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INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team Gyroweb

Dynamic graphs and large networks

Rocquencourt

THEME COM

Activity Report

2005

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1. Team

Gyroweb is a joined team between INRIA, CNRS and Paris 7 University, through the "laboratoire d'informatique algorithmique, fondements et applications", LIAFA *(UMR 7089).*

Head of project-team
Laurent Viennot [Research scientist (partner)]

Vice-head of project team
Dominique Fortin [Research scientist (partner)]

Administrative assistant
Danielle Croisy [shared time (with Hipercom)]

Staff member Paris 7 University
Yacine Boufkhad [Assistant professor]
Fabien de Montgolfier [Assistant professor]

Ph. D. student
Anh-Tuan Gai [BDI]

Student intern
Mehdi Nafa [Master Poitiers University]

2. Overall Objectives

2.1. Overall Objectives

The main objective of the project is to study the structure and the dynamics of the graphs appearing in large networks. The web graph defined by the web pages and the hyper-links between them is one of our main application field. Other natural subjects of interest include the Internet graph (defined by the connections between Internet routers), peer-to-peer networks (where a logical network links the peers together) and social networks.

The first problem comes from measuring such large structures. Usually made through crawling, the process of discovering the large graphs listed above is long and incomplete. How to define precisely what is measured, quantifying how accurate is a measure are still open problems.

The natural follow-up is to model such large networks. Recent work has exhibited power laws in degree distributions of these graphs. However, few efforts have been made on modeling the dynamics of these evolving graphs.

Finally, these graphs are linked to algorithms and protocols as page-rank for the web graph, routing for the Internet graph and indexing for peer-to-peer networks. Optimizing them by using the knowledge of the structure of the underlying graph is one of our goals.

3. Scientific Foundations

3.1. Scientific Foundations

Keywords: *dynamic graphs*, *graph algorithms*, *matrix analysis*, *network protocols*, *stochastic models*.

The main competencies of the team are graph algorithms, networking protocols, matrix analysis, and stochastic models.

3.1.1. Networking protocols and graph theory

The design of networking protocols (such as ad hoc routing protocols or file sharing peer-to-peer protocols) often rely on distributed graph algorithms. Many invariants for the good functioning of them can be expressed as graph theoretical properties. Moreover, many observations of large graphs rely on the underlying protocols allowing to measure them (such as HTTP for crawling the web graph, or BGP and ICMP for discovering the Internet graph). Knowledge of these protocols and network constraints are fundamental when modeling these graphs.

3.1.2. Stochastic graph models

The popular random graph model of Erdõs and Rènyi does not capture the properties observed in real world complex networks (web graph, social graphs, etc). These properties are in general a power law degree distribution, a low diameter, and a high clustering. Consequently, there is a need to find new models for these graphs. The aim at finding such models is to understand the basic mechanisms behind their particular structure to predict their future evolution and to randomly generate graphs having the same properties. Although some results on graphs with power law degree distribution have been published, much still has to be done in this area.

3.1.3. Matrix and spectral analysis of large graphs

Matrix analysis reveals some important properties of large graphs through their adjacency matrix. The page-rank for example can be viewed as an eigenvector of a normalization of the adjacency matrix of the web graph. More generally, structural analysis splits into spectral analysis and actual domain approximation. In the former, we relate eigenvalues and eigenvectors to properties like maximum clique, maximum cut, etc..., while in the latter we devise simpler structures that leads to close approximations of general ones. Due to large sizes, both approaches are rather complementary than competitors.

3.1.4. Dynamic graphs

An abundant literature around fully dynamic algorithms treats the problem of updating a graph computation after slight modification of the graph. Another approach resides in considering a dynamic graph as an evolving structure and trying to characterize the properties of this evolution.

4. Application Domains

4.1. Application Domains

Keywords: *Internet reliability, mapping the web, peer-to-peer protocols*.

Application domains include mapping the web, evaluating Internet reliability, and the design of efficient peer-to-peer protocols.

- The main application of studying the web graph resides in evaluating the importance of web pages (as popularized by the PageRank of Google). A long term application goal is to map the web: that is to identify automatically sites and links between them.
- Modeling the Internet graph main application is to allow realistic simulation of Internet protocols. Another interesting field resides in evaluating the reliability of the Internet connectivity.
- Peer-to-peer protocols are based on a all equal paradigm that allows to design highly reliable and scalable applications. Besides the file sharing application, peer-to-peer solutions could take over in web content dissemination resistant to high demand bursts or in mobility management.

5. Software

5.1. Software

- In collaboration with Fabrice Le Fessant, Anh-Tuan Gai and Laurent Viennot are developping a peer-to-peer client for sharing and backuping personnal data.
- For use in Cplex optimization suite, Dominique Fortin is currently implementing in java 1.5, Field and Ring operations that support arbitrary precision (using Apfloat machinery). It is meant for quaternion or Eisenstein-like cases, e.g. $a + b\sqrt{n}$ for a fixed n which is involved in extreme points enumeration of a polyhedral cone.
- Yacine Boufkhad, Mehdi Nafa and Fabien de Montgolfier have realized a BitTorrent protocol simulator.

6. New Results

6.1. Peer to peer

6.1.1. Comparing strategies for cooperative file downloading

Keywords: *BitTorrent*, *incentive*, *tit-for-tat*.

Participant: Fabien de Montgolfier.

Peer-to-peer filesharing networks take a very large part of the overall Internet bandwidth. Is is thus worth studying their dynamics. Recent protocols like BitTorrent use a "generous tit-for-tat" paradigm that incents symmetric upload and downloads rates. The protocol allows implentations of many strategies. In [7], we investigate some possible players strategies and give simulation results. They show that tit-for-that incentives are efficient, and thus that global network interest meets particular peer interests.

6.1.2. Keyword indexing in a file sharing system

Keywords: *distributed hash tables*, *keyword indexing*, *peer-to-peer*.

Participants: Laurent Viennot, Anh-Tuan Gai.

In [5] we sketch a general architecture framework for balancing the load of publications, storing indexes and answering request in fully distributed file sharing applications. Our design goals include reducing the work of file providers and enabling efficient keyword searching based on the assumption that few words are associated to each file.

6.1.3. Stream multicasting

Keywords: *De Bruijn graph*, *multicast*, *peer-to-peer*, *stream*.

Participants: Laurent Viennot, Anh-Tuan Gai.

In [9], we consider the problem of multicasting a stream of packets in a large scale peer-to-peer environment. In that context, we stress three features: forwarding load should be equally balanced among nodes, the scheme should be resilient to node failures and peers should have incentive to cooperate. Mainly based on the seminal work of SplitStream which partially achieves this goals, we propose an algorithm gathering together these three features. Its main advantage is to reduce the forwarding load of every node to the stream bandwidth (every node uploads as much as it downloads). This ultimate load balancing is achieved together with a clustering scheme allowing bi-directional exchanges. This results in resilience to node failures and the possibility of banishing nodes that do not respect reciprocity of exchanges. This paper promotes disjoint clustering as opposed to previously proposed hierarchical clustering schemes. Interestingly, varying the size of clusters allows to obtain different trade-offs between delay optimization and resilience to node failures. The performances of several algorithms are analyzed and compared with respect to these goals. The propagation delays of these algorithms appear to be within a factor 1.5 to 2 from theoretical optimal.

6.2. Web Graph

Participants: Fabien de Montgolfier, Toufik Bennouas [LIRMM, Montpellier].

Many author in the recent year have written Web Graph models, in order to simulate Web algorithms and obtain a better understanding of the Web graph structure. The graphs produced by these models show properties similar to the Web graph properties, like power-law degree distribution, small mean distances or high clustering. But the generated graphs indeed are compared to Web crawls, and not to the Web graph itself, an unknowable object. We have thus looking for modeling the Web crawls [10], instead of Web graph, using only basic assumptions on how a crawler work. Amazingly, we discover many well-known properties of "Web graphs", like high clustering, bipartite cores or small mean distances, without any assumption of how the page are written (like preferential attachment or copying). Is is thus not excluded that these properties are crawling artefacts rather than genuine Web properties.

6.3. Discrete Optimization Algorithms

6.3.1. Multiknapsack

Participants: Dominique Fortin, Ider Tseveendorj [PRISM, Versailles University].

In the recent past, we focused on reverse convex approach for the multiknapsack as well as the piecewise convex maximization global optimization approach; for this problem, we mixed both in order to devise an exact algorithm whose performance is close to the best (and numerous) heuristics found so far.

6.4. Graph decompositions

Participants: Fabien de Montgolfier, Michel Habib [LIAFA, Paris 7], Ross McConnell [CS dept, Colorado State University].

Decomposition can help a lot when dealing with very large data. We have worked around a wide family of decompositions, the partitive families. It is a general framework that apply to commons interval of a family of permutations [4] as well as to graph decompositions [8], [3]. They are two equivalent compact representations of these families : the well-know PQ-tree [3] and the newly discovered generator [4]. Both allow simple and efficent (linear-time) algorithmics for a wide range of problem used in bioinformatics, graph algorithmics or text algorithmics. Namely, the well-know modular decomposition [3], [4] as the new bijoin decomposition [8] can be computed in linear time, as well as the common interval of a family of permutations [4] or the PQ-tree of a family of intervals givens by their bounds [6].

6.5. SAT related problems

Participants: Yacine Boufkhad, Olivier Bailleux [LERSIA, Bourgogne], Olivier Roussel [CRIL, Univ. Artois].

In [2], we propose a new way to encode pseudo-boolean constraints with arbitrary coefficients into CNF formulae. We prove that the size of the encoding remains polynomial in the most important cases and give some cases where it can generate exponential size formulae. In practice, this encoding have good performances compared to specialized algorithms dedicated to solve pseudo-boolean constraints.

7. Other Grants and Activities

7.1. National initiatives

7.1.1. PairAPair Ministry Grant

Laurent Viennot is the head of the PairAPair national project. Anh-Tuan Gai is funded by this project.

Peer-to-peer networks have become the heaviest source of traffic in the Internet through the use of file sharing applications (such as Gnutella or Kazaa for example). However the protocols behind these applications are still too greedy and waste a lot of the Internet resources. On the other hand, theoretical solutions based on distributed hash tables exist but cannot be used practically. The PairAPair project aims at bridging efficient theoretical solutions to practical applications such as file sharing.

The main goal of the project concerns the conception of peer-to-peer protocols. A first approach consists in optimizing algorithms for existing protocols (without changing the communication rules). Another way consists in developing new protocols based on efficient theoretical solutions. Also important aspects of peer-to-peer networks concerns ethics: how to accept sharing one's resources if they can be used for non moral purposes? Designing protocols allowing the respect of certain rules will be another goal of the PairAPair project. Finally, analyzing and optimizing protocols requires models. For that purpose, crawling of existing peer-to-peer networks is envisioned.

The PairAPair project gathers members of four teams: Gyroweb (INRIA–LIAFA), GraFComm (LRI), Graphes (LABRI) and Hipercom (INRIA). More information is vailable at http://gyroweb.inria.fr/pairapair/.

8. Dissemination

8.1. Services to the scientific community

Laurent Viennot is a scientific editor of the interstices vulgarization site.

8.2. Teaching

Master IFA, Marne-la-Vallee University Laurent Viennot teaches peer-to-peer protocols (10 hours).

Ecole Polytechnique Laurent Viennot is teaching foundations of computer science, java and networks (90 hours). Anh-Tuan Gai is teaching foundations of computer science (30 hours).

D.U.T. Paris 7 University Yacine Boufkhad is teaching scientific computer science and networks (192 hours).

Computer Science U.F.R. Paris 7 University Fabien de Montgolfier is teaching foundation of computer science, algorithmics, and computer architecture (192 hours).

8.3. Theses and Internships

8.3.1. Habilitation Theses

- Laurent Viennot, *Autour des graphes et du routage*, University Paris 7, November 2005.

8.3.2. Ongoing theses

- Anh-Tuan Gai, *Protocoles pair-à-pair*, granted by ACI PairAPair, Rocquencourt.

8.3.3. Internships

- Mehdi Nafa, *Simulation of BitTorrent protocol*, March to August 2005, funded by ACI PairAPair.

9. Bibliography

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Miscellaneous

[10] T. BENNOUAS, F. D. MONTGOLFIER. *Random Web Crawls*, Published in the Phd thesis of Toufik Bennouas, Modélisation de parcours du Web et parcours de communautés par émergence, 2005.