

# ASSYRIAN MERCHANTS MEET NUCLEAR PHYSICS

A HISTORY OF EARLY CONTRIBUTIONS FROM SOCIAL SCIENCES TO  
AUTOMATIC PATTERN DETECTION IN GRAPHS (LATE 1950S–1970S)

Sébastien PLUTNIAK

28 October 2019  
HAPOC Conference, Bergamo, Italy

TODAY, GRAPHS ARE EVERYWHERE...

... BUT IN SOCIOLOGY, THEY HAVE A LONG HISTORY...

... WHICH STILL HAS TO BE WRITTEN

TODAY, GRAPHS ARE EVERYWHERE...

References, direct or indirect, to graph theory are ubiquitous nowadays:

- internet,
- social networks,
- effects of science popularization: *e.g.*

Barabási 2002. *Linked. The New Science of Networks.*

Barabási 2014. *Linked. How Everything is Connected to Everything Else and What it Means for Business, Science, and Everyday Life.*

... BUT IN SOCIOLOGY, THEY HAVE A LONG HISTORY...

... WHICH STILL HAS TO BE WRITTEN

TODAY, GRAPHS ARE EVERYWHERE...

... BUT IN SOCIOLOGY, THEY HAVE A LONG HISTORY...

However, for sociologists, networks (as a metaphor) and graphs (as a model) are not a novelty:

- Moreno 1934. *Who Shall Survive? A New Approach to the Problem of Human Interrelations..*
- Lévi-Strauss 1949. *Les structures élémentaires de la parenté..*
- Barnes 1954. "Class and Committees in a Norwegian Island Parish".

... WHICH STILL HAS TO BE WRITTEN

TODAY, GRAPHS ARE EVERYWHERE...

... BUT IN SOCIOLOGY, THEY HAVE A LONG HISTORY...

... WHICH STILL HAS TO BE WRITTEN

- Both the history of graph theory,
- and the history of the use of graph theory in social sciences.

AIMS OF THIS PRESENTATION

GENERAL CASE: CLIQUE DETECTION

SPECIFIC CASE: ASSYRIAN MERCHANTS

MATERIALS

## AIMS OF THIS PRESENTATION

- to contribute to this history;
- to enlighten the role of social sciences in the development of graph theory;
- focusing on the case of clique detection.

## GENERAL CASE: CLIQUE DETECTION

## SPECIFIC CASE: ASSYRIAN MERCHANTS

## MATERIALS

## AIMS OF THIS PRESENTATION

### GENERAL CASE: CLIQUE DETECTION

Clique detection is important:

- for computer scientists (a NP-complete problem);
- for scientists, as an aspect of the general problem of graph clustering (wide range of application, in biology, sociology, bibliometrics, etc.).

### SPECIFIC CASE: ASSYRIAN MERCHANTS

### MATERIALS



## AIMS OF THIS PRESENTATION

## GENERAL CASE: CLIQUE DETECTION

## SPECIFIC CASE: ASSYRIAN MERCHANTS

- Starting point: an early (first?) *automatized* application on historical materials:  
Gardin and Garelli 1961. “Étude des établissements assyriens en Cappadoce par ordinateur”.
- which used a new method, Jaulin’s algorithm;
- a study which was however rarely cited later on.

## MATERIALS

## AIMS OF THIS PRESENTATION

## GENERAL CASE: CLIQUE DETECTION

## SPECIFIC CASE: ASSYRIAN MERCHANTS

## MATERIALS

- publications,
- archive materials:
  - Jean-Claude Gardin files, Université Paris X, Nanterre, France.
  - HAEU: Historical Archives of the European Union, Fiesole, Italy.
- builds on and extends a Ph.D dissertation (2017).

- 1 THE CLIQUE DETECTION PROBLEM
- 2 THE ASSYRIAN TRADE NETWORK
- 3 ACCESS TO UNUSUAL RESOURCES
- 4 METHODS FOR CLIQUE DETECTION

### 1 THE CLIQUE DETECTION PROBLEM

- Definition
- Bibliography and history

### 2 THE ASSYRIAN TRADE NETWORK

### 3 ACCESS TO UNUSUAL RESOURCES

### 4 METHODS FOR CLIQUE DETECTION

## └ THE CLIQUE DETECTION PROBLEM

### └ DEFINITION

#### 1 THE CLIQUE DETECTION PROBLEM

- Definition
- Bibliography and history

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#### 4 METHODS FOR CLIQUE DETECTION

## └ THE CLIQUE DETECTION PROBLEM

## └ DEFINITION

A clique is a maximal complete subgraph of a graph.

Moon and Moser 1965. "On Cliques in Graphs".

This is a systematization of a current notion in *sociometry*: all the individuals of a clique choose each other.

$G' = (X'; V')$ , a subgraph of  $G = (X; V)$ , is a clique if  $(x, y) \in V' \Leftrightarrow x$  and  $y \in X'$ , that is, if all the possible arcs exist in  $G'$ .

A maximal clique is a clique which is not a subgraph of a clique.

Flament 1965. *Théorie des graphes et structures sociales.*, p. 37.

## └ THE CLIQUE DETECTION PROBLEM

### └ BIBLIOGRAPHY AND HISTORY

#### 1 THE CLIQUE DETECTION PROBLEM

- Definition
- Bibliography and history

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#### 3 ACCESS TO UNUSUAL RESOURCES

#### 4 METHODS FOR CLIQUE DETECTION

Available historical accounts are nothing more than chronological lists of the different methods which have been proposed.

- Flament 1965. *Théorie des graphes et structures sociales.*
- Freeman 1988. “Computers Programs and Social Network Analysis”.
- Barthélemy and Guénoche 1988. *Les arbres et les représentations des proximités.*
- Pardalos and Xue 1994. “The Maximum Clique Problem”.
- ...



## └ THE CLIQUE DETECTION PROBLEM

## └ BIBLIOGRAPHY AND HISTORY

- 1<sup>st</sup> apparition of the concept of clique  
Luce and Perry 1949. “A Method of Matrix Analysis of Group Structure”.
- 1<sup>st</sup> algorithm described (using matrices)  
Harary and Ross 1957. “A Procedure for Clique Detection using the Group Matrix”.
- 2<sup>sd</sup> algorithm (by constructing graphs in succession)  
Paull and Unger 1959. “Minimizing the Number of States in Incompletely Specified Sequential Switching Functions”.
- 1<sup>st</sup> program:  
Coleman and MacRae 1960. “Electronic Processing of Sociometric Data for Groups up to 1,000 in Size”.
- 1961: Jaulin’s algorithm developed for Gardin’s study of the Assyrian trade network.  
Jaulin 1961. “Sur une méthode de détermination des cliques dans un graphe symétrique”.

1 THE CLIQUE DETECTION PROBLEM

2 THE ASSYRIAN TRADE NETWORK

- Actors and publications
- Data
- Method

3 ACCESS TO UNUSUAL RESOURCES

4 METHODS FOR CLIQUE DETECTION

This study of the Assyrian trade network was, in the early 1960s, an outstanding research project, considering:

- the data under study;
- the resources (social and financial supports);
- the methods (programs and computing instruments).

## └ THE ASSYRIAN TRADE NETWORK

### └ ACTORS AND PUBLICATIONS

#### 1 THE CLIQUE DETECTION PROBLEM

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## └ THE ASSYRIAN TRADE NETWORK

### └ ACTORS AND PUBLICATIONS



Jean-Claude GARDIN  
(1925–2013)



Paul GARELLI  
(1924–2006)

## Chronology of the publications:

- 1961: Presentation of the project in a seminar: Gardin 1961. “Détermination du réseau économique des Marchands Assyriens en Cappadoce (19e siècle avant J.C.) d’après l’analyse de leurs archives (Exploitation sur ordinateur IBM 650)”.
- 1961: Presentation of the clique detection method in a seminar: Jaulin 1961. “Sur une méthode de détermination des cliques dans un graphe symétrique”.
- 1961: Publication of a preliminary study in the *Annales* journal: Gardin and Garelli 1961. “Étude des établissements assyriens en Cappadoce par ordinateur”.
- 1963: Publication of the archaeological and philological aspects: Garelli 1963. *Les Assyriens en Cappadoce..*
- 1965: Publication of a paper in English dealing with methodological issues:  
Gardin 1965. “Reconstructing an Economic Network in the Ancient East with a Computer”.

#### 1 THE CLIQUE DETECTION PROBLEM

#### 2 THE ASSYRIAN TRADE NETWORK

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#### 3 ACCESS TO UNUSUAL RESOURCES

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## THE ASSYRIAN TRADE NETWORK

## DATA



Assyrian commercial expansion, 19<sup>th</sup> century B.C.

Map: S. Plutniak, adapted from Gardin and Garelli 1961. "Étude des établissements assyriens en Cappadoce par ordinateur", fig. 2.





H. R. Cole collection, Los Angeles County  
Museum of Art (M.84.31.6)

Evolution of the number of  
cuneiform tablets published:

- early 1920s:  $\approx 500$ .
- end of the 1950s:  $\approx 2600$ .
- 2005: 22 560.

## └ THE ASSYRIAN TRADE NETWORK

### └ METHOD

#### 1 THE CLIQUE DETECTION PROBLEM

#### 2 THE ASSYRIAN TRADE NETWORK

- Actors and publications
- Data
- **Method**

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#### ISSUES DISCUSSED IN GARDIN & GARELLI'S PAPER

- automatisisation of clique detection;
- automatisisation of cycle detection;
- graph visualisation;
- integration of the time dimension in graph analysis.

Later, he wrote that the purpose of this research was to simulate the reasoning of an expert (here a philologist).

Gardin 1971. "Archéologie et calculateurs : nouvelles perspectives", p. 215.

## THE ASSYRIAN TRADE NETWORK

## METHOD

Marchands	Marchands									
Marchands	A.T	P.K	LQ	AM.I	A.T	A.N	AS.T	I.I	HI	TK
ASSUR-TAB	0	1	0	0	0	0	0	1	0	1
PÜSHU-KIN	1	0	1	1	1	1	0	1	1	0
LAQIPUM	0	1	0	1	0	1	0	1	1	0
AMUR-ISHTAR	0	1	1	0	1	1	1	1	1	1
ASSUR-TAKLAKU	0	1	0	1	0	1	0	0	0	1
ASSUR-NA'DA	0	1	1	1	1	0	1	0	0	0
ASSUR-INITTI	0	0	0	1	0	1	0	0	0	0
IM(I)D-ILUM	1	1	1	1	0	0	0	0	1	0
HINA	0	1	1	1	0	0	0	1	0	0
TARAM-KUBIM	1	0	0	1	1	0	0	0	0	0

Fig. 7. — Exemple d'un tableau de relations entre dix marchands. Les « cliques » extraites de ce tableau seraient les suivantes : C1 : Amur-ishtar, Im(i)d-ilum, Püshu-Kin, Hiná, Láqipum — C2 : Amur-ishtar, Assur-takláku, Püshu-Kin — C3 : Im(i)d-ilum, Püshu-kin, Assur-táb. Tarám-Kubim n'entre dans aucune clique.

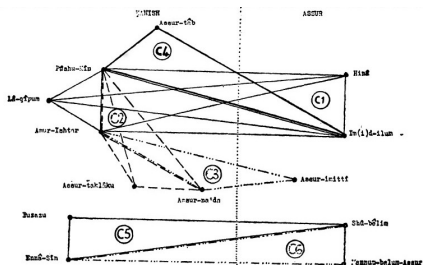


Fig. 10. — Premier essai de représentation graphique du réseau. Pour quatre cliques seulement (C1 à C4), le tableau est déjà peu lisible ; ce genre de schéma ne peut être retenu que pour marquer les relations entre un petit nombre d'individus, et non entre les groupes qu'ils constituent. Noter cependant l'« isolat » (C5-C6), par rapport aux quatre cliques précédentes. Les noms ne sont donnés sur cette figure qu'à titre illustratif ; dans le schéma réel, chacun est accompagné si possible d'une indication patronymique, obtenue d'après l'étude des homonymes.

Gardin and Garelli 1961. “Étude des établissements assyriens en Cappadoce par ordinateur”, p. 865 et 868.

#### WEIGHTED GRAPHS?

Gardin pointed out a flaw in their approach: not considering the different intensities of relations between merchants.

Gardin and Garelli 1961. “Étude des établissements assyriens en Cappadoce par ordinateur”, p. 864.

## WEIGHTED GRAPHS?

Gardin pointed out a flaw in their approach: not considering the different intensities of relations between merchants.

*Une objection vient à l'esprit : cette définition des cliques a le tort de n'envisager que la présence ou l'absence d'un lien entre deux marchands, sans lui accorder aucun "poids" selon le nombre ou la nature des relations qui l'expriment, dans l'analyse.*

Gardin and Garelli 1961. "Étude des établissements assyriens en Cappadoce par ordinateur", p. 864.

## WEIGHTED GRAPHS?

Gardin pointed out a flaw in their approach: not considering the different intensities of relations between merchants.

He justified they had not used weighted graphs:

- they lacked a scale to weight the edges;
- and considering that clique detection and the use of weighted graphs are two different issues (?)

Gardin and Garelli 1961. “Étude des établissements assyriens en Cappadoce par ordinateur”, p. 864.

## WEIGHTED GRAPHS?

Gardin pointed out a flaw in their approach: not considering the different intensities of relations between merchants.

- Indeed, a method to detect cliques in weighted graphs was not published prior to 1969:

Doreian 1969. “A Note on the Detection of Cliques in Valued Graphs”.

Gardin and Garelli 1961. “Étude des établissements assyriens en Cappadoce par ordinateur”, p. 864.



## APPLICATIONS OF CLIQUE DETECTION IN THIS RESEARCH

- 1961: study of the 30 most important merchants  
Gardin and Garelli 1961. “Étude des établissements assyriens en Cappadoce par ordinateur”.
- 1965: mention of a square matrix with the relations between 200 merchants  
Gardin 1965. “Reconstructing an Economic Network in the Ancient East with a Computer”, p. 389.

*The mathematical problem of clique detection has been approached by many authors, from varying angles. The main issue, here, is in the size of the matrix which has to be analyzed to that end (ca. 200 rows x 200 columns); for whatever the detection method may be, it is unrealistic to consider its application on so large a matrix without the help of a computer.*

### 1 THE CLIQUE DETECTION PROBLEM

### 2 THE ASSYRIAN TRADE NETWORK

### 3 ACCESS TO UNUSUAL RESOURCES

- Gardin's rich network
- A commitment in information retrieval and non-numerical computing
- Assyrian merchants meet nuclear physics

### 4 METHODS FOR CLIQUE DETECTION

└ ACCESS TO UNUSUAL RESOURCES

└ GARDIN'S RICH NETWORK

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└ ACCESS TO UNUSUAL RESOURCES

└ GARDIN'S RICH NETWORK

The scientific committee of the CADA included:

LEADING FIGURES IN THE FRENCH SCIENCE POLICY

ORIENTALISTS

METHODOLOGICAL INNOVATORS

└ ACCESS TO UNUSUAL RESOURCES

└ GARDIN'S RICH NETWORK

The scientific committee of the CADA included:

## LEADING FIGURES IN THE FRENCH SCIENCE POLICY

- Michel LEJEUNE (1907–2000): since 1955, deputy director at the CNRS for the humanities and sciences.
- Pierre DEMARGNE (1903–2000): since 1955, Professor of Greek Archaeology at the Sorbonne and, since 1957, Director of the Department of Ancient Architecture of the CNRS.
- M. DELAROCHE (?–?): administrator of the CNRS's general services.

## ORIENTALISTS

## METHODOLOGICAL INNOVATORS

└ ACCESS TO UNUSUAL RESOURCES

└ GARDIN'S RICH NETWORK

The scientific committee of the CADA included:

## LEADING FIGURES IN THE FRENCH SCIENCE POLICY

### ORIENTALISTS

- Claude SCHAEFFER (1898–1982): specialist in Mesopotamian epigraphy; since 1946 Secretary General of the Excavation Commission of the Ministry of Foreign Affairs; since 1953, Professor at the Collège de France and member of the *Académie des inscriptions et belles-lettres*;
- André PARROT (1901–1980): since 1933, director of excavations at the Mari site; since 1946, curator of Oriental Antiquities at the Louvre; since 1958, general secretary of the Commission for Archaeological Excavations and Missions.

### METHODOLOGICAL INNOVATORS

└ ACCESS TO UNUSUAL RESOURCES

└ GARDIN'S RICH NETWORK

The scientific committee of the CADA included:

LEADING FIGURES IN THE FRENCH SCIENCE POLICY

ORIENTALISTS

METHODOLOGICAL INNOVATORS

- Henri SEYRIG (1895–1973): since 1945, director of the IfAB; since 1952, member of the *Institut des inscriptions et belles-lettres*; since 1960, nominated as *directeur des musées de France*.
- Claude LÉVI-STRAUSS (1908–2009): since 1949 *directeur d'études* at the EPHE; since 1958, Professor at the *Collège de France*.

└ ACCESS TO UNUSUAL RESOURCES

└ GARDIN'S RICH NETWORK

The scientific committee of the CADA included:

LEADING FIGURES IN THE FRENCH SCIENCE POLICY

ORIENTALISTS

METHODOLOGICAL INNOVATORS

But also...

- the network of the Free French (during WW2);
- actors of the VI<sup>th</sup> section of the *École pratique des hautes études* (EPHE, Economic and Social Sciences, founded after WW2;
- founders of the “*Maison des sciences de l’homme*” (Fernand Braudel, *etc.*).



└ ACCESS TO UNUSUAL RESOURCES

└ GARDIN'S RICH NETWORK

- But Gardin was not only an archaeologist.
- He was also involved in the first developments of information retrieval and “non-numerical” computing.
- Gardin 1955. “Problems of Documentation”, *Diogene*.

└ ACCESS TO UNUSUAL RESOURCES

└ A COMMITMENT IN INFORMATION RETRIEVAL AND NON-NUMERICAL COMPUTING

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## 4 METHODS FOR CLIQUE DETECTION

└ ACCESS TO UNUSUAL RESOURCES

└ A COMMITMENT IN INFORMATION RETRIEVAL AND NON-NUMERICAL COMPUTING

## GARDIN PARTICIPATED IN SOME KEY CONFERENCES

- *International Conference on Scientific Information*
- organised by the National Academy of Sciences, National Research Council
- 16–21 November 1958, Washington
- Gardin 1959. “On the Coding of Geometrical Shapes and Other Representations, with Reference to Archaeological Documents”.

└ ACCESS TO UNUSUAL RESOURCES

└ A COMMITMENT IN INFORMATION RETRIEVAL AND NON-NUMERICAL COMPUTING

## GARDIN PARTICIPATED IN SOME KEY CONFERENCES

- *International Conference on Information Processing*
- organised by the UNESCO
- 15–20 June 1959, Paris
- *Symposium on the Use of Automatic Computation Techniques in the Social Sciences*: Gardin and Braffort 1960. “Mise en évidence et exploitation mathématique des structures dans les phénomènes humains. Étude topologique des formes de vases”.

└ ACCESS TO UNUSUAL RESOURCES

└ A COMMITMENT IN INFORMATION RETRIEVAL AND NON-NUMERICAL COMPUTING

## GARDIN PARTICIPATED IN SOME KEY CONFERENCES

- *Preparatory training in automatic documentation techniques*
- organised by André Leroy (ex-CEA) from the CETIS
- 15–22 February 1960, Bruxelles
- Leroy 1960. *Enseignement préparatoire aux techniques de la documentation automatique.*

## PREPARATORY TRAINING... PROGRAM (1)

- Introduction:
  - A. LEROY, Présentation des cours
  - E. PIETSCH, Les problèmes de la documentation
  - E. de GROLIER, Historique des Systèmes documentaires
  - P. BRAFFORT, Historique des machines à calculer
  
- Mathematics day:
  - P. BRAFFORT, Introduction à la journée de mathématiques
  - M. SCHÜTZENBERGER, Théorie de l'information
  - A. GAZZANO, Éléments de recherche opérationnelle
  - J. LARISSE, Travaux pratiques de linguistique statistique
  
- Linguistics day:
  - A. LEROY, introduction à la journée de linguistique
  - S. CECCATO, I problemi filosofici del linguaggio
  - P. BRAFFORT, Éléments de linguistique mathématique
  - V. BELEVITCH, On the statistical laws of linguistic distributions
  - Y. LECERF, Travaux pratiques linguistique

## PREPARATORY TRAINING... PROGRAM (2)

- Documentation systems day:
  - A. LEROY, Élaboration d'un système documentaire
  - J.C. GARDIN, Analyse et sélection documentaire dans les sciences humaines
  - Discussion sur les systèmes documentaires
  
- Analyse day:
  - M. DETANT, Y. LECERF, A. LEROY, Travaux pratiques sur l'établissement des diagrammes
  - Y. LECERF, Analyse automatique (Programme d'une expérience par E. Morlet)
  
- Automatisation day:
  - Th. W. TE NUYL, The "L'Unité" documentation system
  - J. POYEN, Quelques problèmes posés par le traitement de l'information non numérique
  - J. IUNG, Points communs entre les problèmes posés par la traduction automatique et la documentation automatique
  - A. LEROY, la documentation complètement automatique
  - P. BRAFFORT, Conclusion générale

## THE “LEIBNIZ” SEMINARS (CETIS/IBM)

- *Non Numerical data-processing Symposium*
- 24–27 April 1961, Blaricum (Netherlands), *IBM World Trade European Education Center*
- participants: Luitzen Egbertus Jan Brouwer, David Hirschberg, Silvio Ceccato, Paul Braffort, Claude Berge, Yves Lecerf, Jean-Claude Gardin...

- *On the Relationship between Non-numerical Programming and the Theory of Formal System*
- October 1961, Blaricum, *IBM World Trade European Education Center*
- Braffort and Hirschberg 1963. *Computer Programming and Formal Systems.*





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### └ ASSYRIAN MERCHANTS MEET NUCLEAR PHYSICS

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For most of these activities, Gardin collaborated with Paul Braffort (1923–2019), then director of the Scientific data processing center (CETIS), at the Ispra Centre for Nuclear Studies.

└ ACCESS TO UNUSUAL RESOURCES

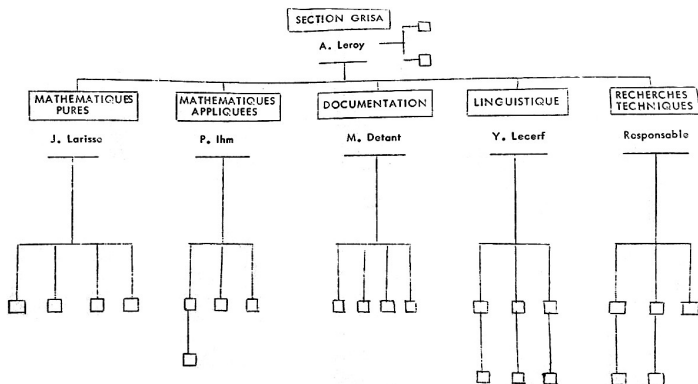
└ ASSYRIAN MERCHANTS MEET NUCLEAR PHYSICS



- 1957: 25 March 1957, signature of the Rome treaty and of the EURATOM treaty;
- 1959: creation of the GRISA;
- 1960: creation of the CETIS and integration of the GRISA.
- 1961: the CETIS settled in Ispra, Italy.

ACCESS TO UNUSUAL RESOURCES

ASSYRIAN MERCHANTS MEET NUCLEAR PHYSICS



Organisation chart of the CETIS' GRISA section (Automatic Scientific Information Research Group) in 1960.

Source : BRAFFORT P., *L'état actuel des organigrammes du Centre de traitement de l'information scientifique*, p. 6, 1960, HAEU.

## CETIS' AIMS

*Nos tâches principales, telles qu'elles se dessinent maintenant, peuvent se grouper de la façon suivante :*

- *étude des stratégies et du matériel de recherche automatique des informations actuellement utilisées (notamment aux U.S.A. et en U.R.S.S.). [...]*
- *choix d'une stratégie globale (codage et machines) pour l'ensemble documentaire d'Euratom.*
- *aide aux institutions scientifiques et documentaires des Pays membres de la Communauté pour le choix de stratégies particulières correspondant à des ensembles documentaires plus petits.*

Source: BRAFFORT P., *Projet d'organisation du groupe de recherche sur l'Information scientifique automatique*, 22-07-1959, HAEU.

└ ACCESS TO UNUSUAL RESOURCES

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## CETIS' AIMS

*Pour résoudre ces problèmes, nous aurons à mener des travaux :*

- *de statistique et de recherche opérationnelle (dynamic programming)*
- *de programmation spécialisée sur machine arithmétique*
- *d'analyse documentaire par les méthodes modernes de diagrammes et de phrases-clés*
- *d'analyse syntaxique des langages "artificiels" ainsi créés.*

Source: BRAFFORT P., *Projet d'organisation du groupe de recherche sur l'Information scientifique automatique*, 22-07-1959, HAEU.



└ ACCESS TO UNUSUAL RESOURCES

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## TOWARDS AN UNIVERSAL DOCUMENTARY LANGUAGE

*C'est ainsi que nous désirons participer à la mise au point d'un langage documentaire adapté au domaine des sciences de l'homme, langage conçu de telle façon qu'il puisse s'inscrire dans le cas général du langage documentaire universel qui nous intéresse tous.*

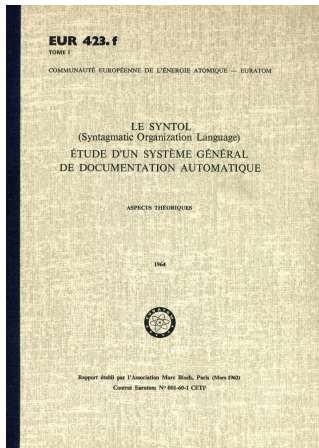
*[...]*

*La personne la mieux qualifiée pour conduire une telle recherche est, sans contestation possible, Monsieur Jean Gardin [sic.], Directeur du Centre d'Analyse Documentaire pour l'Archéologie pour le Centre National de la Recherche Scientifique.*

Source: Lettre de Paul Braffort à Louis Zieglé (DGRST) datée de février 1959, fonds MAE.

ACCESS TO UNUSUAL RESOURCES

ASSYRIAN MERCHANTS MEET NUCLEAR PHYSICS



The main result of this contract was the documentary language SYNTOL (*SYNTagmatic Organization Language*)

- Gardin and Lévy 1962. “Le SYNTOL, ses propriétés et ses applications en documentation automatique”, *Proceedings of the International Federation of Information Processing Societies Conference*.
- Cros et al. 1964. *L'automatisation des recherches documentaires. Un modèle général “Le SYNTOL”*.

└ ACCESS TO UNUSUAL RESOURCES

└ ASSYRIAN MERCHANTS MEET NUCLEAR PHYSICS

## ACCESS TO POWERFUL COMPUTERS

- Gardin & Garelli mentioned the use of an IBM 650.  
Gardin and Garelli 1961. “Étude des établissements assyriens en Cappadoce par ordinateur”.
- In 1961 the CETIS are not yet installed in Ispra.  
Braffort and Gazzano 1961. “Le calcul électronique à Euratom”, p. 56.
- So, the computation were made in Belgium,
  - either at the IBM facilities thanks to a contract made in 1956 between the FNRS and IBM;
  - or with the IBM 650 purchased in 1956 by the Free University of Brussels and the University of Liège.  
Halleux and Xhayet 2007p. 158–159

└ ACCESS TO UNUSUAL RESOURCES

└ ASSYRIAN MERCHANTS MEET NUCLEAR PHYSICS

## ACCESS TO POWERFUL COMPUTERS

*Le “calcul” de ces groupes, à partir de la matrice des relations observées entre une centaine d’individus pris deux à deux, est cependant une opération compliquée, qui dépasse déjà les possibilités d’un ordinateur moyen comme l’IBM 650 ; et un nouveau programme est sur le point d’être achevé, pour une machine plus puissante (IBM 7090), avec la collaboration du Centre européen pour le Traitement de l’Information scientifique (EURATOM)*

Gardin 1962. “Cartes perforées et ordinateurs au service de l’archéologie”, p. 456-457.

└ ACCESS TO UNUSUAL RESOURCES

└ ASSYRIAN MERCHANTS MEET NUCLEAR PHYSICS

## ACCESS TO POWERFUL COMPUTERS



The CETIS's IBM 7090 in 1962.

Gardin 1962. "Cartes perforées et ordinateurs au service de l'archéologie", p. 456-457.

- 1 THE CLIQUE DETECTION PROBLEM
- 2 THE ASSYRIAN TRADE NETWORK
- 3 ACCESS TO UNUSUAL RESOURCES
- 4 METHODS FOR CLIQUE DETECTION
  - The quest for Jaulin's algorithm
  - A substitute: Harary & Ross' algorithm
  - Later developments

## └ METHODS FOR CLIQUE DETECTION

### └ THE QUEST FOR JAULIN'S ALGORITHM

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#### CHRONOLOGY OF RESEARCH

- 1960: 1<sup>st</sup> implementation: in SOAP language, for an IBM 650 computer, by André Debroux (IBM) & Otto Hermann (EURATOM).
- 1962: 2<sup>sd</sup> implementation: for an IBM 704 computer.



Attempts to reproduce Jaulin's method.

ARCHIVES

PUBLICATIONS

Attempts to reproduce Jaulin's method.

#### ARCHIVES

- Gardin's files, Nanterre: various documents indexed, but missing!
- Historical Archives of the European Union: nothing.
- IBM Belgium: (?)

#### PUBLICATIONS

Attempts to reproduce Jaulin's method.

#### ARCHIVES

#### PUBLICATIONS

- review of the literature on clique detection;
- review of Jaulin's publications.

#### MENTIONS OF JAULIN'S PROCEDURE

*C'est à M. Bernard Jaulin que revient le mérite d'avoir trouvé, pour notre problème, une démarche de calcul particulièrement rapide, bien adaptée aux procédés de traitement automatique ;*

Gardin and Garelli 1961. "Étude des établissements assyriens en Cappadoce par ordinateur", p. 865.

#### MENTIONS OF JAULIN'S PROCEDURE

*Another method, based on Boolean algebra, is used in France though it has not yet appeared in print.*

Flament 1963. *Applications of Graph Theory to Group Structure.*, p. 37.

#### MENTIONS OF JAULIN'S PROCEDURE

*Harary et Ross (1957) donne une technique matricielle de recherche des cliques maximales dans un graphe. Une autre méthode, fondée sur l'algèbre de Boole, a été proposée par Jaulin (1961).*

Flament 1965. *Théorie des graphes et structures sociales.*, p. 53.

#### MENTIONS OF JAULIN'S PROCEDURE

Later literature review do not mentioned Jaulin's method, even those published in French, *e.g.*:

Schneider 1973. "Méthodes pour recenser toutes les cliques maximales et q-maximales d'un graphe".

## MENTIONS OF JAULIN'S PROCEDURE

Finally, discovery of a description of the method in the working papers of a seminar held in Paris:

SUR UNE METHODE DE DETERMINATION DES CLIQUES  
DANS UN GRAPHE SYMETRIQUE  
-----

Bernard JAULIN.

Nous nous proposons de décrire une méthode permettant de déterminer toutes les cliques d'un graphe fini et non orienté. Rappelons qu'un graphe est un ensemble  $Y$ , ensemble de marchands,\* etc ..., et une application de  $Y$  dans  $Y$ , les relations commerciales entre ces marchands par exemple. Le graphe est fini c'est-à-dire que l'ensemble  $Y$  est fini, et non orienté,

Jaulin 1961. "Sur une méthode de détermination des cliques dans un graphe symétrique".



#### PROPERTIES OF JAULIN'S METHOD

- suitable for symmetric graphs;
- based on the notion of uncliqual points;
- presented by Jaulin as an improvement over Harary & Ross method.

#### ATTEMPTS TO RE-EXECUTE JAULIN'S METHOD

- with the help of Alain Guénoche, formerly mathematician at Gardin's Centre;
- Attempts failed!
- Furthermore, Jaulin himself pointed out a limit of his method for graphs without uniclqual points; in this case, he wrote to use... Harary & Ross method.

## └ METHODS FOR CLIQUE DETECTION

### └ A SUBSTITUTE: HARARY & ROSS' ALGORITHM

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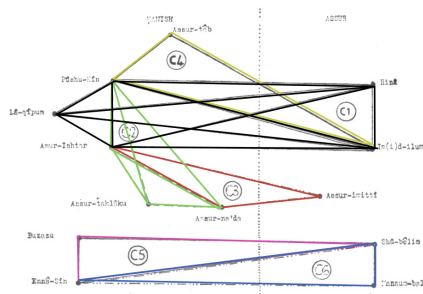
## METHODS FOR CLIQUE DETECTION

## A SUBSTITUTE: HARARY &amp; ROSS' ALGORITHM

Data extracted from:

Marchands	Marchands	A.T	P.K	LQ	AM.I	A.P	A.N	AS.I	I.I	HI	TK
ASSUR-TAB		1	0	0	0	0	0	0	1	0	1
PUSHU-KIN		1	1	1	1	1	0	1	1	0	0
LAQIPUM		0	1	1	1	0	1	0	1	1	0
AMUR-ISHTAR		0	1	1	1	1	1	1	1	1	1
ASSUR-TAKLAKU		0	1	0	1	1	0	0	0	0	1
ASSUR-NA'DA		0	1	1	1	1	1	0	0	0	0
ASSUR-IMITTI		0	0	0	1	0	1	0	0	0	0
IM(I)D-ILUM		1	1	1	1	0	0	0	0	1	0
HINA		0	1	1	1	0	0	0	1	0	0
TARAK-KUBIM		1	0	0	1	1	0	0	0	0	0

Fig. 7. — Exemple d'un tableau de relations entre dix marchands. Les « cliques » extraites de ce tableau seraient les suivantes : C1 : Amur-ishtar, Im(i)d-ilum, Pūshu-Kin, Hinā, Laqipum — C2 : Amur-ishtar, Assur-taklaku, Pūshu-Kin — C3 : Im(i)d-ilum, Pūshu-kin, Assur-tāb. Tarak-Kubim n'entre dans aucune clique.



Gardin and Garelli 1961. "Étude des établissements assyriens en Cappadoce par ordinateur", p. 865 et 868.

## METHODS FOR CLIQUE DETECTION

## A SUBSTITUTE: HARARY &amp; ROSS' ALGORITHM

cNr	cSize	Gardin & Garelli 1961	Harary 1957	Bron & Kerbosch 1973	Makino & Uno 2004	Eppstein 2010
1	5	x	x	x	x	x
2	4	x	x	x	x	x
3	3	x	x	x	x	x
4	3	x	x	x	x	x
5	3	x	x	x	x	x
6	3	x	x	x	x	x
-	3	-	x	-	-	-
-	3	-	x	-	-	-

Clique detected by the different methods.

The Harary & Ross method finds two cliques more.

Indeed, Harary & Ross' method was also wrong.

#### SHORT CHRONOLOGY OF THE HARARY & ROSS METHOD

- 1957: publication:  
Harary and Ross 1957. "A Procedure for Clique Detection using the Group Matrix".
- 1969: extended to valued graph:  
Doreian 1969. "A Note on the Detection of Cliques in Valued Graphs".
- 1970: Harary noted an error in his method:  
Harary 1970. "Graph Theory as a Structural Model in the Social Sciences", p. 6.
- 1973: modified algorithm implemented in PL/1:  
Hunter Dixon 1973. *On the Efficiency of Clique Detection in Graphs*.
- 2019: original algorithm implemented in R.

## METHODS FOR CLIQUE DETECTION

## A SUBSTITUTE: HARARY &amp; ROSS' ALGORITHM

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```

.....
*
*   THE MODIFIED HARARY-ROSS ALGORITHM
*
*
*
.....
HAROSS:PROC(A,N);
  DCL
    (A(N), /* ADJACENCY MATRIX */
     G, /*CURRENT VERTEX SET*/
     CLIQ, /*COMPLETE SUBGRAPH VERTICES */
     CTEMP)
    BIT(N),
    (N, /* NUMBER OF VERTICES IN GRAPH*/
     NT, /*NUMBER OF VERTICES IN G */
     VTX(N), /* LABELS OF VERTICES OF G*/
     R(N), /*ROW SUMS OF (A**2XA) FOR G*/
     D(N)) /* DEGRES OF VERTICES OF G */
    FIXED BIN,
    VSET BIT(*) CTL; /* STACK OF SETS */
  DCL CTR FIXED BIN;
  CTR=0;
  G=G1(G);
  PUT SKIP;
  PUT SKIP LIST ('THE CLIQUES ARE:');
START:
/*
  DETERMINE THE VERTICES IN SUBGRAPH G
*/
  IF G='0'B THEN GO TO NEXT;
  CTEMP=CTEMP; CTRMD1.

```

Hunter Dixon 1973. *On the Efficiency of Clique Detection in Graphs.*

## └ METHODS FOR CLIQUE DETECTION

### └ LATER DEVELOPMENTS

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- The project Assyrian trade network is extended to ethnography: political relations in the New Hebrides.
- A new project at the SAD (Automatic Documentation Section of the Institut Blaise Pascal), also led by Gardin: creation of a “symbolic language” for graph theory.
- Concurrency of another research project about graphs, run at the *Institut de programmation* in Paris and also funded by the DGRST.

- Highlight the less-known role of (sociology) and history in the development of graph theory.
- Identifying two early and erroneous algorithms (and two corresponding receptions, namely correction, oblivion).
- Move towards a contextualized history of algorithms, showing some relationships between the growth of social sciences and nuclear research.

Thank you for your attention!

`sebastien.plutniak_@_posteo.net`