -jar saxon8.jar graph.xml GraphML2Pajek.xsl > graph.net
java org.apache.xalan.xslt.Process -IN p.xml -XSL m.xsl -OUT p.txt
```

XSLT/Zvon

GraphML → Pajek

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Title: 1. D:\vlado\docs\Books\SKRIPTA\Nets\nets\graph.net (12) -->
<!-- Creator: Pajek: http://vlado.fmf.uni-lj.si/pub/networks/pajek/ -->
<!-- CreationDate: 11-03-2006, 17:25:13 -->
<graphml>
  <key id="a1" for="node" attr.name="Label" attr.type="string">
    <desc>Label of the node</desc> <default>NoLabel</default>
  </key>
  <key id="b1" for="edge" attr.name="Weight" attr.type="double">
    <desc>Weight (value) of the edge</desc> <default>1</default>
  </key>
  <graph id="G" edgedefault="directed" parse.nodes="12" parse.edges="23">
    <node id="v1"><data key="a1">a</data></node>
    <node id="v2"><data key="a1">b</data></node>
    <node id="v3"><data key="a1">c</data></node>
    <node id="v4"><data key="a1">d</data></node>
    <node id="v5"><data key="a1">e</data></node>
    <node id="v6"><data key="a1">f</data></node>
    <node id="v7"><data key="a1">g</data></node>
    <node id="v8"><data key="a1">h</data></node>
    <node id="v9"><data key="a1">i</data></node>
    <node id="v10"><data key="a1">j</data></node>
    <node id="v11"><data key="a1">k</data></node>
    <node id="v12"><data key="a1">l</data></node>
    <edge source="v1" target="v2"/> <edge source="v2" target="v1"/>
    <edge source="v1" target="v4"/> <edge source="v1" target="v6"/>
    <edge source="v2" target="v6"/> <edge source="v3" target="v2"/>
    <edge source="v3" target="v3"/> <edge source="v3" target="v7"/>
    <edge source="v3" target="v7"/> <edge source="v5" target="v3"/>
    <edge source="v5" target="v6"/> <edge source="v5" target="v8"/>
    <edge source="v6" target="v11"/> <edge source="v8" target="v4"/>
    <edge source="v10" target="v8"/> <edge source="v12" target="v5"/>
    <edge source="v12" target="v7"/> <edge source="v8" target="v12"/>
    <edge source="v12" target="v8"/>
    <edge directed="false" source="v2" target="v5"/>
    <edge directed="false" source="v3" target="v4"/>
    <edge directed="false" source="v5" target="v7"/>
    <edge directed="false" source="v6" target="v8"/>
  </graph>
</graphml>
```

```
*Vertices 12
1 "a"
2 "b"
3 "c"
4 "d"
5 "e"
6 "f"
7 "g"
8 "h"
9 "i"
10 "j"
11 "k"
12 "l"
*Edges
2 5
3 4
5 7
6 8
*Arcs
1 2
2 1
1 4
1 6
2 6
3 2
3 3
3 7
3 7
5 3
5 6
5 8
6 11
8 4
10 8
12 5
12 7
8 12
12 8
```

GraphML → Pajek using XSLT

```
<?xml version="1.0" encoding="iso-8859-1"?>
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
  <xsl:output method="text" encoding="iso-8859-1"/>
  <xsl:template match="/">
    <xsl:text>*Vertices </xsl:text>
    <xsl:value-of select="count(graphml/graph/node)"/>
    <xsl:text>&#10;</xsl:text>
    <xsl:apply-templates select="graphml/graph/node"/>
    <xsl:text>*Edges&#10;</xsl:text>
    <xsl:apply-templates select="graphml/graph/edge" mode="edge"/>
    <xsl:text>*Arcs&#10;</xsl:text>
    <xsl:apply-templates select="graphml/graph/edge" mode="arc"/>
  </xsl:template>

  <xsl:template match="edge" mode="arc">
    <xsl:if test="not(./@directed='false')">
      <xsl:value-of select="substring(./@source,2)"/>
      <xsl:text> </xsl:text>
      <xsl:value-of select="substring(./@target,2)"/>
      <xsl:text> </xsl:text>
      <xsl:value-of select="./data"/>
      <xsl:text>&#10;</xsl:text>
    </xsl:if>
  </xsl:template>

  <xsl:template match="edge" mode="edge">
    <xsl:if test="./@directed='false'">
      <xsl:value-of select="substring(./@source,2)"/>
      <xsl:text> </xsl:text>
      <xsl:value-of select="substring(./@target,2)"/>
      <xsl:text> </xsl:text>
      <xsl:value-of select="./data"/>
      <xsl:text>&#10;</xsl:text>
    </xsl:if>
  </xsl:template>

  <xsl:template match="node">
    <xsl:value-of select="substring(./@id,2)"/>
    <xsl:text> "</xsl:text>
    <xsl:value-of select="./data"/>
    <xsl:text>"&#10;</xsl:text>
  </xsl:template>

</xsl:stylesheet>
```

Approaches to computer-assisted text analysis

R. Popping: Computer-Assisted Text Analysis (2000) distinguishes three main aproaches to CaTA: *thematic* TA, *semantic* TA, and *network* TA.

Terms considered in TA are collected in a *dictionary* (it can be fixed in advance, or built dynamically). The main two problems with terms are *equivalence* (different words representing the same term) and *ambiguity* (same word representing different terms). Because of these the *coding* – transformation of raw text data into formal *description* – is done mainly manually or semiautomaticly. As *units* of TA we usually consider clauses, statements, paragraphs, news, messages, …

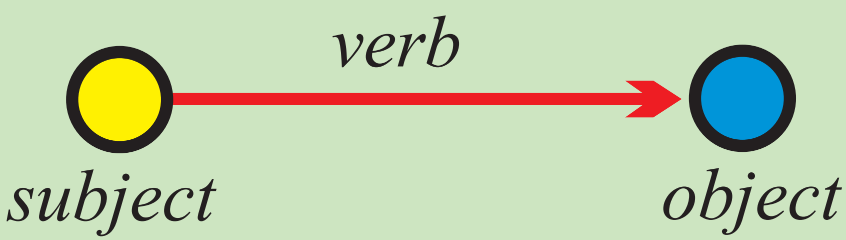
Till now the thematic and semantic TA mainly used statistical methods for analysis of the coded data.

. . . approaches to CaTA

In thematic TA the units are coded as rectangular matrix *Text units* × *Concepts* which can be considered as a two-mode network.

Examples: M.M. Miller: VBPro, H. Klein: Text Analysis/ TextQuest.

In semantic TA the units (often clauses) are encoded according to the S-V-O (*Subject-Verb-Object*) model or its improvements.

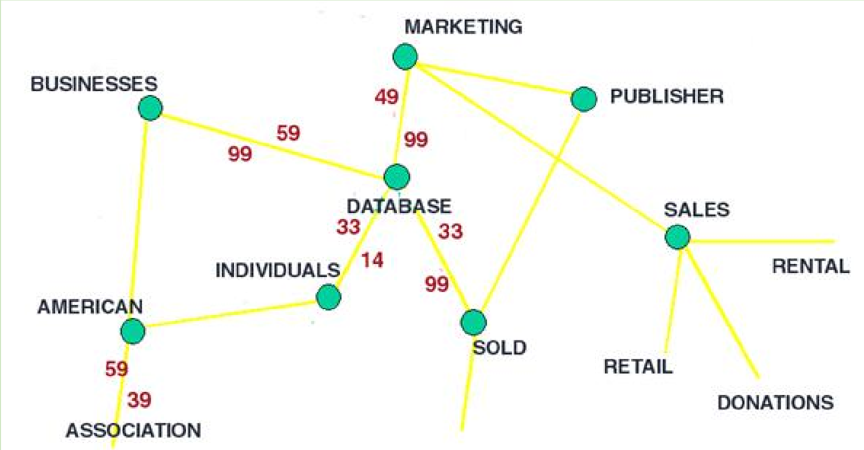


Examples: Roberto Franzosi; *KEDS*, *Tabari*.

This coding can be directly considered as network with *Subjects* ∪ *Objects* as vertices and lines labeled with *Verbs*.

See also RDF triples in semantic web.

Network CaTA



TextAnalyst's 'semantic network'

This way we already steped into the network TA.

Examples:

Carley: Cognitive maps,

J.A. de Ridder: CETA,

Megaputer: TextAnalyst.

See also: W. Evans: Computer Environments for Content Analysis, K.A. Neuendorf: The Content Analysis Guidebook / Online and H.D. White: Publications.

There are additional ways to obtain networks from textual data.

TA – Dictionary networks

book

A collection of leaves of paper, parchment, vellum, cloth, or other material (written, printed, or blank) fastened together along one edge, with or without a protective case or cover. Also refers to a literary work or one of its volumes. Compare with monograph.

To qualify for the special parcel post rate known in the United States as media rate, a publication must consist of 24 or more pages, at least 22 of which bear printing consisting primarily of reading material or scholarly bibliography, with advertising limited to book announcements. UNESCO defines a book as a nonperiodical literary publication consisting of 49 or more pages, covers excluded. The ANSI standard includes publications of less than 49 pages which have hard covers. ***See also***: art book, board book, children's book, coffee table book, gift book, licensed book, managed book, new book, packaged book, picture book, premium book, professional book, promotional book, rare book, reference book, religious book, and reprint book.

Also, a major division of a longer work (usually of fiction) which is further subdivided into chapters. Usually numbered, such a division may or may not have its own title. Also refers to one of the divisions of the Christian ***Bible***, the first being *Genesis*.

book description in ODLIS

In a *dictionary graph* the terms determine the set of vertices, and there is an arc (u, v) from term u to term v iff the term v appears in the description of term u.

Online Dictionary of Library and Information Science *ODLIS*, *Odlis.net* (2909 / 18419).

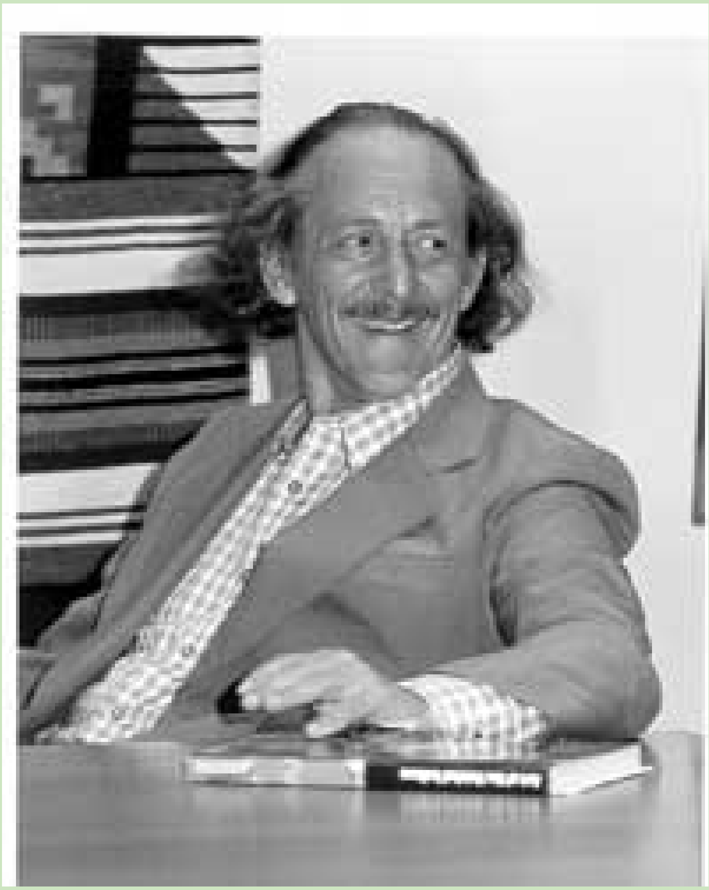
Free On-line Dictionary of Computing *FOLDOC*, *Foldoc2b.net* (133356 / 120238).

Artlex, *Wordnet*, *ConceptNet*, *OpenCyc*.

The Edinburgh Associative Thesaurus (*EAT*) / *net*; NASA Thesaurus.

Paper.

TA – Citation networks

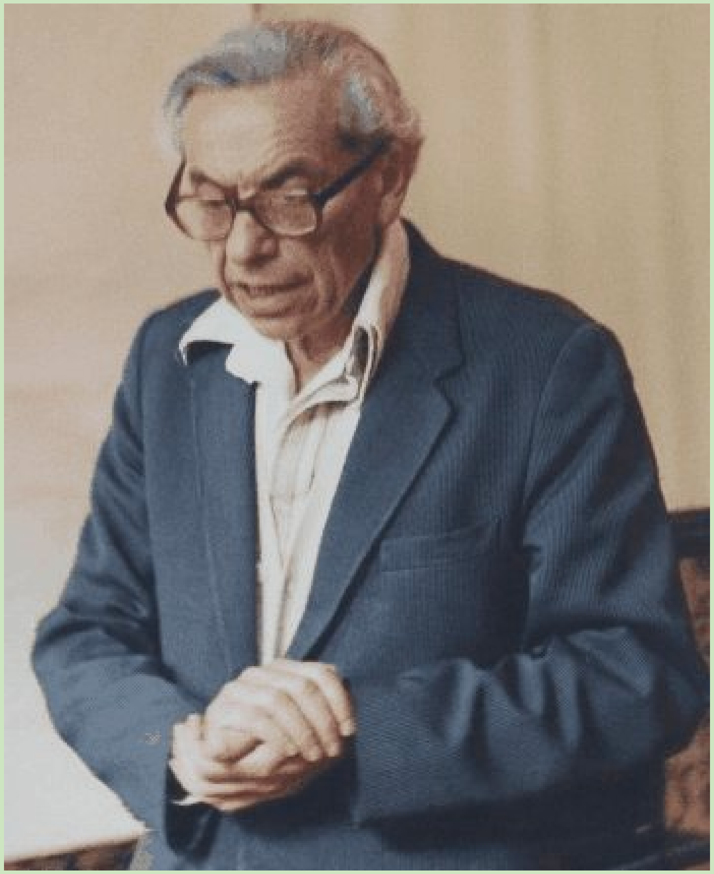


In a *citation graph* the vertices are different publications from the selected area; two publications are connected by an arc if the first is cited by the second. The citation networks are almost acyclic.

E. Garfield: HistCite / *Pajek*, *papers*.

An example of very large citation network is US Patents / Nber,
$n = 3774768$, $m = 16522438$.

TA – Collaboration networks



Units in a *collaboration network* are usually individuals or institutions. Two units are related if they produced a joint work. The weight is the number of such works.

A famous example of collaboration network is *The Erdős Number Project*, *Erdos.net*.

A rich source of data for producing collaboration networks are the BibTEX bibliographies *Nelson H. F. Beebe's Bibliographies Page*.

For example B. Jones: *Computational geometry database* (2002), *FTP*, *Geom.net*.

An initial collaboration network from such data can be produced using some programming. Then follows a tedious 'cleaning' process.

Interesting datasets: *The Internet Movie Database* and Trier DBLP.

Both citation and collaboration networks can be obtained from Web of Science using WoS2Pajek.

TA – International Relations

Paul Hensel's International Relations Data Site,

International Conflict and Cooperation Data,

Correlates of War,

Kansas Event Data System *KEDS*,

KEDS in Pajek's format.

Recoding programs in R.

Recoding of KEDS/WEIS data in Pajek's format

```
% Recoded by WEISmonths, Sun Nov 28 21:57:00 2004
% from http://www.ku.edu/~keds/data.dir/balk.html
*vertices 325
1 "AFG" [1-*]
2 "AFR" [1-*]
3 "ALB" [1-*]
4 "ALBMED" [1-*]
5 "ALG" [1-*]
 ...
318 "YUGGOV" [1-*]
319 "YUGMAC" [1-*]
320 "YUGMED" [1-*]
321 "YUGMTN" [1-*]
322 "YUGSER" [1-*]
323 "ZAI" [1-*]
324 "ZAM" [1-*]
325 "ZIM" [1-*]
*arcs :0 "*** ABANDONED"
*arcs :10 "YIELD"
*arcs :11 "SURRENDER"
*arcs :12 "RETREAT"
 ...
*arcs :223 "MIL ENGAGEMENT"
*arcs :224 "RIOT"
*arcs :225 "ASSASSINATE TORTURE"
*arcs
224: 314 153 1 [4]                890402  YUG     KSV     224   (RIOT)  RIOT-TORN
212: 314 83 1 [4]                 890404  YUG     ETHALB  212   (ARREST PERSON) ALB ETHNIC JAILED IN YUG
224: 3 83 1 [4]                   890407  ALB     ETHALB  224   (RIOT)  RIOTS
123: 83 153 1 [4]                 890408  ETHALB  KSV     123   (INVESTIGATE)   PROBING
 ...
42: 105 63 1 [175]                030731  GER     CYP     042   (ENDORSE)       GAVE SUPPORT
212: 295 35 1 [175]               030731  UNWCT   BOSSER  212   (ARREST PERSON) SENTENCED TO PRISON
43: 306 87 1 [175]                030731  VAT     EUR     043   (RALLY) RALLIED
13: 295 35 1 [175]                030731  UNWCT   BOSSER  013   (RETRACT)       CLEARED
121: 295 22 1 [175]               030731  UNWCT   BAL     121   (CRITICIZE)     CHARGES
122: 246 295 1 [175]              030731  SER     UNWCT   122   (DENIGRATE)     TESTIFIED
121: 35 295 1 [175]               030731  BOSSER  UNWCT   121   (CRITICIZE)     ACCUSED
```

. . . Recoding programs in R

To recode the KEDS/WEIS data we used short programs in R, such as the following one:

```
# WEISmonths
# recoding of WEIS files into Pajek's multirelational temporal files
# granularity is 1 month
# ------------------------------------------------------------------
# Vladimir Batagelj, 28. November 2004
# ------------------------------------------------------------------
# Usage:
#   WEISmonths(WEIS_file,Pajek_file)
# Examples:
#   WEISmonths('Balkan.dat','BalkanMonths.net')
# ------------------------------------------------------------------
# http://www.ku.edu/~keds/data.html
# ------------------------------------------------------------------

WEISmonths <- function(fdat,fnet){

  get.codes <- function(line){
    nlin <<- nlin + 1;
    z <- unlist(strsplit(line,"\t")); z <- z[z != ""]
    if (length(z)>4) {
      t <- as.numeric(z[1]); if (t < 500000) t <- t + 1000000
      if (t<t0) t0 <<- t; u <- z[2]; v <- z[3]; r <- z[4]
      if (is.na(as.numeric(r))) cat(nlin,'NA rel-code',r,'\n')
      h <- z[5]; h <- substr(h,2,nchar(h)-1)
      if (nchar(h) == 0) h <- '*** missing description'
      if (!exists(u,env=act,inherits=FALSE)){
        nver <<- nver + 1; assign(u,nver,env=act) }
      if (!exists(v,env=act,inherits=FALSE)){
        nver <<- nver + 1; assign(v,nver,env=act) }
      if (!exists(r,env=rel,inherits=FALSE)) assign(r,h,env=rel)
    }
  }
```

...Recoding programs in R

```
  recode <- function(line){
    nlin <<- nlin + 1;
    z <- unlist(strsplit(line,"\t")); z <- z[z != ""]
    if (length(z)>4) {
      t <- as.numeric(z[1]); if (t < 500000) t <- t + 1000000
      cat(as.numeric(z[4]),': ',get(z[2],env=act,inherits=FALSE),
        ' ',get(z[3],env=act,inherits=FALSE),' 1 [',
        12*(1900 + t %/% 10000) + (t %% 10000) %/% 100 - t0,
        ']\n',sep='',file=net)
    }
  }

  cat('WEISmonths: WEIS -> Pajek\n')
  ts <- strsplit(as.character(Sys.time())," ")[[1]][2]
  act <- new.env(TRUE,NULL); rel <- new.env(TRUE,NULL)
  dat <- file(fdat,"r"); net <- file(fnet,"w")
  lst <- file('WEIS.lst',"w"); dni <- 0
  nver <- 0; nlin <- 0; t0 <- 9999999
  lines <- readLines(dat); close(dat)
  sapply(lines,get.codes)
  a <- sort(ls(envir=act)); n <- length(a)
  cat(paste('% Recoded by WEISmonths,',date()),"\n",file=net)
  cat("% from http://www.ku.edu/~keds/data.html\n",file=net)
  cat("*vertices",n,"\n",file=net)
  for(i in 1:n){ assign(a[i],i,env=act);
    cat(i,' "',a[i],'" [1-*]\n',sep='',file=net) }
  b <- sort(ls(envir=rel)); m <- length(b)
  for(i in 1:m){ assign(a[i],i,env=act);
  cat("*arcs :",as.numeric(b[i]),' "',
  get(b[i],env=rel,inherits=FALSE),'"\n',sep='',file=net) }
  t0 <- 12*(1900 + t0 %/% 10000)
  slice <- 0
  cat("*arcs\n",file=net); nlin <- 0
  sapply(lines,recode)
  cat(' ',nlin,'lines processed\n'); close(net)
  te <- strsplit(as.character(Sys.time())," ")[[1]][2]
  cat('  start:',ts,'  finish:',te,'\n')
}

WEISmonths('Balkan.dat','BalkanMonthsR.net')
```

Note: The dictionary data structure is in R implemented as *environment*.

Neighbors

Let $\mathcal{V}$ be a *set of multivariate units* and $d(u, v)$ a *dissimilarity* on it. They determine two types of networks:

The *k-nearest neighbors* network: $\mathcal{N}(k) = (\mathcal{V}, \mathcal{A}, d)$

$$(u, v) \in \mathcal{A} \Leftrightarrow v \text{ is among } k \text{ nearest neighbors of } u, \quad w(u, v) = d(u, v)$$

The *r-neighbors* network: $\mathcal{N}(r) = (\mathcal{V}, \mathcal{E}, d)$

$$(u : v) \in \mathcal{E} \Leftrightarrow d(u, v) \leq r, \quad w(u, v) = w(v, u) = d(u, v)$$

These networks provide a link between data analysis and network analysis. Efficient algorithms ?!

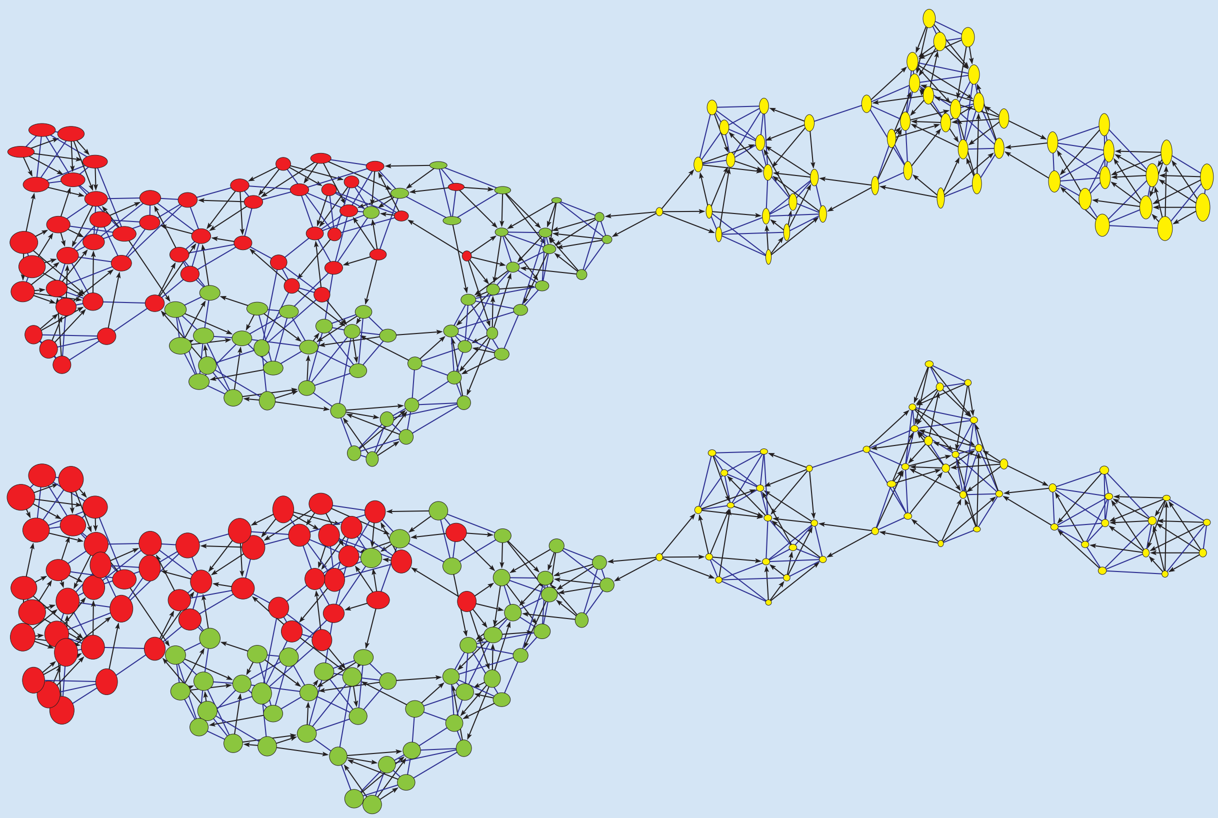
Fisher's *Iris data*.

Details on Multivariate networks and procedures in R.

Nearest k neighbors in R

```
k.neighbor2Net <-
# stores network of first  k  neighbors for
# dissimilarity matrix  d  to file  fnet  in Pajek format.
function(fnet,d,k){
  net <- file(fnet,"w")
  n <- nrow(d); rn <- rownames(d)
  cat("*vertices",n,"\n",file=net)
  for (i in 1:n) cat(i," \"",rn[i],"\"\n",sep="",file=net)
  cat("*arcs\n",file=net)
  for (i in 1:n) for (j in order(d[i,])[1:k+1]) {
    cat(i,j,d[i,j],"\n",file=net)
  }
  close(net)
}
stand <-
# standardizes vector  x .
function(x){
  s <- sd(x)
  if (s > 0) (x - mean(x))/s  else  x - x
}
data(iris)
ir <- cbind(stand(iris[,1]),stand(iris[,2]),stand(iris[,3]),
  stand(iris[,4]))
k.neighbor2Net("iris5.net",as.matrix(dist(ir)),5)
```

Fisher's Irises



`Draw/Draw-Partition-2Vectors`

The size of vertices is proportional to normalized (Sepal.Length, Sepal.Width) and (Petal.Length, Petal.Width). The color of vertices is determined by the original partition. *Iris data*.

Transformations

Words graph – words from a given set are vertices; two words are related iff one can be obtained from the other by change (add, delete, replace) of a single character. `DIC28`, *Paper*.

Text network – vertices are (selected) words from a given text; two words are related if they coappeared in the selected type of 'window' (same sentence, k consecutive words, ...) The weights count such coappearances. Example *CRA*.

Game graph – vertices are states in the game; two states are linked with an arc if the rules of the game allow the transiton from first to the second state.

Networks from the Internet

KartOO network

Internet Mapping Project. Links among WWW pages. KartOO, TouchGraph. Derived from archives of E-mail, blogs, . . . , server's logs. *Cybergeography*, *CAIDA*. Tools: *MedlineR*, *SocSciBot*.

Collecting Networks from WWW

Web wrappers are special programs for collecting information from web pages – often returned in XML format.

Examples in R: Titles of patents from Nber, Books from Amazon.

Several tools for automatic generation of wrappers: (paper / list / LAPIS).

Free programs: XWRAP (description / page) in TSIMMIS (description / page).

Among commercial programs it seems the best is lixto.

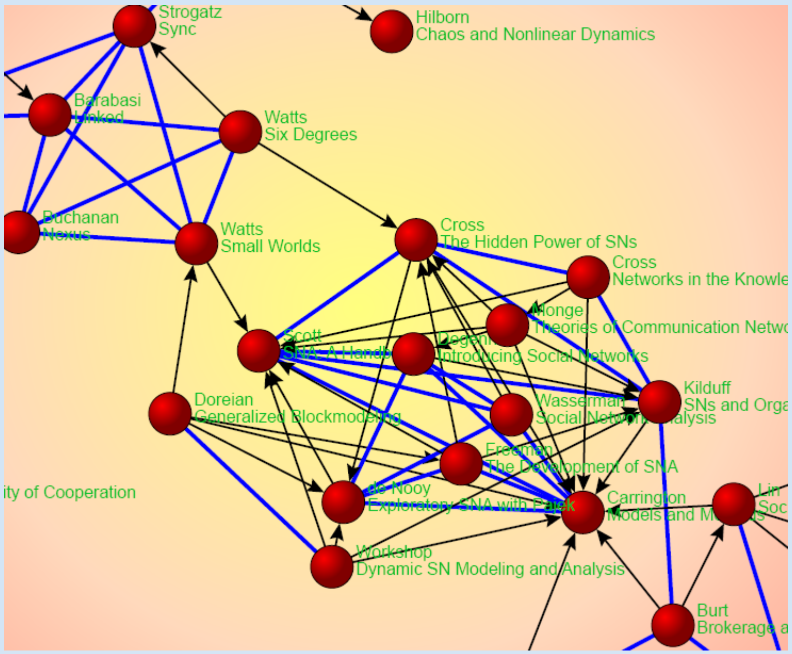
Additional URLs 1, 2, 3.

Networks from Amazon in R

```
amazon <- function(fvtx,flnk,ftit,maxver){
# Creates a network of books from Amazon
#  amazon('v.txt','a.txt','t.txt',10)
# Vladimir Batagelj, 20-21. nov. 2004 / 10. nov. 2006
  opis <- function(line){
    i <- regexpr('\">',line); l <- i[1]+attr(i,"match.length")[1]
    j <- regexpr('</a>',line); r <- j[1]-1; substr(line,l,r)
  }
  vid <- new.env(hash=TRUE,parent=emptyenv())
  vtx <- file(fvtx,"w");  cat('*vertices\n', file=vtx)
  tit <- file(ftit,"w");  cat('*vertices\n', file=tit)
  lnk <- file(flnk,"w");  cat('*arcs\n',file=lnk)
  url1 <- 'http://www.amazon.com/exec/obidos/tg/detail/-/'
  url2 <- '?v=glance';
  book <- '0521840856'
  auth <- "Patrick Doreian"
  titl <- "Generalized Blockmodeling"
  narc <- 0;  nver <- 1
  page <- paste(url1,book,url2,sep='')
  cat(nver, ' "', book, '" URL "',page,'"\n', sep='', file=vtx)
  cat(nver, ' "', auth, ':\\n',titl, '"\n', sep='', file=tit)
  assign(book,nver,env=vid)
  cat('new vertex ',nver,' - ',book,'\n')
  books <- c(book)
```

```
  while (length(books)>0){
    bk <- books[1]; books <- books[-1]
    vini <- get(bk,env=vid); cat(vini,'\n')
    page <- paste(url1,bk,url2,sep='')
    stran <- readLines(con<-url(page)); close(con)
    i <- grep("Customers who bought",stran,ignore.case=TRUE)[1]
    if (is.na(i)) break
    j <- grep("Explore Similar Items",stran,ignore.case=TRUE)[1]
    izrez <- stran[i:j]; izrez <- izrez[-which(izrez=="")]
    izrez <- izrez[-which(izrez=="   ")]
    ik <- regexpr("/dp/",izrez); ii <- ik+attr(ik,"match.length")
    for (k in 1:length(ii)) {
      j <- ii[k];
      if (j > 0) {
        bk <- substr(izrez[k],j,j+9); cat('test',k,bk,'\n')
        if (exists(bk,env=vid,inherits=FALSE)){
          vter <- get(bk,env=vid,inherits=FALSE)
        } else {
          nver <- nver + 1; vter <- nver; line <- izrez[k]
          assign(bk,nver,env=vid)
          if (nver <= maxver) {books <- append(books,bk)}
          cat(nver,' "',bk,'" URL "',url1,bk,url2,'"\n',sep='',file=vtx)
          cat('new vertex ',nver,' - ',bk,'\n');
          t <- opis(line); line <- izrez[k+1]
          if (substr(line,1,2)=='by') {a <- substr(line,4,100)}
            else { a <- 'UNKNOWN' }
          cat(nver, ' "', a, ':\\n', t, '"\n', sep='', file=tit)
        }
        narc <- narc + 1; cat(vini,vter,'\n', file=lnk)
      }
    }
    flush.console()
  }
  close(lnk); close(vtx); cat('Amazon - END\n')
}
```

Networks from Amazon – books on SNA



Books in SNA from Amazon, 10. november 2006; Starting point P. Doreian &: Generalized Blockmodeling.

SVG picture. Files/ZIP.

The program in R is just a skeleton. Possible improvements: list of starting points; continuation after interrupts; . . .

Random networks

Several types of networks can be produced randomly using special generators. The theoretical background of these generators is beyond the goals of this workshop.

Some of them are implemented in **`Pajek`** under

`Net / Random network`

but can be also described by the following functions in R.

Available is also a program `GeneoRnd` for generating random genealogies.

Random undirected graph of Erdős-Rényi type

```
dice <- function(n=6){return(1+trunc(n*runif(1,0,1)))}

ErdosRenyiNet <-
# generates a random undirected graph of Erdos-Renyi type
# with n vertices and m edges, and stores it on the file
# fnet  in Pajek's format.
# Example:
#   ErdosRenyiNet('testER.net',100,175)
# ---------------------------------------------------
# by Vladimir Batagelj, R version: Ljubljana, 20. Dec 2004
# based on ALG.2 from: V. Batagelj, U. Brandes:
#   Efficient generation of large random networks
function(fnet,n,m){
  net <- file(fnet,"w"); cat("*vertices",n,"\n",file=net)
  cat('% random Erdos-Renyi undirected graph G(n,m) / m = ',
    m,'\n',file=net)
#  for (i in 1:n) cat(i," \"v",i,"\"\n",sep="",file=net)
  cat("*edges\n",file=net); L <- new.env(TRUE,NULL)
  for (i in 1:m){
    repeat { u <- dice(n); v <- dice(n)
      if (u!=v) {
        edge <- if (u<v) paste(u,v) else paste(v,u)
        if (!exists(edge,env=L,inherits=FALSE)) break }
    }
    assign(edge,0,env=L); cat(edge,'\n',file=net)
  }
  close(net)
}
```