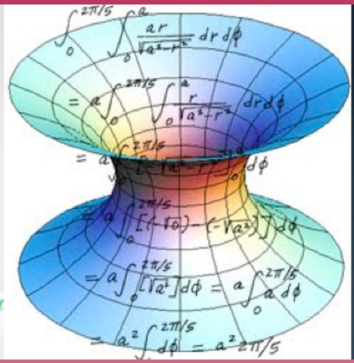
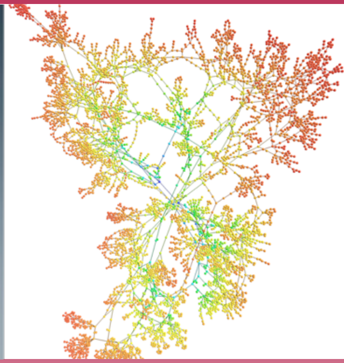
1ST URV DOCTORAL WORKSHOP IN COMPUTER SCIENCE AND MATHEMATICS

Edited by Aïda Valls Mateu and Juan Alberto Rodríguez Velázquez



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Departament d'Enginyeria Informàtica i Matemàtiques

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Preface

These proceedings contain the contributions presented at the 1st URV Doctoral Workshop in Computer Science and Mathematics. This workshop was held in Tarragona (Catalonia, Spain) on October 17th 2014. It was organized by the Doctoral Program on Computer Science and Mathematics of Security of Universitat Rovira i Virgili. The main aim of this workshop is to promote the dissemination of the ideas, methods and results that are developed in the Doctoral Thesis of the students of this program. This has been the first edition of this workshop, but we hope that it starts a long series.

The workshop had two invited talks, oral presentations and posters. The invited talks were given by two prestigious researchers: Prof. Ramon López de Mántaras (from the Artificial Intelligence Research Institute, CSIC) and Dr. Francisco Falcone (from the Public University of Navarra). The rest of the chapters that you will find in this book explain the research topic, goals and first contributions of each of the PhD thesis. Students have tried to present their current research work in a general way so that it can be followed by non-expert readers who are interested in the topics of research involved in this doctorate.

It is worth to note the wide coverage of this workshop, with contributions to the following main research lines: (1) Security and privacy in computer systems, (2) Artificial intelligence, robotics and vision, (3) Telematic architectures and complex networks and (4) Mathematics. All contributions present innovative proposals, methods or applications, with the aim of opening new and strategic research lines.

The editors and organizers hope you find them interesting enough and we invite you to contact the authors for more detailed explanations and to send them helpful suggestions.

The organizing committee was formed by Dr. Aïda Valls (Coordinator of the PhD program), Dr. Juan Alberto Rodríguez, Mrs. Olga Segú and Ms. Sílvia Sanromà.

We would like to finish by thanking to the invited speakers, to all the participants and especially to all the students that presented their work, who all

contributed to make the success of this first DCSM workshop. We also want to thank to Universitat Rovira i Virgili (URV), to the Department of Computer Science and Mathematics (DEIM) and to the School of Engineering (ETSE) for their support.

Dr. Aïda Valls and Dr. Juan Alberto Rodríguez (editors)

Contents

Evolutionary Game theory in multiplex networks

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1 Evolution of cooperation

There is an enormous amount of examples of cooperation in nature from humans that cooperate to build complex societies to animals like wolves that hunt in packs in order to catch preys larger than they are, or meerkats that watch out for predators in turns while the rest of the colony feeds. Even small microorganisms cooperate to survive in hostile environments. For instance, the *Dictyostelium discoideumu*, usually a solitary amoeba, when starves it associates with others in order to form a multicellular slug for the sake of survival. Explaining how cooperation has emerged and has resisted against more selfish behaviours is one of the biggest challenges in natural and social sciences. Several mechanisms has been proposed in order to explain the evolution of cooperation [1][2][3], among them the structure of the interaction's network between individuals. From the mathematical point of view in order to study this kind of social interactions and conflicts in a graph is Evolutionary Game Theory [4][5][6][7], the evolutionary branch of the classical Game Theory.

The study of networks, their properties and dynamics, has experimented a huge advance in the last few decades, empowered by the technological advances that enable the acquisition of data about interactions between individuals from social networks [8][9], mobile communication networks [10] or collaborations between scientific authors [11]. The analysis of network dynamics arises the question of how cooperation evolves in such context[12]. There is a vast literature on the subject studding aspects like the effect of network topology [13], the effect of mesoscopic structure [16], network structures driven by the cooperation [15] and other spatial and temporal effects [14] that offer a novel interpretation of how cooperation can evolve in this scenario.

An innovative way of representing multiple types of social interactions in the same structure are multiplex networks [17][18], successfully applied to disease spreading [20] and synchronisation dynamics [21]. Multiplex networks are

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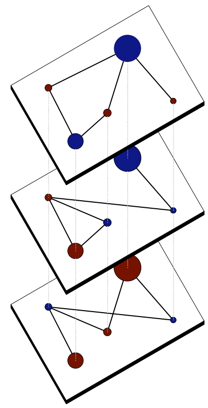

Fig. 1: Example of a multiplex network with 3 layers, 5 nodes per layer and 5 links in each layer. The color of the nodes represents the strategy played in that layer (red for cooperators, blue for defectors. Their size is proportional to their global payoff.

interesting in this field, because many social interactions can be understood as a superposition of interactions at different independent levels, each one representing a different social scenario like family relatives, friends, network of coworkers, etc. The behaviour of each individual can be different in each of these contexts, however is conditioned for each one of them [19][22]. How the evolution of cooperation works on top of this structure remains an open question.

2 Objectives

The objective of my thesis will be cover in depth all the possible implications of using multiplex networks in the field of evolutionary game theory. The subjects of study will be the effect of layer topology, the degree correlation between layers of different topology, percolation in multiplex networks driven by cooperation, dependence on the initial conditions. . . As a first step, we have made an exhaustive analysis of the resilience and propagation of cooperation in the central four dilemmas of game theory literature, how the convergence to a stationary state and which are the fluctuations at this state are affected by the number of layers of a multiplex.

References

[1] M.A. Nowak. Five Rules for the Evolution of Cooperation. *Science* 314, 1560-1563 (2006).

[2] E. Pennisi. How did cooperative behaviour evolve? *Science* 309, 93 (2005).

[3] E. Pennisi. On the origin of cooperation? *Science* 325, 1196-1199 (2009).

[4] J. Maynard-Smith. Evolution and the Theory of Games *Cambridge Univ. Press*, (1982).

[5] H. Gintis. Game Theory Evolving *Princeton University Press*, (2009).

[6] M. A. Nowak. Evolutionary dynamics: exploring the equations of life *The Belknap Press of Harvard University Press*, (2006).

[7] G. Szabó and G. Fáth. Evolutionary games on graphs *Phys. Rep.* 447, 97-216 (2007).

[8] B. Wellman and S.D. Berkowitz. Social Structures: A Network Approach *Harvard University Press*, (2006).

[9] S. Wasserman and K. Faust. Social Network Analysis *Cambridge Univ. Press*, (1994).

[10] M.C. González, C.A. Hidalgo and A.L. Barabási Understanding individual human mobility patterns *Nature* 453, 779-782 (2007).

[11] M.E.J. Newman. Coauthorship networks and patterns of scientific collaboration. *Proc. Natl. Acad. Sci.* 101, 5200-5205 (2004).

[12] F.C. Santos and J.M. Pacheco Scale-Free Networks Provide a Unifying Framework for the Emergence of Cooperation. *Proc. Natl. Acad. Sci* 103, 3490-3494 (2006).

[13] J. Gómez-Gardeñes, M. Campillo, L.M. Flora and Y. Moreno. Dynamical Organization of Cooperation in Complex Topologies. *Phys. Rev. Lett.* 98, 108103 (2007).

[14] C.P. Roca, J.A. Cuesta and A. Sánchez. Evolutionary game theory: Temporal and spatial effects beyond replicator dynamics. *Physiscs of Life Reviews* 6, 208-249 (2009).

[15] J. Poncela, J. Gómez-Gardeñes and Y. Moreno. Growing networks driven by the Evolutionary Prisoners's Dilemma game. *Handbook of Optimization in Complex Networks*, Springer, 115-136, (2012).

[16] S. Lozano, A. Arenas and A. Sánchez. Mesoscopic structure conditions the emergence of cooperation on social networks. *PLoS ONE* 3, e1892 (2008).

[17] M. Kurant and P. Thiran. Layered Complex Networks. *Phys. Rev. Lett.* 96, 138 (2006).

[18] P.J. Mucha, T. Richardson, K. Macon, M.A. Porter and J.P. Onnela. Community structure in time-dependent, multiscale, and multiplex networks. *Science* 328, 876-878 (2010).

[19] Z. Wang, A. Szolnoki and M. Perc. Evolution of public cooperation on interdependent networks: The impact of biased utility functions. *EPL* 97, 48001 (2012).

[20] C. Granell, S. Gómez and A. Arenas. Dynamical interplay between awareness and epidemic spreading in multiplex networks. *Physical review letters* 111.12 :128701 (2013).

[21] S. Gómez, A. Diaz-Guilera, J. Gómez-Gardeñes, C. J. Perez-Vicente, Y. Moreno and A. Arenas Diffusion dynamics on multiplex networks. *Physical review letters*, 110(2), 02870 (2013).

[22] J. Gómez-Gardeñez, I. Reinares, A. Arenas and L.M. Floria. Evolution of Cooperation in Multiplex Networks. *Sci. Rep.* 2, 620; DOI:10.1038/srep00620 (2012).

Reducing Costs in Personal Clouds

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1 Context

Cloud storage services have become very popular these days as a paradigm that enables individuals and organizations to store, edit and retrieve data stored in remote servers and which can be accessed all over the Internet. Such systems are generally equipped with a set of features that allow sharing and collaboration between the users. That is why, nowadays, millions of users are putting their files into online cloud storage systems (like *Dropbox*, *Google Drive* or *Box* ...) in order to be able to access them wherever they go or just as a backup.

To cope with this increasing demand, cloud storage service providers need to provide huge amounts of resources both in terms of storage and bandwidth. The goal of this PhD is to investigate new optimized mechanisms that can be adopted by the service providers in order to reduce the global costs.

2 Reducing the bandwidth cost

The first part of the thesis is related to the reduction of bandwidth cost. In this context, we introduce the BitTorrent [3] protocol as an alternative to the client-server model. Rather than downloading a file from a single source server, the BitTorrent protocol allows users to join a swarm[2] of peers[3] to download and upload from each other in addition to the original cloud seed [4]. This makes the approach especially suitable for files shared between a set of devices. In such scenarios, it is possible to benefit from the common interest

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[2] A BitTorrent swarm is the set of all the peers sharing the file.

[3] A BitTorrent peer is an instance of a BitTorrent client running on a computer on the Internet to which other clients can connect and transfer data.

[4] The cloud seed is an instance of a BitTorrent client running in the cloud which has a complete version of the shared file.

of users in the same file and use their upload bandwidth to offload the cloud from doing all the serving.

Unfortunately, the use of BitTorrent may incur a longer download time compared to HTTP especially for small files. The main challenge is to decide when it is worth switching to BitTorrent. The key elements in making the decision are the gain in download time and the peers' contribution. The former represents the difference in download time between HTTP and BitTorrent from the peer's perspective. The latter measures the total amount of data that can be obtained from the peers.

Another possible way to reduce the bandwidth cost is the use of bundling i.e. grouping a batch of small files (or chunks) that need to be transferred as a single object. The main goal of this technique is to reduce transmission latency and control overhead. However, there is a tradeoff between the bundling period and the saved bandwidth that needs to be studied.

We studied the efficiency of the BitTorrent protocol in downloading small files which form the major part of files in personal cloud systems. To refute the general assumption that BitTorrent is only efficient for big files, we have proven in [1] that even for small files (size in the order of 1MB), with appropriate swarm size and bandwidth settings, downloading the content via BitTorrent can be more rapid than HTTP. Moreover, it results in offloading the cloud server from doing all the serving. We proposed also in [1], an algorithm that chooses the most appropriate protocol to download the requested content based on our accurate formulas for the gain and offload percentages. We validated the algorithm using a real trace of the Ubuntu one file services and we proved that it can achieve important savings in terms of bandwidth costs. We detailed in [2] the complete architecture of the system with the components needed to add the BitTorrent behavior.

In [5], we focused more on the bandwidth allocation of the cloud seed. We presented an algorithm that allocates the seeder bandwidth optimally among swarms in order to maximize the global throughput. We proved that the system delivers higher performance when dealing with large volumes of data compared to the traditional client-server paradigm.

3 Reducing the storage cost

The reduction of storage cost is part of the focus of the next two years of the thesis. The future work includes focus on the file replication. According to [4], 20% of *Dropbox* have more than 15% of **content** replicated and 50% of Dropbox have more than 15% of **files** replicated. Overall, 42% (1.3 millions) of *Dropbox* **files** are replicas which corresponds to 14% of the **bytes**. The experiments have shown that the replication problem is not only present in folders that are shared among different users, but is also very common inside folders of individual users. Therefore, cloud storage services should implement mechanisms to avoid replication.

Some cloud storage providers (including *Dropbox* and *Wuala*) implement a deduplication mechanism in order to eliminates replicas on the storage server. The main idea is that, if a file is already present, replicas in the client folder can be identified to save upload capacity too. This can be accomplished by calculating a hash value using the file content. The hash is sent to servers prior to submitting the complete file. Servers can check whether the hash is already stored in the system and skip the upload of repeated files. While this algorithm proves to be efficient for file deduplication, it is equally important to provide similar intelligent techniques for the "chunk" level. In fact, most personal cloud provides split the files into smaller pieces called chunks. Chunking is advantageous especially to users with slow networks since it simplifies upload recovery in case of failures. To this extend, studies on replication on a chunk level could prove the efficiency of a chunk-level deduplication mechanism in personal cloud systems.

Acknowledgement. This work has been partially supported by the Martí-Franquès Research grants Program, the EU in the context of the project *CloudSpaces*: Open Service Platform for the Next Generation of Personal clouds (FP7-317555) and the Spanish research project DELFIN (TIN2010-20140-C03-03) funded by the Ministry of Science and Innovation.

References

[1] R. Chaabouni, P. Garcia-Lopez, M. Sanchez-Artigas, S. Ferrer-Celma and C. Cebrian. Boosting content delivery with BitTorrent in online cloud storage services. *Peer-to-Peer Computing (P2P), 2013 IEEE Thirteenth International Conference on*, pp.1,2, 9-11 Sept. 2013

[2] R. Chaabouni, M. Sanchez-Artigas and P. Garcia-Lopez. Reducing costs in the Personal Cloud: Is BitTorrent a better bet? *to appear in the proceedings of Peer-to-Peer Computing (P2P), 2014 IEEE Fourteenth International Conference on*

[3] B. Cohen. Incentives Build Robustness in BitTorrent. *Workshop on Economics of P2P systems.* June 2003.

[4] I. Drago. Understanding and Monitoring Cloud Services. *PhD thesis, University of Twente. CTIT Ph.D. thesis* Series No. 13-279. ISBN 978-90-365-3577-9.

[5] X. Leon, R. Chaabouni, M. Sanchez-Artigas and P. Garcia-Lopez. Smart Cloud Seeding for BitTorrent in Datacenters *Internet Computing, IEEE*, vol.18, no.4, pp.47,54, July-Aug. 2014

On Personal Storage Systems: Architecture and Design Considerations

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1 Summary of this Ph.D. Thesis

This thesis focuses on the study of storage systems aimed to provide off-site storage services to end-users. We divide our contributions in three main blocks:

Friend-to-friend (F2F) storage systems[2]. We study the storage service provided by pure Friend-to-Friend (F2F) storage systems. We are interested on analyzing their achievable data availability and transfer times, given the inherent shortcomings related with storing data only in trusted friends.

Cloud-assisted social storage architecture[3]. We propose to wisely employ Cloud storage services to improve a pure F2F system, while preserving the data confidentiality of users. We also analyze the role of the social graph and the correlated availabilities of users on the service provided.

Measurement analysis of Personal Clouds[4]. We present a measurement study of various Personal Clouds (DropBox, Box, SugarSync). We analyzed important aspects to characterize their Quality-of-Service (QoS), such as in/out transfer speed, service variability and failure rate.

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* PhD advisors: Marc Sánchez Artigas, Pedro García López

[2] -*Analysis of Data Availability in F2F Storage Systems: When Correlations Matter*. Raúl Gracia-Tinedo, Marc Sánchez-Artigas and Pedro García-López (IEEE P2P'12)

[3] -*F2BOX: Cloudifying F2F Storage Systems with High Availability Correlation.* Raúl Gracia-Tinedo, Marc Sánchez Artigas and Pedro García López (IEEE CLOUD'12)
-*FRIENDBOX: A Hybrid F2F Personal Storage Application.* Raúl Gracia-Tinedo, Marc Sánchez Artigas, Adrián Moreno-Martínez and Pedro García López (IEEE CLOUD'12).
-*FRIENDBOX: A Cloudified F2F Storage Application* (demo paper). Raúl Gracia-Tinedo, Marc Sánchez Artigas, Adrián Moreno-Martínez and Pedro García López (IEEE P2P'12).
-*Giving form to Social Cloud Storage through Experimentation: Issues and Insights*. Raúl Gracia-Tinedo, Marc Sánchez Artigas, Aleix Ramírez, Adrián Moreno-Martínez, Xavier León and Pedro García López (Future Generation Computer Systems, 2014)

[4] -*Actively Measuring Personal Cloud Storage.* Raúl Gracia-Tinedo, Marc Sánchez Artigas, Adrián Moreno-Martínez, Cristian Cotes and Pedro García López (IEEE CLOUD'13)
-*Cloud-as-a-Gift: Effectively Exploiting Personal Cloud Free Accounts via REST APIs*. Raúl Gracia-Tinedo, Marc Sánchez Artigas and Pedro García López (IEEE CLOUD'13)

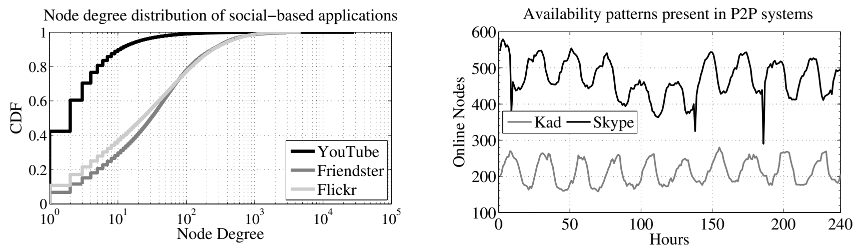

Fig. 1: Degree distribution and availability correlations of social/p2p applications.

2 Data Availability in F2F storage systems

Friend-to-Friend (F2F) storage systems are an interesting research topic and they constitute an alternative approach to leverage personal storage [1],[2],[3]. The F2F paradigm is based on the synergy between social networks and storage systems: users store their data in a set of trustworthy friends.

Generally, F2F storage systems have been treated as a particular case of P2P systems where nodes are connected by social relationships. However, very little attention has been paid to the characterization of these systems. Understanding the characteristics of F2F systems is crucial for providing an adequate storage service to users (Fig. 1).

We consider two main aspects which clearly differentiate F2F systems from traditional P2P systems: *High availability correlations* [4] and *extremely small friendsets* [5]. The combination of these issues poses new challenges which remain unsolved in a F2F scenario. In this paper, we focus on the problem of data availability in F2F systems. Our contributions are summarized as follows:

C1. We analyze the impact of availability correlations on the data availability provided by a small group of friends. Contrary to conventional wisdom, we found that correlations can be exploited to achieve an adequate trade-off between data availability and redundancy.

C2. We evaluate the performance of common ways of estimating data availability when users are correlated. We demonstrate that these techniques are severely biased and this impacts on the data redundancy calculation.

C3.We propose a history-based method to calculate data availability tailored to heterogeneous and correlated availabilities. Making use of it, we can precisely calculate data redundancy required for a user, providing important benefits to the storage service.

C4. Finally, we explore the relationship between data availability and download times. Our results suggest that, due to availability patterns, we should distinguish between if file is currently available and if it is retrievable in a reasonable amount of time.

3 Cloudifying Social Storage Systems

The specific characteristics of F2F storage systems (reduced node degree, correlated availabilities) represent a hard obstacle to their performance. Actually, it is extremely difficult for a F2F system to guarantee an acceptable storage service quality in terms of transfer times and data availability to end-users. In this landscape, we propose to resort to the Cloud for improving the storage service of a F2F system.

C1. We present FriendBox: a hybrid F2F personal storage system. FriendBox is the first F2F system that efficiently combines the resources of trusted friends with Cloud storage for improving storage service quality while preserving privacy. FriendBox provides a flexible and user-defined Cloud usage: users are able to decide where to store their data, which can be completely on friends, only in the Cloud or in a mix of them. We implemented in FriendBox advanced mechanisms which strategically use the Cloud to mitigate the problems of pure decentralization, improving the resulting service quality.

C2. Moreover, we quantify the role that the *social graph* and the *correlated availabilities* of friends have on load balancing, fairness and transfer performance, as well as on the consumed Cloud resources.

4 Actively Measuring Personal Clouds

Personal Clouds provide a mainstream service that meets the growing demand of millions of users for reliable personal off-site storage. However, despite their broad adoption, very little is known about the QoS of Personal Clouds.

We present a measurement study of various Personal Clouds. Concretely, during two months, we have actively measured the REST API service of DropBox, Box and SugarSync free accounts. We gathered information from more than 900,000 storage operations, transferring around 70TB of data. We analyzed important aspects to characterize their QoS, such as in/out transfer speed, service variability and failure rate. To our knowledge, this work is the first to deeply explore many facets of these popular services and reveals new insights. We contribute all of our research observations, including:

C1. The transfer performance of these services greatly varies from one provider to another, which is a valuable piece of information for designers and developers.

C2. In general, transfer speeds of files can be approximated using well-known statistical distributions. This opens the door to create Personal Cloud simulation environments.

C3. The variability of transfers depends on several factors, such as the traffic type (in/out) or the hour of the day. Actually, we found daily patterns in the DropBox service.

C4. These services are in general reliable and, in some cases, service failures can be modeled as a Poisson process.

C5. We observed a radical change in the transfer speed of SugarSync in late May 2012. This suggests that Personal Clouds may change their freemium QoS unexpectedly, due to internal policy changes or agreements

C6. We also observed that by combining open APIs and free accounts, these companies are exposing automated access to a free storage infrastructure, which may lead to abuse by malicious parties. By exploiting the freemium API service, users may fraudulently consume resources or they can use free accounts as a Cloud storage layer to support abusive applications. We call this vulnerability the *storage leeching problem.*

We show how easy it is to implement a file-sharing application able to distribute digital content by abusing Personal Clouds. Making use of open APIs, this application transparently aggregates the limited-space free accounts from multiple providers into a single larger storage layer, while achieving better transfer speed than that received from one provider alone.

5 Future Directions

We are analyzing the UbuntuOne (U1) storage service in the context of the FP7 CloudSpaces project. The traces gathered capture the back-end activity of ≈ 1 million users during 3 months. The analysis of these traces will provide unique insights and opportunities to improve large scale Personal Clouds.

Acknowledgement. This Ph.D. thesis is partly sponsored by the Spanish government through projects DELFIN (TIN-2010-20140-C03-03) and RealCloud (IPT-2011-1232-430000), and by the European Commission FP7 through project CloudSpaces (FP7-317555). The Ph.D. grant of Raúl Gracia Tinedo is funded by Universitat Rovira i Virgili though the Martí-Franquès Research Fellowship Programme.

References

[1] D. N. Tran, F. Chiang, and J. Li. Friendstore: cooperative online backup using trusted nodes. *SocialNets*, 37-42, 2008.

[2] K. Chard, S. Caton, O. Rana, and K. Bubendorfer. Social cloud: Cloud computing in social networks. *IEEE CLOUD*, 99-106, 2010.

[3] J. Li and F. Dabek. *F2f: Reliable storage in open networks.* IPTPS, 2006.

[4] S. A. Golder, D. M. Wilkinson, and B. A. Huberman. Rhythms of social interaction: Messaging within a massive online network. *Communities and Technologies*, 41-66, 2007.

[5] C. Wilson, B. Boe, A. Sala, K. P. Puttaswamy, and B. Y. Zhao. User interactions in social networks and their implications. *EuroSys*, 205-218, 2009.

Use of Decision Tables to Train Residents in the Application of Clinical Guidelines for the Medical Process

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1 Introduction

The medical process includes three phases, diagnosis, treatment and prognosis. Clinical Practice Guidelines (CPG) contain the evidence-based knowledge required to make decisions during all the medical process, but this knowledge is scattered across the guidelines of all the multiple diseases that can explain the patient condition. The seamless integration of all this knowledge for practical use is an intellectual complex learning process that residents have to train for internal medicine specialization.

Decision tables [2,4] are knowledge structures in which columns represent rules, and rows represent either conditions (in the antecedent of the rules) or actions (in the consequent of the rules).

Decision tables have been used to represent knowledge in medicine as a support for making immediate decisions, but less applied to support medical decision processes.

This study tries to model the medical process, focusing on the diagnosis and treatment, with decision tables. To accomplish this, is necessary to define what kinds of decision tables are required for each step of the medical process.

The resulting tables will be filled with information from clinical practice guidelines and will be used as the basis for a training system for residents.

2 Diagnosis

Differential diagnosis is the process of determining the set of diseases affecting a patient from a set of candidates by means of getting some findings that reinforce or weaken the candidate diseases and driving some of them to rejection or to final acceptance. The process uses to be divided into three steps (see figure 1): making diagnostic hypotheses, selecting appropriate diagnostic tests, and discarding negligible hypotheses.

* PhD advisor: David Riaño

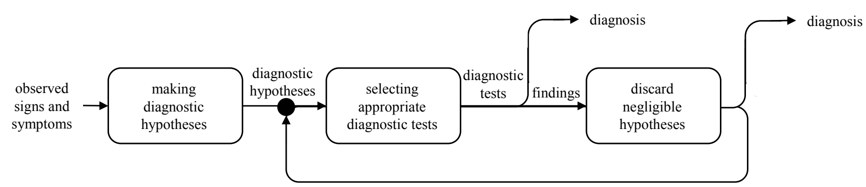

Fig. 1: Differential Diagnosis

All the initial signs and symptoms of the patient are used by the first step to identify the set of feasible diseases of the patient. These are called the diagnostic hypotheses. Each one of these hypotheses represents the probability of having a single disease.

Then, according to the hypotheses, the second step identifies a set of unknown signs and symptoms (or diagnostic tests required for these signs and symptoms) in order to reduce the set of hypotheses in a third last step.

If the third step detects, after the application of the selected tests, that a hypothesis (disease) must be refuted then this hypotesis is deleted from the set of diagnostic hypotheses. After the evaluation of several test, if the second step cannot provide new tests to refute the set of hypotheses then the remaining hypothesis become the final diagnosis of the patient, that can be composed of one or several diseases.

Each one of those steps has been modeled with a different decision table. To test these tables, we select the case of secondary causes of hypertension.

Arterial Hypertension is an abnormal high blood pressure in the patient's arteries [1] that can be considered a disease (i.e., essential hypertension) or a clinical condition induced by other causes or diseases (i.e., secondary causes). The clinical practice guideline of arterial hypertension identifies achromegaly, adrenal Cushing's syndrome, coarctation of the aorta, glomerulonephritis, hyperparathyroidism, pheochromocitoma, renovascular disease, and sleep apnea as eight of the main secondary causes of arterial hypertension.

The clinical practice guidelines corresponding to arterial hypertension and the 8 secondary causes of arterial hypertension were analyzed with the help of two senior GPs of the health care centers Hospital Clinic of Barcelona (HBC) and SAGESSA.

The obtained tables were used to create a system to train 23 residents at HCB in the differential diagnosis with 30 clinical cases.

The results of these tests has been analyzed and they have been published in [3].

3 Treatment

In medicine, treatment is the management and care of a patient or the combating of disease or disorder. When one or more diseases have been diagnosed, the physician must select the appropriate treatment to the patient. Once the patient begins to be treated, its evolution must be evaluated regularly.

Patients may respond in different ways to treatments. Sometimes the treatment is not effective or may cause secondary effects. In these cases, the physician has to adjust the doses, or change the treatment or even reconsider the diagnosis.

To test the tables in treatment, we will simulate the treatment of shock in urgencies and train the residents with the clinical practice guidelines of shocks.

4 Indications about the references

Acknowledgement. I would like to acknowledge Dr. David Riaño, as a thesis advisor, Dr. Antoni Collado from SAGESSA, who worked in the first version of decision tables extracted from the clinical practice guidelines and Dr. Jose Ramon Alonso from HCB, who made the tests with the residents in HCB.

References

[1] P.A. James, S. Oparil, et al. 2014 evidence-based guideline for the management of high blood pressure in adults. *Report from the panel members appointed to the Eighth Joint National Committee (JNC 8)*, JAMA, 2014; 311(5): 507-20.

[2] P.J.H. King. Decision tables. *The Computer Journal.*, 1967; 10: 135-42.

[3] F. Real, D. Riaño, J. R. Alonso Training residents in the application of clinical guidelines for differential diagnosis of the most frequent causes of arterial hypertension with decision tables *6th International Workshop on Knowledge Representation for Health Care (KR4HC 2014)*, Vienna, July, 2014

[4] R.N. Shiffman. Representation of Clinical Practice Guidelines in Conventional and Augmented Decision Tables. *J Am Med Inform Assoc.*, 1997; 4(5): 382-93.

Teaching mathematics to primary school children through an experiential learning

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1 State of the art

Learning is a process of change that occurs in the individual, in its cognitive abilities, in its understanding of a phenomenon (cognoscitive component), in its motivation, in its emotions (affective component) and/or behavior (behavioral component) as a result of the action or experience of the indivi- dual, the appropriation of sociocultural context, the reorganizations made about knowledge, and/or the association between a stimulus and a response (Sarmiento, 1999).

1.1 Learning through play

Play is a changing reality and especially a driving force for the mental development of the child (Vygotsky, 1933).

In play a child always behaves beyond his average age, above his daily behavior. In play it is as though he were a head taller than himself. As in the focus of a magnifying glass, play contains all developmental tendencies in a condensed form and is itself a major source of development (Vygotsky, 1933).

If play were just a unique, isolated outcropping, a widespread but temporary and harmless aberration of childhood, then it would be interesting as a fact, perhaps, but the study of play would have little redeeming scientific value. However, play has been linked with creativity, problem solving, language learning, the development of social roles, and a number of other cognitive and social phenomena. The need to specify the nature of these links continues to motivate research (Garvey, 1977).

In order to modify school practices and ways of teaching and learning, it is required to change the perspective of all those involved directly and indirectly in the process of teaching and learning (teachers, students, managers, parents, politicians, researchers ...) " (Goñi, 2000).

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You need to break the myth of natural play and promote favorable conditions for teaching and learning to play within the school system (Brougère, 1998).

1.2 Learning mathematics through play

Play encourages children to develop cognitive strategies, enhance logical thinking, develop habits of reasoning and teaches to have critical thinking. It also promotes divergent thinking processes transferable to other areas of knowledge (Ferrero, 1991).

School educational practices that are focused on play and mathematics can generate the context of problem solving, which its goal is to create environments that encourage players to think mathematically (Edo and Deulofeu, 2006).

Play is itself a problematic situation where its resolution involves the use of strategies, concepts and procedures. That is, it is a source, place and criteria of the development of knowledge (Charnay, 1994).

1.3 Competition and cooperation

Competition raises fears and inhibits communication (Keith and Goldman, 1961).

If you ask those who have achieved a great deal in their lives, often say that success comes from cooperative efforts (Kouzes and Posner, 1987).

Cooperation is linked to success and, on the other hand, it has been observed that competitiveness is detrimental. The more competitive a person is, the less are its chances of success (Kohn, 1992).

Cooperating means striving to attain a common goal while coordinating one's own feelings and perspective with a consciousness of another's feelings and perspective (Piaget, 1950).

Our higher functions and achievements originate as actual relationships between individuals (Vygotsky, 1978).

1.4 Conclusions

In the previous sections I have shown some quotations from authors who have worked on learning, some of them at a general level and others are specialized in play. In this area, there are some authors that investigates games that support learning of mathematics. All of them point that relational and experiential learning is very important for the mental growth and development of the student. When a student is faced with the challenge of a problem in a play environment, the situation encourages the child to move forward to achieve the goal without the pressure of the eye of a reviewer, so the cognitive functions are not inhibited. On the other hand, it is important to note that the teacher has to work as a guide. The idea that he dictates instructions and the students copy them is completely outdated because it does not help the student to develop strategies and a critical thinking. The games of this project will have the strategy and logic as a central theme. This is why I think that it is important that students acquire the skills and abilities to find different ways to tackle the various problems they may have.

The other important part of this project is to check if the children work and learn better if they are in a cooperative play or challenge rather than competitive activity. I think that the student, free of feeling alone and knowing that is part of a group, will be able to move forward and improve his strategy for achieving the final goal of the game.

2 Presentation

In this document, I will explain the project that I am developing on didactics of mathematics in primary education and the importance that it has to have good mathematicians and scientists in the future.

I have considerable experience teaching mathematics to children and adults and, during this time, I could see the deficiencies and mental blocks of my students towards this science. They have many difficulties in understanding the problem statements, and if they succeed, they often don't know what to do next if the solution is not automatic. In most cases, students only want to solve the problem as soon as possible. If they learn an immediate methodology to solve the problem, they have no interest in understanding what is being asked. Many students take this subject as an obstacle to be overcome, but they have no curiosity to relate it to their lives.

This last point is important, because it often seems that mathematics are dealt as an abstract concept that is not part of our environment. This is precisely a completely wrong idea. Mathematics are part of our lives, many things that we do every day are related to them. To buy bread and know what we have to pay and give the correct change or calculate the amount of food needed to make a dish, are some examples.

In most schools mathematics are taught using sheets with operations or simple problems that has automatic resolution methods. The children are only dedicated to follow a few steps that the teacher has previously stated. This is often due to the fact that the teacher is not interested in this subject because he/she also learned in this way. It can be observed that they are in a circle of teaching which can not show the importance and scope that mathematics may have.

But there is a little group of schools where the way of view them is changing. The teachers, sometimes mathematicians, are seeking new ways to explain them, through life-experience. This means that children initially work concepts from what they have around, and can relate it to their own experiences, and that produces an extra motivation that makes them want to advance in this field. Part of my job is to create new situations that draw attention. Through them, the teacher guides (but not dictates) students to understand the problem and deduce what to do next.

The teacher does not indoctrinate, but is involved in the problem guiding and giving some indications so that students can progress. This fact is important for the internal development of the child. The student has to be aware of what he is doing at any moment, and must be able to feel that he is solving the statement on his own and not following the steps that has dictated the adult. The student will develop new ideas to solve the new situation using the experiences he has had before. These new thoughts can be used when new obstacles appear. Thus, he can really assimilate the concepts, and he is able to improve in mathematics when the problems are more complicated. It is important that the degree of difficulty of the statements gradually grows.

The teachers must take into account that each child has their own learning pace, especially when they are young. At this stage, most of them can reach the results, but each one does it in a different way. Some of them will do it directly and others will require more time to get it because they will have to make more redundant relations to obtain the same conclusion. To progress, go backward, go forward, be blocked, have to start again, are common behaviors and feelings at these ages. The teacher must have patience and observation skills so that all students can deduce the solution to the problem.

If a student takes a long time to solve a problem in early stages does not mean that it will always happen as he grows up. It is important that students who work slowly do not feel pressure from the teacher, because if they begin to notice that have failed and the teacher is losing patience, they will feel frustration that eventually result in demotivation. The child will think he is silly, and each time it will be harder to progress on his own and he will want to solve (or teacher solves) the problem quickly without thinking. A way to ensure that all children have acquired new concepts and to discover if there is any detail that is not understood is posing problems that require a similar type of deduction to solve them. Thus, the students that need to refine the knowledge will be able to catch up their classmates.

When I refer to that discouraged students that do not want to keep thinking, I'm talking about the mental block that some children feel towards mathematics. As I mentioned before, this is often due to the disconnection that often seem to have with the real world.

This fact may occur because the student has not achieved a set of concepts and does not feel capable to continue. Many children do not have a good start with mathematics because they do not acquire the notion of quantity. To achieve this concept, the child has to go through a series of mental processes. If he does not develop some of these processes, he does not assimilate this notion. If this happens, the student can not progress in many areas of mathematics, and from an early age, he will start to show a lack of interest in this subject. This concept is basic, so it is essential that the teacher check the initial development of the child in this field.

In the previous paragraphs I have presented the difficulties that exist when learning mathematics and that this occurs at very early ages. I think that a mathematician or scientist has many capabilities to solve it because he can better convey the connection between mathematics and real life. In addition, he can perform more rigorous studies on this area. So I think it is important to do research in this field in a department like ours and I am a good candidate to work on didactics of mathematics.

This project will develop a series of experiences so that children learn mathematical concepts in experiential way.

Currently I have worked in a kindergarten, a primary school and a secondary school. They are Centre dEducació Intantil i Familiar Vapor Buxeda, CEIP La Trama and IES Montserrat.

In the kindergarten it was carried out an experience. There was a presentation of the baby sister of a girl of three years old, and we take this opportunity to work the small and large sizes. In parallel we wanted to develop the logic through comparisons, classifications, correspondences, matches and transformations.

For the secondary school I am preparing an article that deals with open problems (unsolved problems) and it shows how they can be presented to baccalaureate students. In kindergarten and primary school children learn that open problems are those with multiple solutions, so they can see that not everything has a unique solution. In this article, I intend to explain to students what is an open problem for a mathematician. In this way, students can see that not everything is solved in the world of mathematics, and even a problem has a simple statement, the solution should not necessarily be logical and easy.

For primary school, I am developing a project in which some competitive games, which have a significant mathematical component, will be converted to cooperative games. Previously I mentioned the mathematical mental block that some children feel, and I think that they can progress in this area through play, especially if there is not any competitive pressure. Some children lose the capacity to progress in an activity due to the competitive pressure that sometimes is around them. However, in relaxing situations, the child feels capable to progress, and the result is often better than when he is being watched by the eyes of his classmates or the teacher. Therefore, it is interesting to play with children with competitive games, and see their reaction and learning, as well as with cooperative games (which will also have a significant mathematical component). So I will be able to observe the different reactions of the children, and if they can reinforce some deficiencies through recreational activities. Also I want to see if they can further progress if they have the support of his colleagues with whom will find the way to achieve the goal instead of feeling the stress of competition that may sometimes inhibit their capabilities.

As I witness more classes with students, I do not reject to conceive new experiences to work with children to enhance this thesis.

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References

[1] G. Brougère. Juego y educación. *Biblioteca Artes Médicas: psicopedagogia*, 1998.

[2] R. Charnay. Aprender por medio de la resolución de problemas. *Didáctica de matemáticas*, cap. 3, 1995.

[3] M. Edo, J. Deulofeu. Investigación sobre juegos, interacción y construcción de conocimientos matemáticos. *Enseñanza de las ciencias* 24(2), 257-268, 2006.

[4] L. Ferrero. El juego y la matemática. *Ed. La Muralla*, 1991.

[5] C. Garvey. Play. *Harvard University*, 1977.

[6] A. Goñi. Relationships between physical education classes and the enhancement of fifth grade pupils' self-concept. *Perceptual and Motor Skills*, 91, 146-150, 2000.

[7] A. Kohn. No contest, The case against competition. *Ed. Houghton Mifflin*, 1992.

[8] J. M. Kouzes, B. Z. Posner. The Leadership Challenge. *How to Make Extraordinary Things Happen in Organizations*, 1987.

[9] L. Keith Hammond, M. Goldman Competition and Non-Competition and its Relationship to Individual and Group Productivity. *Sociometry*, 24, 46-60, 1961.

[10] M. I. Sarmiento Díaz. Cómo aprender a enseñar y como enseñar a aprender. Psicología educativa del aprendizaje. *Universidad Santo Toms, Colombia*, 1999.

[11] L. Vygotsky. Play and its role in the Mental Development of the Child. *Lecture, Leningrad Pedagogical Institute*, 1933.

[12] L. Vygotsky. Mind in Society: Development of Higher Psychological Processes. *Harvard University Press*, 1978.

Urban Electronic Road Pricing Systems Preserving Drivers' Privacy

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Abstract. The high levels of pollution and traffic congestion present in almost all major cities around the world have brought solutions such as the deployment of electronic toll systems in some of these cities. The main purpose of those electronic toll systems is to restrict the access of vehicles to certain city areas, named low emission zones (LEZs). Since its adoption, this solution has proven to be quite promising. However, current proposals are still far from being ideal. More specifically, current schemes still introduce a significant error percentage in the detection of fraudulent drivers. Moreover, they usually require toll systems to be equipped with cameras that take pictures of all the vehicles that pass through the control points. This behavior may represent a serious privacy threat for the drivers. This research focuses on proposing new electronic toll systems, which detect fraud while preserving drivers privacy. More concretely, they provide a non-probabilistic fraud control and the control points only take pictures of the vehicles that misbehave. Last but not least, these systems apply an enhanced dynamic pricing that can help the authorities to better distribute traffic over the road network.

Keywords: electronic road pricing, low emission zone, driver privacy, security, dynamic pricing

1 Introduction

In recent years, traffic congestion has become a significant problem for almost all major cities in the globe since it has a clear negative impact on their citizens (i.e., air pollution, waste of time, stress, etc.) [4]. In order to solve this situation, or at least, reduce its harmful effects, governmental and private institutions have put important efforts in finding suitable solutions that are mainly based on discouraging people from using their own vehicles. Well-known measures resulting from these efforts are providing better public transportation services, by introducing new taxes to the owners of vehicles or implementing toll systems.

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Among these methods, the use of toll systems has received a lot of attention [9,2,7,6,1,8,3,5]. The main reason behind the success of this method is that it enables an authority to restrict the access to drivers willing to pay a certain amount of money. In this way, only those drivers that drive in a certain area of the city have to pay for this concept (in contrast, governmental taxes are paid by all drivers, regardless of the real individual usage). This method is especially popular in Europe, where it is often used for preserving historical city centers (i.e., Athens or London).

In order to be really successful, toll systems have to be managed in a fully unsupervised way. In this way, Singapore can be considered the leading example as it has implemented an electronic road pricing system since 1998, with variable prices. Similar approaches are being gradually adopted worldwide. For instance dynamic toll systems are already used in Washington, Georgia, Virginia and Toronto.

In addition to reducing the traffic, dynamic toll systems can use the variable prices to manage the flow of vehicles and, hence, the traffic density. More specifically, the traffic authority can increase the toll taxes in congested roads and suggest drivers to take cheaper routes.

It has been acknowledged that these already deployed toll systems, while reducing congestion to some extent, exhibit several shortcomings related to payment fairness, privacy issues, moving congestion to other routes or lack of proportionality. As a consequence, the scientific community has recently focused on this topic in order to design new electronic road pricing (ERP) systems that address these drawbacks.

1.1 State of the Art

In general, all ERP systems that can be found in the literature ([9,2,7,6,1,8,3,5]) calculate road usage pricing by considering the vehicle itinerary and use on-board units (OBU), equipped in each vehicle, to record its path. OBUs are enabled with GPS and wireless communication capabilities; they periodically collect their geographical position; and they send it to a service provider (or similar) together with other relevant data.

Even though ERPs share common features such as using OBUs and pricing the drivers according to their itinerary, they mainly differ in the way the road usage fees are computed. In [9,7,6,2], the service provider (*SP*) is in charge of calculating the fees in each billing period according to the vehicle path. By contrast, in [1,8,5,3], fees are calculated locally in each OBU, and they are then sent, as a unique sum, to the *SP*.

All these systems are designed to prevent any possible misbehavior by the drivers that enable them to save money illegally. Disconnecting the OBU or modifying the flow of data generated by this device in any way are possible examples of misconduct. In order to avoid these situations, these proposals adopt control mechanisms based on the use of checkpoints (*Chp*s), which are equipped with cameras and are randomly located in the restricted areas. *Chp*s take pictures of all the vehicles that pass through them. In this way, their number plates are stored together with the different geo-positions and the exact time of each one. These three items allow the system to build a partial path of all the vehicles moving around the restricted area and to verify that a certain driver has not altered the set of positions recorded by her cars OBU and provided to the *SP* during the billing period. It is worth mentioning that this approach for fraud detection has a certain failure probability that directly depends on the number of *Chp*s deployed in the restricted area, and also on preventing drivers from ascertaining their exact position in advance.

Following this point, the work presented in [8] concludes that all these proposals rely on the wrong assumption that checkpoint locations are unpredictable by drivers and this issue makes those schemes unable to effectively control drivers potential misbehavior (or fraud). This fact, in turn, represents a relevant problem that clearly limits the deployability of those schemes in real environments. On the other hand, increasing the number of checkpoints that are deployed in a restricted area directly affects drivers' privacy due to the fact that, the more checkpoints there are, the bigger the set of registered real drivers locations will be; and, therefore, the more accurate the drivers paths will be. Note that the drivers' privacy directly depends on the accuracy of the paths that the system can built by using the drivers recorded locations. If the system knows the whole path of a certain driver with high accuracy, her whereabouts are no longer private. In this way, in order to preserve the privacy of the drivers, the way the checkpoints behave should be revisited.

1.2 Contributions

In this research, new *ERP* systems for low emission zones (*LEZ*s) are proposed. These schemes provide three main contributions:

- They provide a non-probabilistic fraud control, therefore, it is better at preventing driver misbehavior than current proposals in the literature.
- *Chp*s are equipped with cameras but they only take pictures of the vehicles that misbehave. In this way, accurate routes of the honest drivers are not obtained and their privacy is preserved. Moreover, *OBUs* do not register vehicles geolocations.
- They provide a better traffic management than classic dynamic toll systems.

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References

[1] Balasch, J., Rial, A., Troncoso, C., Preneel, B., Verbauwhede, I., Geuens, C.: Pretp: Privacy-preserving electronic toll pricing. In: USENIX Security Symposium. pp. 63–78 (2010)

[2] Chen, X., Lenzini, G., Mauw, S., Pang, J.: A group signature based electronic toll pricing system. In: ARES. pp. 85–93. IEEE Computer Society (2012)

[3] Day, J., Huang, Y., Knapp, E., Goldberg, I.: Spectre: spot-checked private ecash tolling at roadside. In: WPES. pp. 61–68. ACM (2011)

[4] for Europe, W.H.O.R.O., Organization, W.H.: Air quality guidelines: global update 2005: particulate matter, ozone, nitrogen dioxide, and sulfur dioxide. World Health Organization (2006)

[5] Garcia, F.D., Verheul, E.R., Jacobs, B.: Cell-based privacy-friendly roadpricing. Computers & Mathematics with Applications 65(5), 774–785 (2013)

[6] Hoepman, J.H., Huitema, G.: Privacy enhanced fraud resistant road pricing. In: Berleur, J., Hercheui, M., Hilty, L. (eds.) What Kind of Information Society? Governance, Virtuality, Surveillance, Sustainability, Resilience, IFIP Advances in Information and Communication Technology, vol. 328, pp. 202–213. Springer Berlin Heidelberg (2010)

[7] Jonge, W., Jacobs, B.: Formal aspects in security and trust. chap. Privacy-Friendly Electronic Traffic Pricing via Commits, pp. 143–161. Springer-Verlag, Berlin, Heidelberg (2009)

[8] Meiklejohn, S., Mowery, K., Checkoway, S., Shacham, H.: The phantom tollbooth: Privacy-preserving electronic toll collection in the presence of driver collusion. In: USENIX Security Symposium. pp. 32–32 (2011)

[9] Popa, R.A., Balakrishnan, H., Blumberg, A.J.: Vpriv: Protecting privacy in location-based vehicular services. In: USENIX Security Symposium. pp. 335–350. USENIX Association (2009)

Considering a hierarchical structure of criteria in decision support systems

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1 Introduction

Decision support systems (DSS) have been widely studied from a long time in many different research areas. Multi-Criteria Decision Aiding (MCDA), which belongs to decision support area, is also a sub-discipline of operations research dedicated to study decision support methods dealing with decision problems involving multiple conflicting criteria [1]. In MCDA applications, the decision maker (DM) is facing a finite set of alternatives evaluated on multiple conflicting criteria. The decision aiding methods are based on different models for representing the preferences of the DM, taking into account a value system of the DM. The decision aiding process is based on three elements: (1) a finite set of alternatives A; (2) a finite set of criteria $G = g_1, g_2, .., g_n$, where each criterion g_j provides a performance score for each alternative in A; and (3) a preference system that for each possible pair of alternatives assigns one of the following binary relations: indifference, preference or incomparability.

Initially, the alternatives are evaluated with respect to each criterion separately. To combine the scores of the alternatives on individual criteria into an overall preference order of the alternatives, two main approaches are distinguished in MCDA: (1) Functional models: a value system is used to associate marginal preferences upon each criterion to each of the reference indicators that describe the alternatives. The value functions permit to rate each alternative according to its performance. (2) Relational models: preferences are expressed as binary relations between the alternatives. Each criterion defines a partial preference structure on the set of alternatives, with three types of relations: preference (P), indifference (I) and incomparability (R), which are modeled through outranking relations.

This thesis is focused on one of the most popular family of outranking methods, named ELECTRE [2], which presents the following strong features: (1) ELECTRE methods are able to take into account the qualitative nature

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of some criteria, allowing the DM to consider the original data directly; (2) ELECTRE methods can deal with heterogeneous criteria scales, preserving the original scores of the alternatives on each criterion; (3) ELECTRE follows a non-compensatory character in the aggregation, in contrast to utility-based models; (4) ELECTRE methods incorporate the notion of incomparabilities, referring to the case where alternatives have highly satisfactory values for some criteria and simultaneously extremely poor values for others.

However, classical ELECTRE method considers that all the criteria are at the same level, so that they are analyzed together to give an overall solution to the DM. However, in some real-world decision problems, it may become cognitively difficult for the DM to consider all criteria together [4]. This can be due to the large number of criteria or to the fact that there is a natural organization of the criteria into subgroups. In such situations, using a hierarchical structure, distinguishing different levels of generality, we can easily model the implicit taxonomical relations between the criteria, which divide the decision process in different steps [3].

The introduction of hierarchical structures arises new questions that require of new tools to help the DM to support their decisions. In this work we consider the two most common decision problems:

- Sorting. It consists of an assignment of each alternative to one category from a set predefined categories, which must be ordered according to some preference consideration.
- Ranking. The goal is to find a preference-based order structure of the set of alternatives, which permits to rank the alternatives from the best to the worst.

2 Hierarchy of criteria

In this PhD thesis we consider hierarchical structures of criteria as follows. Three types of criteria will be distinguished, depending on their level of generality in the taxonomy:

- Root: is a set composed by a unique element that is the most general criterion. This corresponds to the root node, placed at the top of the tree. This criterion represents the main goal of the decision maker.
- Elementary: is the set of the most specific criteria. They are placed at the lowest level of the hierarchical tree (i.e., the leaves). The performance of the alternatives is evaluated only in relation to these elementary criteria.
- Intermediate: They correspond to generalizations of other sub-criteria or elementary criteria. They are placed at intermediate levels of the tree, between the root and elementary criteria. Multiple levels of intermediate criteria are allowed.

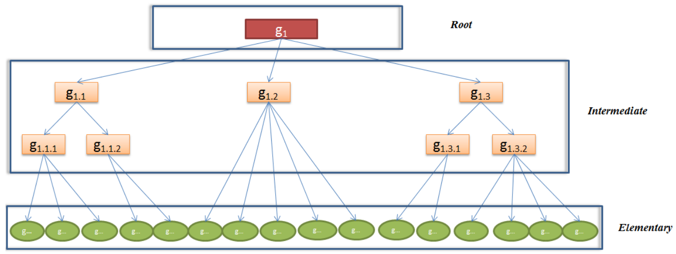

Fig. 1: Elements in a hierarchy of criteria

2.1 Ranking

The first contribution of this PhD thesis is an extension of the classical ELECTRE-III method [2] that follows a hierarchical structure of criteria. ELECTRE-III has two basic steps: 1) construction of a binary outranking relation based on partial concordance and discordance indices obtained from the consideration of a given set of criteria; and 2) exploitation of the outranking relation via distillation to obtain a partial pre-order of the alternatives.

The method proposed is called ELECTRE-III-H and is designed to generate and propagate the partial pre-orders calculated from the bottom level up to the root. The method applies classical ELECTRE-III at the elementary criteria in subsets, calculating the outranking relations based on the performance of the alternatives, generating a partial pre-order on their direct parent. To propagate the result to upper levels, the construction of outranking relations relies (step 1) are calculated from the partial pre-orders in the descendant nodes. These outranking relations are then exploited by distillation as applied in classical ELECTRE-III. In the example shown in Figure 1, classical ELECTRE-III is applied on $g_{1.1.1}$, $g_{1.1.2}$, $g_{1.2}$, $g_{1.3.1}$ and $g_{1.3.2}$, obtaining partial pre-orders at each of those subcriteria. Then, the partial preorders on $g_{1.1.1}$, $g_{1.1.2}$ are aggregated and exploited, obtaining a partial preorder on $g_{1.1}$. The same procedure applies for $g_{1.3}$ with their direct descendants. Finally, a global pre-order is obtained on g_1 from the aggregation of the partial preorders on $g_{1.1}$, $g_{1.2}$, and $g_{1.3}$.

The ELECTRE-III-H method is applied in two real-world case studies. The first case study is a Web analysis related to tourist brands, with collaboration of the Communication Departments of Pompeu Fabra and Rovira i Virgili universities. The second case study is a hierarchical decision support system to evaluate the effects of climate change in water supply in a Mediterranean river basin. In this case we collaborate with the AGA team and TECNATOX company.

2.2 Sorting

The second contribution is for the sorting problem. In the ELECTRE literature, the ELECTRE-TRI-B method is the first sorting method proposed. This method is based on boundary profiles (or limiting profiles) that are fictive alternatives that separate two consecutive categories. ELECTRE-TRI-B considers a finite set of ordered categories from the worst to the best, in which the alternatives are assigned. The assignment procedure takes into account the outranking relations of the alternatives against the boundary profiles.

The ELECTRE-TRI-B-H method is proposed to propagate the assignment of the alternatives from the lowest level up to the root. We consider heterogeneous sets of categories at each node on the root and intermediate criteria, such that the categories can be defined differently at each criterion. This heterogeneous character will provide a more representative and meaningful qualitative assessment of the alternatives. The method propagation is analogous to ELECTRE-III-H, first assigns alternatives to intermediate criteria in which all their direct descendants are elementary criteria applying classical ELECTRE-TRI-B. Then, ELECTRE-TRI-B-H calculates outranking relations at higher levels of the hierarchy in a similar way but considering categorical boundary profiles, which are defined using decision rules.

The ELECTRE-TRI-B-H method will be applied on a real case study for the recommendation of tourist activities with the collaboration of Parc Científic i Tecnològic de Turisme i Oci (PCTTO) and the Foundation of Tourism Studies Costa Daurada.

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References

[1] Figueira J., Greco S., Ehrgott M. Multicriteria decision analysis: State of the Art Surveys. Springer, Berlin, 2005.

[2] Figueira J., Greco S., Roy R., Slowinski R. An overview of ELECTRE methods and their recent extensions. Journal of Multi-Criteria Decision Analysis 20(1-2):61-85, 2013.

[3] Matsatsinis N.F., Doumpos M., Zopounidis C. Knowledege acquisition and Representation for Expert Systems in the Field of Financial Analysis. Expert Systems With Applications, 12(2):247-262, 1997.

[4] Mustajoki J. Effects of imprecise weighting in hierarchical preference programming. European Journal of Operational Research. 218:193-201, 2012.

Unsupervised semantic clustering of Twitter hashtags

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1 Introduction

Micro-blogging services such as Twitter constitute one of the most successful kinds of applications in the current Social Web. Every day more than 500 million tweets are sent, providing up to date information about any imaginable domain of knowledge. Each tweet is a string of up to 140 characters that usually contains text, links and hashtags (strings preceded by the # symbol with which the user tags his/her message). An important research area is the design and development of tools that allow users to analyse large unstructured repositories of user-tagged data in order to discover and extract meaningful knowledge from them.

In this work we have focused on the problem of clustering English hashtags that refer to the same topic, which is a first step to classify tweets and help to solve the problems of data visualisation, semantic information retrieval, information extraction, detection of users with similar interests, etc. Classifying freely chosen hashtags automatically in an unsupervised way is a very complex task [1]. Previous works on automated hashtag clustering (e.g. [2], [3]) mostly consider their co-occurrence or the co-occurrence of the words in the tweets containing the hashtags. Some authors (e.g. [4], [5]) have tried to classify tweets, usually employing a bag-of-words model to represent them and also using the co-occurrence between words as a similarity measure between tweets. Most works on Twitter topic detection try to classify a tweet into a general pre-defined small set of categories (e.g. [6]). The lack of a semantic treatment of the content of the tweets, including the hashtags, is the main shortcoming of all these approaches.

The contribution of this paper is twofold: on the one hand, we propose a methodology to perform an unsupervised semantic classification of a set of hashtags; on the other hand, we describe how to analyse the hierarchical classification in order to identify the classes that are really significant.

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The rest of the paper is structured as follows. Section 2 explains the novel methodology of analysis, which is applied in section 3 to a corpus of tweets related to Oncology, in which encouraging results have been obtained. The final section summarizes the work and sketches future lines of work.

2 Methodology

Given a set of tweets, we extract the hashtags they contain. Word-breaking techniques are applied to split those that are composed by more than one word. Then, the three steps of the analysis are applied: semantic annotation (section 2.1), semantic clustering (section 2.2) and class selection (section 2.3).

2.1 Semantic annotation of hashtags

This stage aims to discover the link between hashtags and their meanings (in our case, WordNet concepts) in order to be able to compare later pairs of hashtags at the conceptual level using semantic similarity measures. The set of WordNet concepts potentially associated to each hashtag is calculated as follows. If the hashtag matches directly a WordNet concept, then there is a single candidate. If the hashtag is not contained in WordNet (a very common situation, due to the nature of Twitter hashtags), we use Wikipedia to try to find concept candidates, as shown in the getWikipediaCandidates function (Figure 1). If there is an entry for the hashtag, all its associated Wikipedia categories are retrieved. A category is proposed as an annotation candidate if the main noun of its description matches with a WordNet concept. The hashtags with a final empty list of candidate concepts are removed.

```
getWikipediaCandidates (hashtag h)
 wikiCandidates := Ø
 if existsWikiEntry(h)
  auxCategories:= getCategoriesFromWiki(h)
  forall cat in auxCategories
   mainNoun := getMainNoun(cat)
   auxCat := getWordNetConcept(mainNoun)
   if auxCat != Ø
    wikiCandidates = wikiCandidates + auxCat
 return wikiCandidates
```

Fig. 1: Algorithm of getWikipediaCandidates function

2.2 Hashtag clustering

At this point each hashtag h has an associated list of WordNet concepts LCh. After choosing any suitable ontology-based semantic similarity measure

[7], the similarity between two hashtags *h1* and *h2* is defined as the maximum similarity between one concept in *LCh1* and another in *LCh2*. It may be argued that the use of the maximum pairwise similarity solves, indirectly, the problem of disambiguating the correct sense of the hashtag [8]. A symmetric semantic similarity matrix between all pairs of hashtags is taken as the input of a hierarchical clustering method, which obtains as a result a classification of the hashtags in a taxonomical hierarchy.

2.3 Selection of relevant clusters

Due to the nature of social tags, the result of traditional clustering methods contains a large proportion of noise. A method to filter the results is presented in figure 2, where *HC* is the result of the clustering, *t1* is the minimum inter-cluster homogeneity required to select a class (the average semantic distance between all its elements) and *t2* is the minimum number of elements required to select a class. The *filtering* function iteratively makes horizontal cuts in the tree, from the one that provides *maxK* classes down to the one that gives *minK* classes. *HCkc* denotes the *c*-th class when the tree is divided into *k* classes. A class is selected if it is homogeneous and large enough, and it is not a superset of a previously selected class. The main topic of each selected class is its semantic centroid, calculated on WordNet with the method described in [9].

```
filtering (HC, minK, maxK, t1, t2)
 finalClusts := Ø
 forall k in maxK .. minK
  forall c in 1 .. k
   b := inter-cluster-homogeneity(HCkc)
   if ((b >= t1) && (|HCkc| >= t2)
     && (∄ e in finalClusts | e ⊆ HCkc))
      finalClusts <- HCkc
 return finalClusts
```

Fig. 2: Selection algorithm

3 Case study

A test was conducted on a set of tweets related to Oncology, which was extracted from the Symplur website[2] and is composed of 5000 tweets (Oct2012-Jan2013) containing 1086 different hashtags. 930 of them (85.6 %) were annotated, and the remaining 156 hashtags (14.4%) were removed. A manual

[2] www.symplur.com. Last access: February 26th, 2014

analysis of this set showed 536 (57.6%) relevant medical hashtags, which were classified in a set A of 16 manually labelled categories (organs, professions, medical tests, etc.) and 394 hashtags (42.4 %) that were listed as either noise or unrelated to Medicine. The Wu-Palmer semantic similarity function [7] was used in the clustering step. The selection parameters were *minK*=5, *MaxK*=200, *t1*=0.70 and *t2*=10.

A final set B of 31 classes was obtained. We compared each class in B with the 16 manually defined classes (plus a 17^{th} class containing the 394 unclassified hashtags). For each class Bi in B Table 1 shows the class Aj in A with a higher precision (number of elements in Bi that belong to Aj) and the recall with respect to that class (the proportion of elements of Aj that appear in Bi). Each row shows on the left side the identifier of Bi, its semantic centroid and its number of elements, and on the right side the Aj class with a best match, with its associated precision and recall (the best results are shown in bold face). 15 classes in B (with a total number of 266 hashtags) matched one of the classes in A, whereas the other 16 matched the noisy 17^{th} class. In two cases a couple of classes in B matched the same class in A ({*B10*, *B14* } and {*B13*, *B15* }). Thus, 13 of the 16 target manual clusters were identified by the system with varying degrees of precision (5 classes 70-80 %, 4 classes 60-64 %, 4 classes 38 50 %). The recall is much lower, mostly due to the subjectivity of the manual classification (2 classes over 60 %, 4 classes 37-45 %, 5 classes 14-24 %).

Id	Centroid	Size	Prec.	Rec.	Manual class
1	Woody_Plant	11	64%	41%	Substances
2	Day	10	50%	24%	Temporal
3	Therapy	20	75%	37%	Medical tests
4	Medicine	17	76%	23%	Medications
5	Cancer	46	80%	62%	Cancer
6	Court	14	43%	43%	Hospitals
7	Biotechnology	10	60%	15 %	Biological
8	Health	23	43%	45%	Health Care
9	Medicine	43	60%	63%	Medical Fields
10	System	10	40%	21%	Body Parts
11	Area	11	73%	18%	Geographical Locations
12	Teaching	10	40%	14%	Academic, Research
13	Person	16	38%	12%	Medical Jobs
14	Center	10	40%	12%	Body Parts
15	Doctor	15	60%	18%	Medical Jobs
16-31	-	-	-	-	Noise

Table 1: Results on Oncology tweet set.

4 Conclusions and future work

This unsupervised domain-independent methodology allows a semantic clustering of a set of hashtags and the identification of its most relevant topics, filtering the large proportion of noise inherent to these sets. The lines of future work include the analysis of the full content of the tweets, the use of general sets of millions of tweets and the study of the treatment of polysemic hashtags.

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References

[1] K.Bontcheva and D.Rout. Making sense of social media streams through semantics: a survey. Semantic Web Journal. 2012.

[2] X.Wang, F.Wei, X.Liu, M.Zhou and M.Zhang Topic sentiment analysis in twitter: a graph-based hashtag sentiment classification approach. Procs. of the 20^{th} ACM Conference on Information and Knowledge Management. 10311040, Glasgow, Scotland (2011).

[3] O.Tsur, A.Littman and A.Rappoport. Scalable multi stage clustering of tagged micro-messages. Poster at the 21^{st} Int. World Wide Web Conference. Lyon, France (2012).

[4] S.Bhulai, P.Kampstra, L.Kooiman, G.Koole, M.Deurloo and B. Kok. Trend visualization in Twitter: whats hot and whats not? Procs. of the 1^{st} Int. Conference on Data Analytics. 4348. Barcelona (2012).

[5] P.Teufl and S.Kraxberger. Extracting semantic knowledge from Twitter. Procs. of the 3^{rd} IFIP WG 8.5 Int. Conference on Electronic Participation. 4859. Springer-Verlag, Berlin, Heidelberg (2011).

[6] K.Dela Rosa, R.Shah, B.Lin, A.Gershman and R. Frederking. Topical clustering of tweets. Procs. of the 3^{rd} Workshop on Social Web Search and Mining. Beijing, China (2011).

[7] Z.Wu, M.Palmer. Verbs semantics and lexical selection. Procs. of the 32^{nd} annual meeting on Association for Computational Linguistics. 133138. Stroudsburg, PA, USA (1994).

[8] A.Tversky. Features of similarity. Psyc.Review. 84, 327352 (1977).

[9] S.Martínez, A.Valls, D.Sánchez. Semantically-grounded construction of centroids for datasets with textual attributes. Knowledge-Based Systems. 35, 160172 (2012).

The k-metric dimension of a graph

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1 Introduction

The problem of uniquely determining the location of an intruder in a network was the principal motivation of introducing the concept of metric dimension in graphs by Slater in [9,10], where the metric generators were called *locating sets*. The concept of metric dimension of a graph was also introduced independently by Harary and Melter in [5], where metric generators were called *resolving sets*.

Nevertheless, the concept of metric generator, in its primary version, has a weakness related with the possible uniqueness of the vertex identifying a pair of vertices of the graph. Consider, for instance, some robots which are navigating, moving from node to node of a network. On a graph, however, there is neither the concept of direction nor that of visibility. We assume that robots have communication with a set of landmarks S (a subset of nodes) which provide them the distance to the landmarks in order to facilitate the navigation. In this sense, one aim is that each robot is uniquely determined by the landmarks. Suppose that in a specific moment there are two robots x, y (are located in v_{11} and v_{12} in the example of Figure 1 (a)) whose positions are only distinguished by one landmark $s \in S$ ($s = v_{13}$ and $S = \{v_{13}, v_{21}, v_{22}\}$ in the example of Figure 1 (a)). If the communication between robots x, y and s is "unexpectedly blocked", then the robots will get "lost‘" in the sense that they can assume that they have the same position as we show in the example of Figure 1 (b). So, for a more realistic settings it could be desirable to consider a set of landmarks where each pair of nodes is distinguished by at least two landmarks, such that the set of landmarks be as "small" as possible.

A generator of a metric space is a set S of points in the space with the property that every point of the space is uniquely determined by its distances from the elements of S. Given a simple graph $G = (V, E)$ we consider the metric $d_G : V \times V \to \mathbb{N}$, where $d_G(x, y)$ represents the length of a shortest $a - b$ path. The pair (V, d_G) is clearly a metric space. It is said that a vertex

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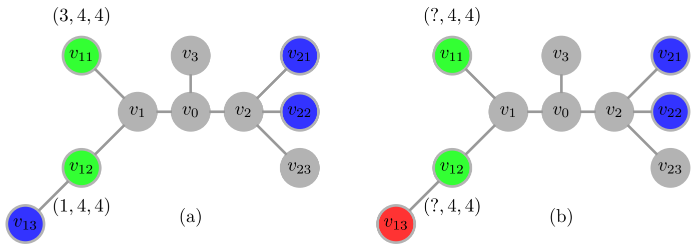

Fig. 1: Example of weakness of metric generator in robot navigation in networks.

$v \in V$ distinguish two different vertices $x, y \in V$, if $d_G(v, x) \neq d_G(v, y)$. A set $S \subseteq V$ is a *metric generator* for G if any pair of vertices of G is distinguished by some element of S. Such a name for S raises from the concept of *generator* of metric spaces, since a metric generator S has the property that every point of the space is uniquely determined by its "distances" from the elements of S. A metric generator of minimum cardinality is called a *metric basis*, and its cardinality the *metric dimension* of G, denoted by $\dim(G)$.

In this investigation we consider an extension of the concept of metric generators in the following way. Given a simple and connected graph $G = (V, E)$, a set $S \subseteq V$ is said to be a *k-metric generator* for G if and only if any pair of vertices of G is distinguished by at least k elements of S, *i.e.*, for any pair of different vertices $u, v \in V$, there exist at least k vertices $w_1, w_2, ..., w_k \in S$ such that

$$d_G(u, w_i) \neq d_G(v, w_i), \text{ for every } i \in \{1, ..., k\}. \tag{1}$$

A k-metric generator of minimum cardinality in G will be called a *k-metric basis* and its cardinality the *k-metric dimension* of G, which will be denoted by $\dim_k(G)$.

As an example we take a graph G obtained from the cycle graph C_5 and the path P_t of order $t \geq 2$, by identifying one of the vertices of the cycle, say u_1, and one of the extremes of P_t, as we show in Figure 2. Let $S_1 = \{v_1, v_2\}$, $S_2 = \{v_1, v_2, u_t\}$, $S_3 = \{v_1, v_2, v_3, u_t\}$ and $S_4 = \{v_1, v_2, v_3, v_4, u_t\}$. For $k \in \{1, 2, 3, 4\}$ the set S_k is k-metric basis of G.

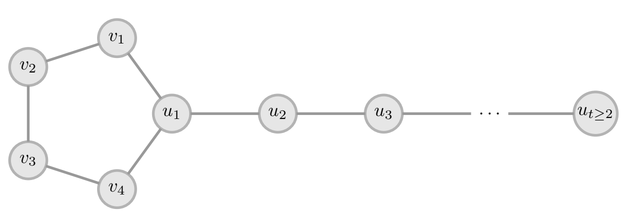

Fig. 2: For $k \in \{1, 2, 3, 4\}$, $\dim_k(G) = k + 1$.

The literature about metric dimension in graphs shows applications to the robot navigation in networks discussed in [7] and applications to chemistry in [6]. Several variations of metric generators including resolving dominating sets [1], independent resolving sets [2], and local metric sets [8] have been introduced and studied. It is therefore our goal to introduce this extension of metric generators in graphs as a possible future tool for other possible more general variations of the applications described above.

2 Objectives and results achieved

In this research we extend the concepts of metric basis and metric dimension of a graph and we study several problems related to k-metric basis and the k-metric dimension of a graph.

The first research line is to find the values of k for which there exists a k-metric generator in a connected graph G and the second research line is to calculate the value of the k-metric dimension of arbitrary graphs.

Given a connected graph G, the first problem is to determine if there exists an integer t such that G does not contain any k-metric generator for every $k > t$. According to that fact, a connected graph G is said to be a *k-metric dimensional graph*, if k is the largest integer such that there exists a k-metric basis for G.

In [11] we showed an algorithm that compute the integer k for which a graph of order n is k-metric dimensional in a time complexity of $O(n^3)$.

Since the problem of computing the value k' for which a given graph is k'-metric dimensional is polynomial, we studied in [11] the problem of deciding whether the k-metric dimension, $k \leq k'$, of G is less than r, for some $r \geq k+1$, *i.e.*, the following decision problem.

k-METRIC DIMENSION PROBLEM
INSTANCE: A connected k'-metric dimensional graph G of order n and integers k, r such that $k \leq k'$ and $r \geq k+1$.
PROBLEM: Deciding whether the k-metric dimension of G is less than r.

We proved that the k-METRIC DIMENSION PROBLEM is NP-complete by a reduction of our problem to 3-SAT problem. Taking into account this, we have obtained closed formulae and tight bounds for the k-metric dimension of some k'-metric dimensional graphs, where $1 \leq k \leq k'$. Many of these formulas and bounds were calculated from known parameters of graphs. In addition, we have given a result in [3] that allowed us to present an algorithm for a tree different from path in lineal time in [11]. In future works we will continue to obtain closed formulae and tight bounds for the k-metric dimension of arbitrary graphs. Also, we will analyse the complexity time of computing the k-metric dimension of specific family of graphs and we will intend to develop heuristics that allow us to compute or accurately estimate the k-metric dimension of some graphs.

Graphs are basic combinatorial structures, and product of graphs occur naturally in discrete mathematics as tools in combinatorial constructions. They give rise to important classes of graphs and deep structural problems. Thus, we are interested in the study of relationships between the k-metric dimension of Cartesian, strong, corona and rooted product graphs and the k-metric dimension of its corresponding factors. Recently, we have studied the particular case of Corona product of graphs in [4].

Finally we want to study some variants developed for the metric dimension in the k-metric dimension of graphs. Such would be the case of k-independent resolving sets, k-resolving dominating sets and local k-metric dimension.

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References

[1] R. C. Brigham, G. Chartrand, R. D. Dutton, P. Zhang, Resolving domination in graphs, Mathematica Bohemica 128 (1) (2003) 25–36.

[2] G. Chartrand, C. Poisson, P. Zhang, Resolvability and the upper dimension of graphs, Computers & Mathematics with Applications 39 (12) (2000) 19–28.

[3] A. Estrada-Moreno, J. A. Rodríguez-Velázquez, I. G. Yero, The k-metric dimension of a graph, arXiv:1312.6840 [math.CO].

[4] A. Estrada-Moreno, I. G. Yero, J. A. Rodríguez-Velázquez, The k-metric dimension of corona product graphs, Bulletin of the Malaysian Mathematical Sciences Society. To appear.

[5] F.Harary, R. A. Melter, On the metric dimension of a graph, Ars Combinatoria 2 (1976) 191–195.

[6] M. Johnson, Structure-activity maps for visualizing the graph variables arising in drug design, Journal of Biopharmaceutical Statistics 3 (2) (1993) 203–236, pMID: 8220404.

[7] S. Khuller, B. Raghavachari, A. Rosenfeld, Landmarks in graphs, Discrete Applied Mathematics 70 (3) (1996) 217–229.

[8] F. Okamoto, B. Phinezy, P. Zhang, The local metric dimension of a graph, Mathematica Bohemica 135 (3) (2010) 239–255.

[9] P. J. Slater, Leaves of trees, Congressus Numerantium 14 (1975) 549–559.

[10] P. J. Slater, Dominating and reference sets in a graph, Journal of Mathematical and Physical Sciences 22 (4) (1988) 445–455.

[11] I. G. Yero, A. Estrada-Moreno, J. A. Rodríguez-Velázquez, The k-metric dimension of a graph: Complexity and algorithms, arXiv:1401.0342 [math.CO].

Strong resolvability in product graphs

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1 Background of the thesis

The problem of uniquely recognizing the position of an intruder in a network was the principal motivation of introducing the concept of metric generators in graphs by Slater in [10]. An analogous concept was also introduced independently by Harary and Melter in [3]. Furthermore, other applications of resolving sets in graphs have been described in several articles. The usefulness of these ideas into chemistry for representing chemical compounds [4,5], or in problems of pattern recognition and image processing, some of which involve the use of hierarchical data structures [7] have appeared. Also, applications to navigation of robots in networks are discussed in [6]. Some interesting connections between resolving sets in graphs and the Mastermind game or coin weighing were presented in [1].

A vertex v of a connected graph G is said to distinguish two vertices x and y of G if $d_G(v,x) \neq d_G(v,y)$, *i.e.*, the distance between v and x is different from the distance between v and y. A set $S \subseteq V(G)$ is said to be a *metric generator* for G if any pair of vertices of G is distinguished by some element of S. A minimum generator is called a *metric basis*, and its cardinality the *metric dimension* of G.

In [9] the authors asked, for a given metric generator T of a graph H, the following question: whenever H is a subgraph of a graph G and the metric vectors of the vertices of H relative to T agree in both H and G, is H an isometric subgraph of G? Even though the metric vectors relative to a metric generator of a graph distinguish all pairs of vertices in the graph, they do not uniquely determine all distances in a graph as was first shown in [9]. Fig. 1 shows two graphs of order 7 having the same metric vectors relative to the metric generator $\{1,2\}$, but for which the distances between pairs of vertices having the same metric vector are not the same. It was observed in [9] that, if "metric generator" is replaced by a stronger notion, namely that of "strong

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metric generator" (defined below), then the above question can be answered in the affirmative.

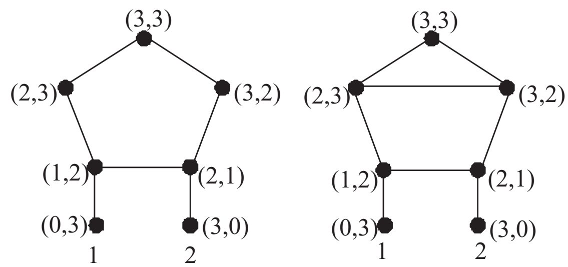

Fig. 1: Non-isomorphic graphs with the same metric vectors

A vertex $w \in V(G)$ *strongly resolves* two vertices $u, v \in V(G)$ if $d_G(w,u) = d_G(w,v) + d_G(v,u)$ or $d_G(w,v) = d_G(w,u) + d_G(u,v)$, *i.e.*, there exists some shortest $w - u$ path containing v or some shortest $w - v$ path containing u. A set S of vertices in a connected graph G is a *strong metric generator* for G if every two vertices of G are strongly resolved by some vertex of S. The smallest cardinality of a strong metric generator of G is called the *strong metric dimension* and is denoted by $dim_s(G)$. A *strong metric basis* of G is a strong metric generator for G of cardinality $dim_s(G)$.

Moreover, some applications of strong resolving sets to combinatorial searching were presented in [9]. Specifically, there were analyzed some problems on false coins arising from the connection between information theory and extremal combinatorics. Also, they dealt with a combinatorial optimization problem related to finding "connected joins" in graphs. In such a work, several results about detection of false coins are used to approximate the value of the strong metric dimension of some specific graphs, like for example the Hamming graphs.

On the other hand, studies about graph operations are being frequently presented and published in the last years. The book [2] is a very rich compendium of the existent theory of product graphs. In general, a graph product of graphs G and H is a graph whose vertex set is $V(G) \times V(H)$ and where, its edges are determined by a function on the edges of the factors (graphs G and H). There are a lot of graph products but according to [2] only four of them are the most important: the Cartesian product, the direct product, the lexicographic product and the strong product, which are also called *standard products*.

It is therefore natural that several graphs invariants are studied for such classes of graph products and the strong metric dimension of product graphs has not, of course, escaped to these kind of investigations.

Oellermann and Peters-Fransen [8] showed that the problem of finding the strong metric dimension of a graph G can be transformed into a more well-known problem, the vertex cover problem. This result is an important tool for study the strong metric dimension. Furthermore, it was shown in [8] that the problem of computing $dim_s(G)$ is NP-hard. It is therefore desirable to reduce the problem of computing the strong metric dimension of product graphs, to the problem of computing some parameter of the factor graphs. Moreover, this suggests obtaining closed formulaes for the strong metric dimension of specific families of graphs or bounding the value of this invariant as tight as possible.

Aims of the research:

- To obtain exact values or sharp bounds for the strong metric dimension of product graphs, like the Cartesian product, the direct product, the strong product, the lexicographic product, the Cartesian sum, the rooted product and the corona product.
- To study relationships between the strong metric dimension of product graphs and the strong dimension of its factors.
- To investigate the metric dimension of product graphs, like the strong product graph, the rooted product and the corona product.
- To study metric dimension related parameters in product graphs.

References

[1] J. Cáceres, C. Hernando, M. Mora, I. M. Pelayo, M. L. Puertas, C. Seara and D. R. Wood. On the metric dimension of Cartesian product of graphs. *SIAM J. Discrete Math.*, 21(2):273–302, 2007.

[2] R. Hammack, W. Imrich and S. Klavžar. *Handbook of Product Graphs, Second Edition.* CRC Press, Boca Raton, FL, 2011.

[3] F. Harary and R. A. Melter. On the metric dimension of a graph. *Ars Combin.*, 2:191–195, 1976.

[4] M. A. Johnson. Structure-activity maps for visualizing the graph variables arising in drug design. *J. Biopharm. Statist.*, 3:203–236, 1993.

[5] M. A. Johnson. Browsable structure-activity datasets. *In: Advances in Molecular Similarity, R. Carbó–Dorca and P. Mezey, eds., JAI Press Connecticut*, 153–170, 1998.

[6] S. Khuller, B. Raghavachari and A. Rosenfeld. Landmarks in graphs. *Discrete Appl. Math.*, 70:217–229, 1996.

[7] R. A. Melter and I. Tomescu. Metric bases in digital geometry. *Computer Vision, Graphics, and Image Processing*, 25:113–121, 1984.

[8] O. R. Oellermann and J. Peters-Fransen. The strong metric dimension of graphs and digraphs. *Discrete Appl. Math.*, 155:356–364, 2007.

[9] A. Sebő and E. Tannier. On metric generators of graphs. *Math. Oper. Res.*, 29(2):383–393, 2004.

[10] P. J. Slater. Leaves of trees. *Proceeding of the* 6^{th} *Southeastern Conference on Combinatorics, Graph Theory, and Computing. Congr. Numer.*, 14:549–559, 1975.

Notions of Simultaneous Resolvability in Graph Families

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1 Definitions and aims of our work

A generator of a metric space is a set S of points in the space with the property that every point of the space is uniquely determined by its distances from the elements of S. Given a simple and connected graph $G = (V, E)$, we consider the function $d_G : V \times V \rightarrow \mathbb{N}$, where $d_G(x, y)$ is the length of a shortest path between u and v and $\mathbb{N}$ is the set of non-negative integers. Clearly, (V, d_G) is a metric space. A vertex $v \in V$ is said to *distinguish* two vertices x and y if $d_G(v, x) \neq d_G(v, y)$. A set $S \subset V$ is said to be a *metric generator* for G if any pair of distinct vertices of G is distinguished by some element of S. A minimum metric generator is called a *metric basis*, and its cardinality the *metric dimension* of G, denoted by $\dim(G)$.

The concept of metric dimension of a graph was introduced by Slater in [5], where metric generators were called *locating sets*, and, independently, by Harary and Melter in [1], where metric generators were called *resolving sets*.

Now we present the navigation problem proposed in [3] where navigation was studied in a graph-structured framework in which the navigating agent (which was assumed to be a point robot) moves from node to node of a "graph space". The robot can locate itself by the presence of distinctively labeled "landmark" nodes in the graph space. On a graph, there is neither the concept of direction nor that of visibility. Instead, it was assumed in [3] that a robot navigating on a graph can sense the distances to a set of landmarks. Evidently, if the robot knows its distances to a sufficiently large set of landmarks, its position on the graph is uniquely determined. This suggests the following problem: given a graph G, what is the smallest number of landmarks needed, and where should they be located, so that the distances to the landmarks uniquely determine the robot's position on G? The solution of this problem requires us to determine the metric dimension and a metric basis of G. In our work we consider the following extension of this problem. Suppose that the topology of the navigation network may change within a range of possible

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graphs, say $G_1, G_2, ..., G_k$. In this case, the above mentioned problem becomes that of determining the minimum cardinality of a set S which is a metric generator for each graph G_i, $i \in \{1, ..., k\}$. So, if S is a solution for this problem, then the position of each robot can be uniquely determined by the distance to the elements of S, regardless of the graph G_i that models the network at each moment.

Given a family $\mathcal{G} = \{G_1, G_2, ..., G_k\}$ of (not necessarily edge-disjoint) connected graphs $G_i = (V, E_i)$ with common vertex set V (the union of whose edge sets is not necessarily the complete graph), we define a *simultaneous metric generator* for $\mathcal{G}$ as a set $S \subseteq V$ such that S is simultaneously a metric generator for each G_i. We say that a minimum simultaneous metric generator for $\mathcal{G}$ is a *simultaneous metric basis* of $\mathcal{G}$, and its cardinality the *simultaneous metric dimension* of $\mathcal{G}$, denoted by $\mathrm{Sd}(\mathcal{G})$ or explicitly by $\mathrm{Sd}(G_1, G_2, ..., G_k)$. An example is shown in Figure 1 where $\{u_3, u_4\}$ is a simultaneous metric basis of $\{G_1, G_2, G_3\}$.

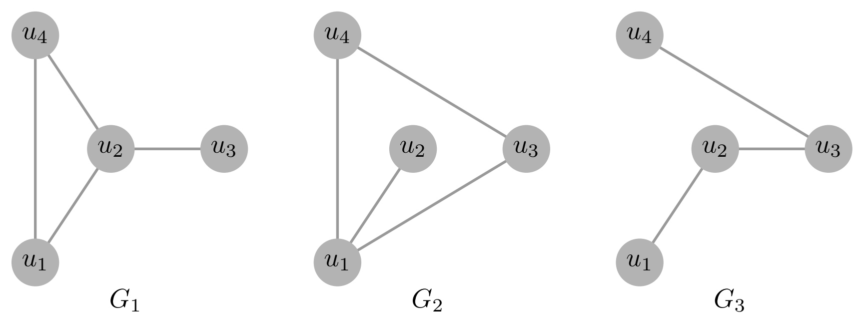

Fig. 1: The set $\{u_3, u_4\}$ is a simultaneous metric basis of $\{G_1, G_2, G_3\}$. Thus, $\mathrm{Sd}(G_1, G_2, G_3) = 2$.

Several variations on the concept of metric dimension have been studied. Here, we extend the idea of simultaneous resolvability to two of them, namely the local metric dimension and the adjacency dimension.

A set $S \subset V$ is said to be a *local metric generator* for $G = (V, E)$ (also *local resolving set*) if any pair of adjacent vertices of G is distinguished by some element of S. A minimum local metric generator is called a *local metric basis*, and its cardinality the *local metric dimension* of G, denoted by $\dim_l(G)$ [4]. The local metric dimension is a useful parameter, as many practical situations arise when it is not necessary to distinguish any pair of vertices, but only neighbouring ones. Note that any metric generator of a graph $G = (V, E)$ is also a local metric generator.

For a vertex $v \in V(G)$ the set $N_G(v) = \{u \in V : \ u \sim v\}$ is the open neighborhood of v. A set $S \subset V$ of vertices in a graph $G = (V, E)$ is an *adjacency generator* for G (also *adjacency resolving set*) if for every $x, y \in V(G) - S$ there exists $x \in S$ such that $|N_G(x) \cap \{x, y\}| = 1$. A minimum adjacency generator is called an *adjacency basis*, and its cardinality the *adjacency dimension* of G, is denoted by $\dim_A(G)$. These concepts were introduced in [2] with the aim of studying the metric dimension of the lexicographic product of graphs in terms of the adjacency dimension of graphs. Observe that an adjacency generator of a graph $G = (V, E)$ is also a metric generator, and an adjacency basis is also a metric basis in a suitably chosen metric space, namely by considering $(V, d_{G,2})$, with $d_{G,2}(x, y) = \min\{d_G(x, y), 2\}$, and vice versa.

We define a *simultaneous local metric generator* for $\mathcal{G}$ as a set $S \subset V$ such that S is simultaneously a local metric generator for each G_i. We say that a minimum simultaneous local metric generator for $\mathcal{G}$ is a *simultaneous local metric basis* of $\mathcal{G}$, and its cardinality the *simultaneous local metric dimension* of $\mathcal{G}$, denoted by $\mathrm{Sd}_l(\mathcal{G})$ or explicitly by $\mathrm{Sd}_l(G_1, G_2, ..., G_k)$. Likewise, a *simultaneous adjacency generator* for $\mathcal{G}$ is a set $S \subset V$ such that S is simultaneously an adjacency generator for each G_i. We say that a minimum simultaneous adjacency generator for $\mathcal{G}$ is a *simultaneous adjacency basis* of $\mathcal{G}$, and its cardinality the *simultaneous adjacency dimension* of $\mathcal{G}$, denoted by $\mathrm{Sd}_A(\mathcal{G})$ or explicitly by $\mathrm{Sd}_A(G_1, G_2, ..., G_t)$.

To illustrate the relations between the simultaneous metric dimension, the simultaneous local metric dimension and the simultaneous adjacency dimension, Figure 2 shows a graph family where $\mathrm{Sd}(G_1, G_2, G_3) = 2$ (as any pair of vertices is a simultaneous metric basis), whereas $\mathrm{Sd}_l(G_1, G_2, G_3) = 1$ (as any one-vertex set is a simultaneous local metric basis) and $\mathrm{Sd}_A(G_1, G_2, G_3) = 3$ (for instance, the set $\{u_1, u_3, u_5\}$ is a simultaneous adjacency basis).

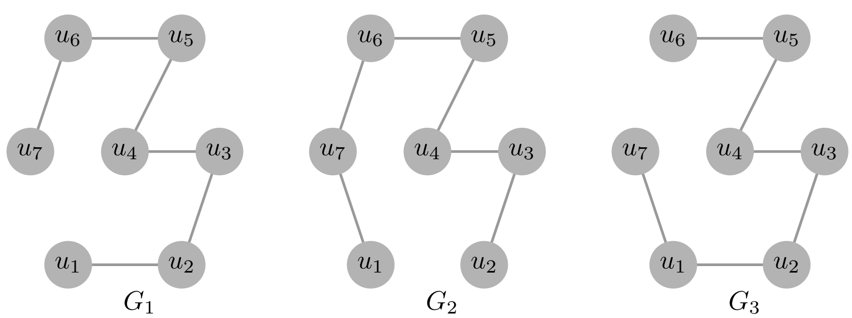

Fig. 2: The set $\{u_1, u_3, u_5\}$ is a simultaneous adjacency basis of $\{G_1, G_2, G_3\}$, whereas any pair of vertices is a simultaneous metric basis and any one-vertex set is a simultaneous local metric basis, so $\mathrm{Sd}(G_1, G_2, G_3) = 2$, $\mathrm{Sd}_l(G_1, G_2, G_3) = 1$ and $\mathrm{Sd}_A(G_1, G_2, G_3) = 3$.

The general objective of our work is to investigate the properties of these three types of simultaneous dimension, and possibly some additional variants, by obtaining closed formulae or tight bounds for these parameters on several notable graph families, and studying the relations among the different types.

2 Some basic results

As a sample of the work currently in progress, we show the general bounds of the three variants of simultaneous dimension, some relations among them, and the conditions under which extreme values are reached.

Theorem 1. *For any family $\mathcal{G} = \{G_1, G_2, ..., G_k\}$ of connected graphs on a common vertex set V, the following results hold:*

1. $\mathrm{Sd}(\mathcal{G}) \geq \max_{i \in \{1,...,k\}} \{\dim(G_i)\}$.
2. $\mathrm{Sd}_l(\mathcal{G}) \geq \max_{i \in \{1,...,k\}} \{\dim_l(G_i)\}$.
3. $\mathrm{Sd}_A(\mathcal{G}) \geq \max_{i \in \{1,...,k\}} \{\dim_A(G_i)\}$.
4. $\mathrm{Sd}_l(\mathcal{G}) \leq \mathrm{Sd}(\mathcal{G}) \leq \mathrm{Sd}_A(\mathcal{G}) \leq |V| - 1$.
5. *If* $D(G_i) \leq 2$ *for every* $G_i \in \mathcal{G}$*, then* $\mathrm{Sd}_A(\mathcal{G}) = \mathrm{Sd}(\mathcal{G})$.
6. $\mathrm{Sd}_A(\mathcal{G}) = \mathrm{Sd}_A(\overline{G}_1, \overline{G}_2, \ldots, \overline{G}_k)$.
7. $\mathrm{Sd}(\mathcal{G}) = 1$ *if and only if* $\mathcal{G}$ *is composed by paths having a leaf in common.*
8. $\mathrm{Sd}_l(\mathcal{G}) = 1$ *if and only if* $\mathcal{G}$ *is composed by bipartite graphs.*
9. *If* $\mathcal{G}$ *is composed by odd-order cycles, then* $\mathrm{Sd}(\mathcal{G}) = \mathrm{Sd}_l(\mathcal{G}) = 2$.
10. $\mathrm{Sd}_A(\mathcal{G}) = 1$ *if and only if* $\mathcal{G} \subseteq \{P_2, \overline{P}_2\}$, $\mathcal{G} \subseteq \{P_3^{(1)}, P_3^{(2)}, \overline{P}_3^{(1)}, \overline{P}_3^{(2)}\}$, $\mathcal{G} \subseteq \{P_3^{(1)}, P_3^{(3)}, \overline{P}_3^{(1)}, \overline{P}_3^{(3)}\}$ *or* $\mathcal{G} \subseteq \{P_3^{(2)}, P_3^{(3)}, \overline{P}_3^{(2)}, \overline{P}_3^{(3)}\}$*, where* $P_3^{(1)} = v_2v_1v_3$*,* $P_3^{(2)} = v_1v_2v_3$ *and* $P_3^{(3)} = v_1v_3v_2$ *are the three distinct path graphs that can be defined on the common vertex set* $V = \{v_1, v_2, v_3\}$.
11. *If* $\mathcal{G}$ *contains a complete graph, then* $\mathrm{Sd}(\mathcal{G}) = \mathrm{Sd}_l(\mathcal{G}) = \mathrm{Sd}_A(\mathcal{G}) = |V| - 1$.

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References

[1] F. Harary, R. A. Melter. On the metric dimension of a graph. *Ars Combinatoria* 2:191–195, 1976.

[2] M. Jannesari, B. Omoomi. The metric dimension of the lexicographic product of graphs. *Discrete Mathematics* 312(22):3349–3356, 2012.

[3] S. Khuller, B. Raghavachari, A. Rosenfeld. Landmarks in graphs. *Discrete Applied Mathematics* 70(3):217–229, 1996.

[4] F. Okamoto, B. Phinezy, P. Zhang. The local metric dimension of a graph. *Mathematica Bohemica* 135(3):239–255, 2010.

[5] P. J. Slater. Leaves of trees. *Congressus Numerantium* 14:549–559, 1975.

Behavior Of Gabor Features Under Nonlinear Deformation

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1 Abstract

In this paper, we focus on the behavior of Gabor features under Nonlinear deformation. The recognition ability of Gabor features starts to degrade depending on the applied type of deformation. In this work, we demonstrate the degradation of Gabor features caused by the none-linear deformation. SVM classification is used as a measure of the degradation level.

2 Introduction

Texture analysis is a very important and complicated problem in image processing and computer vision. It is due to the nature of texture of the images which can vary from regular to random. This problem has been interesting for huge number of researchers for decades [1]. Texture analysis has been studied for a long time, and the result of those studies is dividing the texture methods into 4 different categories [1,5]: statistical methods, geometrical methods, model based methods, and filter-based methods. In this paper, we are focusing on the fourth category, namely on Gabor features. According to the experts of computer vision community, Gabor features become a very popular method because of their relation with the vision system of the mammals particularly with regard to textures. In this paper we analyze the effect of the deformation on Gabor features using the accuracy of SVM classifier as measure of degradation in the behavior. The rest of paper will be organized follows: In Section 2, we describe a brief introduction of Gabor Filters, then we discuss our experiments in Section 3 and conclude the outcomes of this research in Section 4.

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3 Gabor Filters

Gabor filters have been widely used to extract texture features in many Computer Vision problems such as texture classification, texture segmentation, face recognition, and cancer detection [6]. A two dimensional Gabor filter $g(x, y)$ can be viewed as follows:

$$g(x, y) = e^{-\frac{1}{2}(\frac{x^2}{\sigma^2{}_x} + \frac{y^2}{\sigma^2{}_y})}. \tag{1}$$

where (u_0, v_0) is the center of Euler function and σ_x, σ_y are the standard deviations along two orthogonal directions. Given an input image $I(x, y)$, the filtered image $f(x, y)$ is the result of convolving $I(x, y)$ and $g(x, y)$:

$$f(x, y) = I(x, y) * g(x, y) \tag{2}$$

Eq. 2 defines a band-pass filter in the frequency domain, where the bandwidth and center frequency of the filter are controlled by the standard deviation of the Gaussian function and the frequency of the complex sinusoid respectively. A Gabor filter bank has a number of band-pass filters (with varying center frequencies, bandwidths and orientations) and it is controlled by the parameters of Gabor wavelets. The feature vector f is constructed using the mean μ_{mn} and the variance σ_{mn} of the filtered images:

$$f = [\mu_{11}, \sigma_{11}, \mu_{12}, ..., \mu_{mn}, \sigma_{mn}] \tag{3}$$

where m and n are the numbers of scales and orientations of the filter, respectively. In this work, 6 orientations and 4 scales were used, so have a vector of 48 features. Using Gabor filters to specific frequencies and directions can capacitate them to detect both local orientation and frequency information from an image. We can assume that local image regions are spatially homogeneous and use the mean and standard deviation of the magnitude of the filter responses to represent the region for classification. The feature vector f is constructed using the mean μ_{mn} and the variance σ_{mn} of the filtered images and it is called Homogenous Texture features.

4 Experiments

To demonstrate the degradation of Gabor features, some experiments were done as follows. Suppose that I is a textured image. Firstly, we randomly choose the point p in I. Then, we take the window W of size NxN around p and use W as input to get Gabor features vector. Repeating that for different images $I_1, I_2, .., I_n$ of the same textures (without deformation) we extract n vectors of Gabor features. This set of vectors presents the positive set for SVM classifier. In order to create the negative set we can take n images of different

	Sensitivity	Accuracy
KNN	0.75	0.647
SVM lin	0.96	0.82
SVM Poly	0.96	0.56
SVM RBF	0.76	0.84

Table 1: Classification measures using Gabor features without deformation.

	Sensitivity	Accuracy
KNN	0.57	0.49205
SVM lin	0.4	0.575
SVM Poly	0.35	0.68
SVM RBF	0.88	0.52

Table 2: Classification measures using Gabor features after nonlinear deformation.

textures. In Table 1 we see stability of classifier behavior for texture without deformation.

In the case of texture under deformation, the process of window selection is the same, except the input texture images. We select images with same texture under different types of deformation (see Fig.1). Comparing results in the Table 1 and Table 2, it is easy to notice the degradation of Gabor features under deformation.

5 Conclusion

We show the degradation of Gabor feature as a descriptor using for UIUC data set. As recommended in [3], we have used Gabor filters with 6 orientations and 4 scales. Some parameter values suffer from problem of curse of dimensionality and others lack of expressive ability. Classification was done using Support Vector Machines (SVM) [4] with linear, polynomial and RBF kernels SVM and KNN classifiers using Matlab IDE. Existence of huge degradation in results achieved for deformable textures is our motivation to develop new methods to overcome that degradation.

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References

[1] M. Andrzej,S. Michal. Texture-analysis methods. *www.eletel.p.lodz.*

[2] B. S. Manjunath and W. Y. Ma. Texture features for browsing and retrieval of image data. *IEEE Trans. Patt. Anal. Mach. Intell.,vol.18,no.8,1996.*

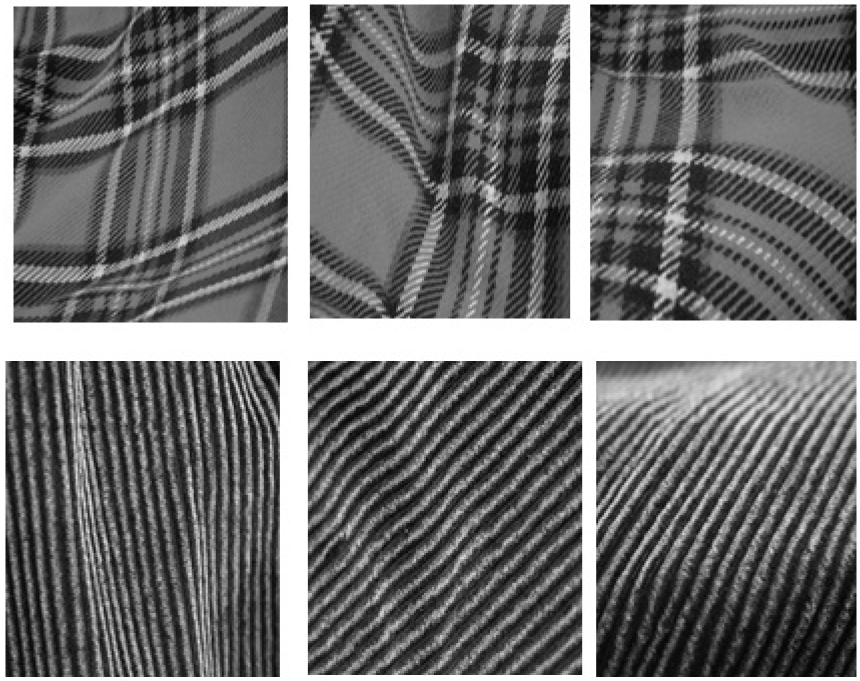

Fig. 1: Textures under nonlinear deformation (UIUC data set).

[3] F Riaz, A Hassan, S Rehman, U Qamar. Texture Classification Using Rotation- and Scale-Invariant Gabor Texture. *IEEE, 5, 2013.*

[4] V. Vapnik. The Nature of Statistical Learning Theory. *Berlin, Germany: Springer, 1995.*

[5] L. Xiuwen Liu, W. DeLiang Wang. Texture classification using spectral histograms. *IEEE trans. Image Processing, vol. 12, no. 6, 2003, pp. 661-670.*

[6] Y. Zheng. Breast Cancer detection with Gabor features. *Digital mammograms, algorithms 3.1 (2010), 44-62.*

Active Contour Method for Intensity Inhomogeneous Image Segmentation

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1 Introduction

Segmentation of intensity inhomogeneous regions is a well-known problem in computer vision and image processing. Inhomogeneous regions are hard to segment due to the intensity variations and non-uniform distribution throughout the region. To date numerous methods of image segmentation have been developed [4,9]. The active contour method introduced by Kass et al. in late 1980s, is one of the methods used for image segmentation [6]. In this method a curve evolves towards the object boundary by minimizing the energy. The energy functional is based on different image characteristics e.g., image gradient, curvature, and image statistical properties. The existing active contour models are categorized into two categories: edge-based models [3,6] and region-based models [2,5,7,8,10]. Both of these types have their own paybacks and drawbacks. The edge-based model builds an edge indicator function using image edge information, which can drive the contour towards the object boundaries [3]. The edge indicator function based on the image gradient can hardly stop at the right boundaries, for the images with intense noise or a weak edge. On the other hand, a region-based model uses statistical information to construct a region stopping function that can stop the contour evolution between different regions. Compared to the edge-based model, the region-based model can perform better for images with weak or blurred edges. The region-based model is not sensitive to initialization of the level set function and can recognize the objects boundaries efficiently. Therefore, region-based models, especially the Chan et al. (CV) model [2] have been widely applied for image segmentation. Although the region-based model is better than edge-based model in some aspects, it still has limitations. CV model, which was proposed in the context of binary image with the assumption that each image region is statistically homogeneous can not properly segment image with intensity inhomogeneity. Li et al. [7,8] proposed the local binary fitted (LBF) model by embedding the local image information to solve the segmentation problem in the context of

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intensity inhomogeneity. The basic idea of LBF was to introduce a Gaussian kernel function in the energy functional formulation to compute the means using local neighborhood. This paper presents a hybrid active contour method in the context of intensity inhomogeneity, which embeds both edge and region information. It contains both length and area term unlike traditional active contour methods. Length term, which exploits the edge information from Li et al., [3] method accelerates the contour evolution by detecting the object boundaries during the regularization process. Whereas, the area term which practices a new SPF function, helps to segment regions with the intensity inhomogeneity. The proposed method can properly segment images with intensity inhomogeneity because it uses an SPF function that is formulated by embedding both local and global mean values of the image. Finally, a Gaussian kernel introduced by Zhang et al., [10] is used to regularize the level set curve and to remove the computationally expensive re-initialization. The proposed segmentation algorithm is applied to synthetic images in order to demonstrate the accuracy, effectiveness, and robustness of the algorithm. Finally, the result comparison with previous related methods shows the advantages of the proposed method.

2 Active Contour Method with Local and Global Signed Pressure Force (LGSPF) function

Active contours are dynamic curves that move toward the object boundaries to partition an image into non-overlapping regions. To segment an image, we define energy functional containing a region-based area and an edge-based length term. Let $I\colon \Omega \to \mathbf{R}$ be an input image and C be a closed curve then the proposed energy functional, $E_{g,spf}$ is defined as follows:

$$E_{g,spf}(\phi(x)) = \lambda L_g(\phi(x)) + vA_{spf}(\phi(x)). \tag{1}$$

where $\lambda > 0$ and v are constants, and the terms $L_g(\phi)$ and $A_{spf}(\phi)$ are defined below:

$$L_g(\phi(x)) = \int_{\Omega} g(I(x))\delta_\epsilon(\phi(x))|\nabla(\phi(x))|dx. \tag{2}$$

and

$$A_{spf}(\phi(x)) = \int_{\Omega} K_{\sigma_2}(x-y)spf(I(y))H_\epsilon(-\phi(y))dy. \tag{3}$$

Here, the zero level curve C is driven into a smooth curve to minimize the function $L_g(\phi)$, which utilizes edge information in regularization process. While, $A_{spf}(\phi)$ contains the both locally and globally computed image intensity information, which derives the contour to the weak and blur edges by distinguishing inhomogeneous regions. Here, $\delta_\epsilon(z) = \frac{\epsilon}{\pi(z^2+\epsilon^2)}$ is regularized Dirac function, and $H_\epsilon(z) = \frac{1}{2}\left(1 + (\frac{2}{\pi})arctan(\frac{z}{\epsilon})\right)$ is the regularized Heaviside function. While, the edge indicator function $g(I)$ is a positive and strict decreasing function as defined:

$$g(I(x)) = \frac{1}{1 + |\nabla G_{\sigma_1} * I(x)|^2}. \tag{4}$$

and the $spf(I)$ is the proposed SPF function which utilizes both local and global means in an image. SPF function is defined as:

$$spf(I(x)) = \begin{cases} \frac{(I(x)-I_{LFI})I_{GFI}}{max(|I(x)-I_{LFI}|)}, & I(x) \neq 0 \\ 0, & I(x) = 0. \end{cases} \tag{5}$$

where, I_{LFI} is the local fitted image and I_{GFI} is the global fitted image defined as below:

$$I_{LFI} = f_1 H_\epsilon(\phi(x)) + f_2(1 - H_\epsilon(\phi(x))). \tag{6}$$

and

$$I_{GFI} = c_1 H_\epsilon(\phi(x)) + c_2(1 - H_\epsilon(\phi(x))). \tag{7}$$

where, f_1, f_2 and c_1, c_2 are local and global mean values, respectively, inside and outside of the object boundaries in the image, which are defined as below:

$$f_1 = \frac{K_{\sigma_1} * [H_\epsilon(\phi(x))I(x)]}{K_{\sigma_1} * H_\epsilon(\phi(x))},\ f_2 = \frac{K_{\sigma_1} * [(1 - H_\epsilon(\phi(x)))I(x)]}{K_{\sigma_1} * (1 - H_\epsilon(\phi(x)))}. \tag{8}$$

and

$$c_1 = \frac{\int_\Omega H_\epsilon(\phi(x))I(x)dx}{\int_\Omega H_\epsilon(\phi(x))dx},\ c_2 = \frac{\int_\Omega [(1 - H_\epsilon(\phi(x)))I(x)]dx}{\int_\Omega (1 - H_\epsilon(\phi(x)))dx}. \tag{9}$$

where, σ_1 is the standard deviation of the truncated Gaussian kernel, which is used to compute the local intensity means of the image. By the calculus of variations [1], the Gateaux derivative (first variation) of the functional $E_{g,spf}(\phi)$ in (1) can be written as:

$$\frac{\partial\phi(x)}{\partial t} = \lambda\delta_\epsilon(\phi(x))div\left(g(I(x)).\frac{\nabla\phi(x)}{|\nabla\phi(x)|}\right) + v(K_{\sigma_2} * spf(I(x)))\delta_\epsilon(\phi(x)). \tag{10}$$

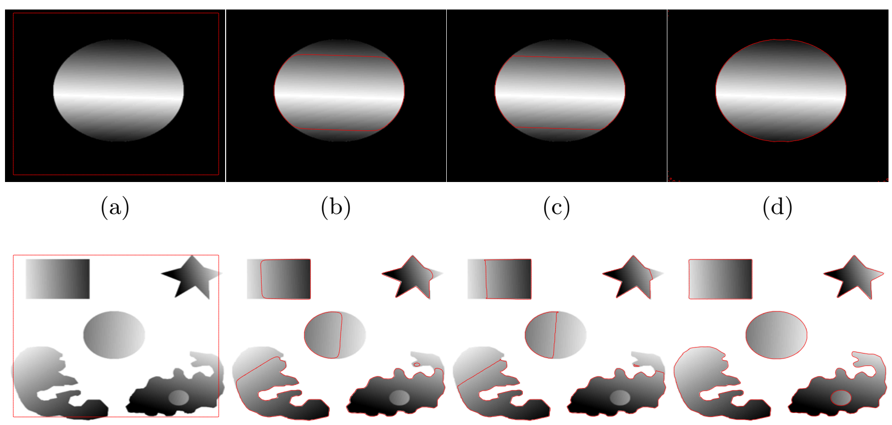
The function ϕ that minimizes the above energy functional satisfies the Euler Lagrange equation $-\frac{\partial E_{g,spf}}{\partial\phi} = 0$. A signed distance function (SDF) defined below, is used for the initialization of the level set function.

$$\phi_0(x) = \begin{cases} -\rho, & x \in \Omega_0 - \partial\Omega_0 \\ 0, & x \in \partial\Omega_0 \\ \rho, & x \in \partial\Omega - \Omega_0. \end{cases} \tag{11}$$

where, $\rho > 0$ is a constant and we used $\rho = 1$. After evolving the level set using (10) we regularize it by using $\phi^k = G_{\sigma_2} * \phi^k$. It not only regularizes the level set function but also eliminates the need of re-initialization, which is computationally very expensive. Here, σ_2 is the standard deviation of the Gaussian kernel used in the regularization process.

3 Results and Comparison

In this section we compared the segmentation results with the other state-of-the-art active contour methods, which use traditional SPF function in their model. Figure 1(a),(e) show initial contours, figure 1(b),(f) show the final contour using Jiang et al. method [5], figure 1(c),(g) show the final contour using Zhang et al. method [10], while figure 1(d),(h) show the final contour using the proposed method. Figure 1, shows that both Zhang et al. and Jiang et al methods, which use traditional SPF function in their models could not properly segment synthetic images used in the experiment. While, the proposed method by using new SPF function, which contains both local and global means of image, accurately segmented inhomogeneous regions in the synthetic images.



(a) (b) (c) (d)

(e) (f) (g) (h)

Fig. 1: Segmentation comparison using intensity inhomogeneous synthetic images

4 Conclusion

This paper presents a hybrid active contour method in the context of intensity inhomogeneity, which utilizes both edge-based and region-based information. In order to deal with the intensity inhomogeneity problem this paper presents a new SPF function, which is built by using both local and global means of the image. Moreover, a Gaussian kernel is used to regularize the level set function, which also contributes in reducing the time complexity of the proposed method by removing the computationally expensive re-initialization. The result comparison with the state-of-the-art active contour methods, which use traditional SPF function, shows that the proposed method provides better segmentation. It properly segmented images with intensity inhomogeneity, while the state-of-the-art active contour methods failed to do so.

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References

[1] G. Aubert and P. Kornprobst. Mathematical Problems in Image Processing: Partial Differential Equations and the Calculus of Variations. *Springer, New York.*, 2002.

[2] T. F. Chan and L. A. Vese. Active contours without edges. *IEEE Transactions on Image Processing.*, 10(2):266–277, 2001.

[3] L. Chunming, X. Chenyang, G. Changfeng and M. D. Fox. Level set evolution without re-initialization: a new variational formulation. *Proc. IEEE Conference on Computer Vision and Pattern Recognition*, 430–436, 2005.

[4] A. Elnakib, G. Gimel, J. J. Suri, A. El-baz and G. Gimelfarb. Medical image segmentation: A brief survey. *Multi Modality State-of-the-Art Medical Image Segmentation and Registration Methodologies.*, Springer, New York, 1–39, 2011.

[5] H. Jiang, R. Feng and X. Gao. Level Set Based on Signed Pressure Force Function and Its Application in Liver Image Segmentation. *Wuhan University Journal of Natural Sciences.*, 16(3):265–270, 2011.

[6] M. Kass, A. Witkin and D. Terzopoulos. Snakes: Active contour models. *International Journal of Computer Vision.*, 1(4):321–331, 1988.

[7] C. Li, C. Y. Kao, J. C. Gore and Z. Ding. Implicit active contours driven by local binary fitting energy. *Proc. IEEE Conference on Computer Vision and Pattern Recognition*, 1–7, 2007.

[8] C. Li, C. Y. Kao, J. C. Gore and Z. Ding. Minimization of region-scalable fitting energy for image segmentation. *IEEE Transactions on Image Processing.*, 17(10):1940–1949, 2008.

[9] H. Zhang, J. E. Fritts and S. A. Goldman. Image segmentation evaluation: A survey of unsupervised methods. *Computer Vision and Image Understanding.*, 110(2):260–280, 2008.

[10] K. Zhang, L. Zhang, H. Song and W. Zhou. Active contours with selective local or global segmentation: A new formulation and level set method. *Image Vision and Computing.*, 28(4):668–676, 2010.

Automatic Understanding of Human Activities through Video

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1 Introduction

Nowadays, videos are an indispensable part of our life. In 2013, more than 100 hours of video were uploaded to YouTube every minute. In addition, more than 1 billion people come to YouTube to access news, answer questions and have a little fun, every month. Adding the movies and TV series which are recorded in studios, there is a quickly growing huge database of videos in the Internet.

From security perspective, surveillance cameras are widely used in different places. For example, it is estimated that there are 5.9 million closed-circuit cameras in England from which 750,000 are mounted in sensitive locations such as schools, hospitals and airports. According to another report, there are approximately 30 million surveillance cameras in the United States which are recoding about 700,000 hours of video every day.

In an another scenario, there are 1826 football matches in total in top five European football leagues. Adding other football leagues and popular sports such as volleyball, basketball, cricket, hokey and tennis to this list, there are plenty of sport videos recorded every day worldwide.

Humans plays an important role in the all above applications. More precisely, about 34 percent of the pixels in a movie belongs to humans. On the other hand, videos give us important information. For example, assume a human expert who is monitoring people in the airport. At a given moment, the expert identifies that a person abandoned a bag on the ground after doing some works on it. Clearly, this is not a normal *activity* in an airport. There are some important technical details in this hypothetical example. First, the expert identifies a person and track him/her in the video stream. He also recognizes an object (bag) which is carried by the person. Then, the person does something on the object and puts it on the ground. Finally, he leaves the object and walks away from it.

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Using this definition, the above activity can be decomposed into different *actions* (walking, bending, putting down and standing up) and *human-object interactions* (carrying and doing something on the bag). The temporal relations between the actions and human-object interactions define this unusual activity. This is a type of activity recognition in the on-line stream of videos.

In an another scenario, we may need to mine some specific activities from a huge database of videos. For example, suppose we are interested in finding those videos in which two people are dancing in a mall. Here, we first need to recognize the frames of the videos that are indicating a mall and then try to find whether or not there is a dancing action in these video sequences. Dancing is a very complex activity since it needs different actions to happen concurrently or consecutively. On the other hand, “mall”is one of the scenes among hundreds of different scenes that can be found in a video.

Obviously, it is impossible for a user to manually mine the specific activities from a tremendous amount of on-line or off-line video streams. With the advent of new technologies, it is possible to develop an intelligent system for this purpose. The ultimate goal of a human activity detection and prediction system is to identify the parts of the videos which include some specific activities. While there are some impressive results on the video taken from “lab-setting”environments, they are still far away in realistic conditions (“in the wild”setting). The most recent studies [4][5] show approximately 55% accuracy on realistic videos collected from Hollywood movies.

Inter-class variability (every person does the same action in different ways) and intra-class similarity (two different actions such as smoking and drinking are similar) make this problem more complicated. Moreover, even if we ignore the two aforementioned issues, there are some other challenging problems which need to be tackled. Among them are cluttered background, lightening, camera motion and view point, occlusions and context.

Recently, with the introduction of cheap 3D capture devices such as Microsoft Kinect, it is possible to perceive not only the RGB information of the scene but also the depth of every pixel in the image. Furthermore, the uptake of 3D display technology in the homes and cinemas has prompted television networks and movie studios to begin the broadcast of 3D programs and to produce commercially available 3D movies. Using the 3D information, it is possible to segment out the clutter background and also deal with the camera view.

2 Methodology

In this study, our aim is to detect and predict the ongoing activities from video streams. Here, we follow three different lines. In the first line, we utilize RGB-D (color and depth) information to detect and track the human body parts (*e.g.* head, arms, legs and shoulders) in 3D space. Then, using the tracking information, our aim is to model the human activities using pattern recognition techniques. Having different models for human activities, it is possible to detect unusual activities from the video chunks. However, activities such as smoking and drinking can not be distinguished using only the 3D location of the joints. In this case, the RGB information will help us to model the appearance of the cup and the cigarette so the system can discriminate them and consequently, it will be able to distinguish the smoking action from the drinking action. Figure 1 illustrates some frames of different actions and their corresponding 3D map.

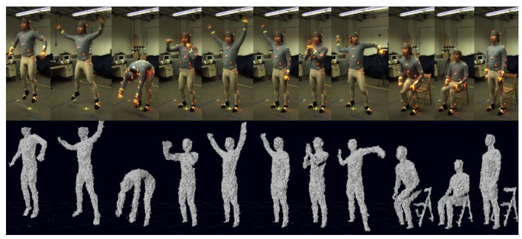

Fig. 1: 3D human action recognition [8]

From another perspective, an action is an abstract definition. While only the kicking of a person can be thought as fighting, the punching also can illustrate a fight. In addition, kicking and punching together are a sign of a fight. Firm push, hold and pull sub-actions are also signs of fighting. There are also other scenarios in which all of them can be thought as fighting action. Methods that try to model the actions using only the data are called data-driven techniques. If the data covers the whole feature space, the data-driven techniques will work accurately. In contrast, without enough data, the feature space is not covered and consequently the trained model will not be generalized adequately.

On the other hand, annotating the training videos is a time consuming task and for this reason, it is not trivial to collect all possible scenarios for one action. In the second line of our research, we will try to learn the semantics of each action and build a knowledge-base using these semantics. Then, given the input video sequence the possible semantics can be extracted and using them the actions can be inferred.

Last not the least, our final goal is to model the long term activities of human. For example, *stealing* is a long term activity. Assuming that only two people (the cashier and the thief) are involved in this activity, the first objective is to recognize the thief from cashier by their actions. For example, the thief may force the cashier to open the cash register by pointing a gun toward him. After identifying the thief and the cashier, the system will take into account their interactions with the objects and each other to predict the future actions. This high level description of “stealing”activity may take more than 30 seconds which can be considered as a long-term activity.

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References

[1] J.K. Aggarwal, M.S. Ryoo. Human activity analysis: A review. *ACM Computing Surveys*, 43:1–43, 2011.

[2] L. Chen, H. Wei, J. Ferryman. A survey of human motion analysis using depth imagery. *Pattern Recognition Letters*, 34:1995-2006, 2013.

[3] S. Hadfield, R. Bowden. Hollywood 3D: Recognizing Actions in 3D Natural Scenes. *IEEE conference on Computer Vision and Pattern Recognition*, 3398–3405, 2013.

[4] H. Wang, A. Kläser, C. Schmid, C. Lin Lie. Dense Trajectories and motion boundary descriptors for action recognition. *International Journal of Computer Vision*, 103:60–79, 2013.

[5] H. Wang, A. Kläser, C. Schmid, C. Lin Lie. Action recognition by dense trajectories. *Proc. IEEE conference on Computer Vision and Pattern Recognition*, 3169–3176, Colorado, USA, 2011.

[6] C. Lu, J. Jia, Ch. Tang. Range-Sample Depth Feature for Action Recognition. *The IEEE Conference on Computer Vision and Pattern Recognition*, 2014.

[7] J. Luo, W. Wang, H. Qi. Group Sparsity and Geometry Constrained Dictionary Learning for Action Recognition from Depth Maps. *The IEEE International Conference on Computer Vision*, 1809–1816, 2013.

[8] F. Ofli, R. Chaudhry, G. Kurillo, R. Vidal, R. Bajcsy. Berkeley MHAD: A Comprehensive Multimodal Human Action Database. *In Proceedings of the IEEE Workshop on Applications on Computer Vision*, 53–60, 2013.

[9] R. Vemulapalli, F. Arrate, R, Chellappa. Human Action Recognition by Representing 3D Skeletons as Points in a Lie Group. *The IEEE Conference on Computer Vision and Pattern Recognition*, 2014.

[10] M. Zanfir, M. Leordeanu, C. Sminchisescu. The Moving Pose: An Efficient 3D Kinematics Descriptor for Low-Latency Action Recognition and Detection. *The IEEE International Conference on Computer Vision*, 2752–2759, 2013.

Large Scale Object Detection and Recognition

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1 Introduction

Humans are inherently able to analyze the scene and take appropriate actions based on these analyses. More precisely, a scene is formed by collection of different objects. For instance, we may find objects such as chair, table, stationery, laptop and etc. in an office. The major goal of object detection is to find a specific class of the object (*e.g.*, a chair) in the given image. Furthermore, we may want to recognize the type of the detected object. For example, the rocky chair and the office chair are both a chair. However, they are different types of chair. The task of object recognition is to determine if the detected image of the chair is a rocky chair or office chair.

Automatic object detection and recognition plays an important role in our life. Face Detection and Pedestrian detection are two well-known areas in object detection. Nowadays, digital cameras and cellphones use face detection techniques for localizing the faces in the frames of video. The detected face region is used for adjusting the lens of the camera to achieve the best focus. Also, object detection and recognition has been used in lip reading and head pose estimation problems. In this case, the intelligent system detects the face region and then it detects the lips in this region.

Recently, the cars have been equipped with Advanced Driver Assistance Systems (ADAS) to increase driver's safety. In the cluttered scenes, for example, there might be many cars, trees and pedestrians. The ADAS system must be able to detect them to avoid collisions.

Medical image analysis is another field which utilizes the object detection and recognition methods. In computer aided detection systems the major goal is to find the abnormal regions. For example, the breast cancer can be detected in mammograms, MRI and ultrasound images. Here, the cancer is the object that needs to be detected. However, the cancer is not the only abnormal region in the breast and other regions such as micro-calcifications, macro-calcifications and cysts are considered as abnormal regions. According

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to this definition, the problem of breast cancer detection can be cast as an object recognition task. While the object detection system tries to identify all unusual regions, the object recognition system tries to distinguish between cancerous and non-cancerous regions. Figure 1 shows these applications.

Fig. 1: Applications of object detection and recognition in digital cameras (left), driver assistant systems (middle) and medical images (right).

From security perspective, object detection and tracking is the main part of the video surveillance systems. For instance, to detect any unusual activity, we need to identify the humans, cars and animals. Finally, by tracking the detected objects in the video sequence we can analyse the activity. In overall, for any tracking problem we use the object detection algorithms.

On the other hand, robotic manipulators need to grasp a specific object using their end-effector. This problem is called visual servoing. For moving the manipulator, we first need to detect the object and estimate its posture. Then, the manipulator will be guided toward the object by using an open-loop or a closed-loop control methods. For example, suppose that there are different kinds of objects on the table and the manipulator should take the glass and put it in the box. To this end, the computer vision system must detect the table as well as the all other objects on it. Next, the system recognizes the glass among other objects. Finally, using the control methods, the manipulator moves toward the glass and grabs it. In the second phase, the system detects the box and then, the manipulator puts the glass inside the box.

Another important application of object detection is in the field of rescue robotic. The rescue robots are used for rescuing the trapped and hurt human in natural disasters or accidents. In this scenario, the system detects many objects from surrounding environment. For example, in an earthquake disaster, there are damaged buildings and cars, lots of accessories and injured people in the environment. Clearly, the robot has to detect the injured humans among the objects. There are many challenges in this problem such as different point of view, occlusion and cluttered background. For example, suppose that only one hand of the injured person is visible for the robot. However, it is not guaranteed that the robot will perceive the image of the hand from a fixed perspective. For instance, the system can see the hand from above view or side of the hand. The occlusion problem happens when some part of the object is obscured by other objects. For example, the hand can be occluded by wreckages. However, the system must be able to detect the occluded hand.

Another application of object detection is in analyzing the aerial images. The difference between this application with previous applications is the distinct perspectives which can affect the detection process. For example, there might be many buildings, cars, trees, etc., from above view in the aerial images. However, they all appear as 2D objects since the depth information is weakened in these type of images. For this reason, the method that is used for modeling the objects (*e.g.*, cars) in the aerial images is different from the ground images. Figure 2 illustrates some of these applications.

Fig. 2: Applications of object detection and recognition in visual servoing (left), rescue robot (middle) and aerial images (right).

There are two general approaches for solving the object detection problem namely *3D geometry* and *data-driven*. The former approach assumes only the 3D structure of the object. The theory behind this approach is that humans interpret the objects using their 3D skeleton. Assuming this, the object detection system learns the 3D geometry of the object during the training phase by creating new structures after applying different affine transformations and deformations to the basic 3D structure. In contrast, the basic idea behind the second approach is that we have a large collection of the images from the object-of-interest under different lightening and transformations. Using this dataset, it is possible to build a model for the object. The advantage of the first approach is that it does not need a large collection of datasets. As it is clear, the only problem with the second approach is the data collection process. Another advantage of the data-driven approach over the 3D geometry approach is that beside the appearance of the object, it also learns the geometry of the object implicitly.

2 Methodology

Our aim is to work on large scale object detection problem. We follow the data-driven approach and we combine both qualitative and quantitative features to achieve our goal. One of the important clues in object detection problem is the *context*. For example, we can not expect to see a truck in an office. Also, it is not normal to see a chair in a highway. In other words, the context "office"provides us a priori knowledge about the presence of objects in this context.

One of the successful methods for detecting the context is bag-of-features model. This model has been originally used for modeling the text documents. However, it can also be used for modeling the context. In this method, a dictionary of features is created using unsupervised learning methods. Using the dictionary, a histogram of atoms of the input image is computed. Finally, the obtained histogram is matched with the examples in the dataset to determine the context of the image.

While most of the works in literature consider a small number of classes, our goal is to propose a method for large scale databases. Methods such as *Support Vector Machines* are naturally binary classifiers. To have a multi-classifier, methods such as one-against-all or one-against-one are usually used. However, these methods have their own problems and in a highly non-linear space they can decrease the accuracy. To solve this problem, we create a taxonomy of classifiers. Using this approach, we start with a high-level classification and eventually divide the problem into smaller classification problems.

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References

[1] A. Andreopoulos, J. K. Tsotsos. 50 Years of object recognition: Directions forward. *Computer Vision and Image Understanding*, 8:827-891, 2013.

[2] T. Barbu. Pedestrian detection and tracking using temporal differencing and HOG features. *Computers & Electrical Engineering*, 40:1072-1079, 2014.

[3] S. Lazebnik, C. Schmid, J. Ponce. Beyond Bags of Features: Spatial Pyramid Matching for Recognizing Natural Scene Categories. *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 2169-2178, 2006.

[4] N. A. Mandellos, I. Keramitsoglou, C. T. Kiranoudis. A background subtraction algorithm for detecting and tracking vehicles. *Expert Systems with Applications*, 38:16191631, 2011.

[5] G. Silveira. On intensity-based 3D visual servoing. *Robotics and Autonomous Systems*, 2014.

[6] J. Yan, X. Zhang, Z. Lei, S.Z. Li. Face detection by structural models. *Image and Vision Computing*, 2013.

[7] R. Zhang , J. Ding . Object Tracking and Detecting Based on Adaptive Background Subtraction. *Procedia Engineering*, 29:1351-1355, 2012.

Image Retrieval and Classification Through Object Recognition

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Abstract
In image classification, an image is classified according to its visual content. An important application is image retrieval (i.e., searching through an image dataset to obtain those images with a particular visual content). In this paper, we propose a method for image retrieval and classification using Bag of Visual Words (BofVW). The proposed strategy is based on object recognition by means of structural feature vectors. Those vectors consist of SIFT features computed on a regular grid across the image (dense SIFT) and vector quantized into visual words. The classifier is a linear Support Vector Machine (SVM). Experiments demonstrate that image retrieval and classification using BofVW yields high-accuracy scores in object recognition and classification.

1 Introduction

Object recognition or classification is one of the most active topics in the computer vision research community. Object recognition/classification task is more or less obvious according to the visual scene complexity, and the object to find. It is indeed easier to find an object in a controlled environment than in a natural scene. Furthermore, in a real-life visual scene, objects can be numerous and located in the foreground, and also in the background. The object recognition task is often dependent on the global semantic interpretation task. One do not seek to recognize all objects in a visual scene, but only those which are of interest for him.

Content-based image retrieval is a key technique for improving object recognition or classification. The most effective approaches currently used are based on a vocabulary of local patches, called visual dictionaries [1]. Visual dictionary representations take images as bags of local appearances. That model has several important advantages, such as compactness (it encodes

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local properties into a single feature vector) and invariance to image/scene transformations.

Creating a visual dictionary takes several steps. First and foremost, local characteristics must be obtained from a set of training images, usually by extracting local patches and describing them. The patches may be taken around points of interest [2] or by dense sampling [3], and image descriptors, such as SIFT [4], are used to extract feature vectors for each of them. Once the learning set of feature vectors is obtained, they are used to quantize the feature space (using, for example, k-means clustering) to choose a visual word of feature vectors representative of the training set. The clusters tend to contain visually similar patches and each cluster is a visual word of the bag. Once the bag of visual words is available, images are represented by statistical information about how they activate the visual words. The final image feature vector is commonly called bag of (visual) words(BoW).

Special attention has been given to the lack of geometrical information encoded by the traditional BoW representation [5,13]. The spatial arrangement of visual words in images is important to understand image semantics and is often crucial to distinguish different classes of scenes or objects. In that direction, approaches are proposed for image classification [10,9] and retrieval [8,11,12,13]. In the classification scenario, usually relied on Support Vector Machines (SVM), the high dimensionality of vectors does not degrade effectiveness, because SVMs suffer less from the curse of the dimensionality.

In this paper we present an image retrieval and classification method based on Bag of Visual Words (BofVW) through object recognition, by using feature vectors computed on the image.

2 Background

The most popular and effective approach to represent visual content nowadays is based on visual dictionaries, which generate the BoW representation [1]. One of the benefits of using such a representation is its ability to encode local properties into a single feature vector per image. To generate a BoW representation, one must first create the visual dictionary. Image local features, usually obtained by SIFT descriptor [4] computed on the detected points of interest [2], or in a dense grid [3], are clustered in the feature space. Each cluster represents a visual word and tends to contain patches with similar appearance.

Several recent works in the area present interesting advances for creating better dictionaries and better coding techniques. However, many of the recent advances built over the visual dictionary model relies on encoding geometrical information of visual words. Researchers faced the problem of having many different images with identical or very similar color histograms, motivating the creation of new methods for encoding the spatial arrangement of colors, like, for example by using color correlograms or color-coherence vectors [5]. This issue is being revisited nowadays with the visual dictionary model, for discriminating image content and encoding image semantics. Consider the images shown in Fig.1. They have different semantics but their BoW representations are very similar.

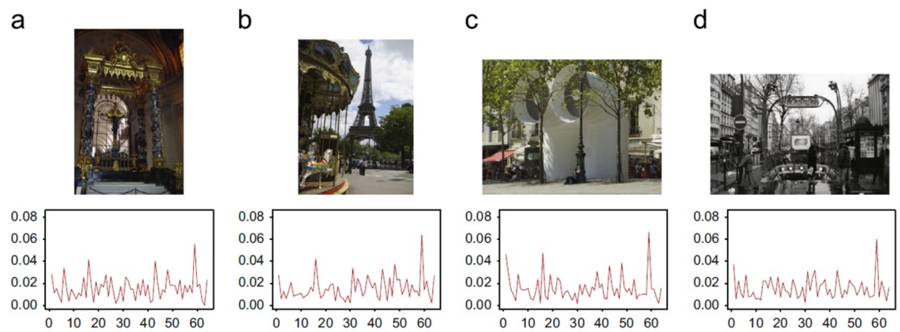

Fig. 1: Examples of images with different semantics but similar BoW. This figure is partially a reprint from [5].

Graph-based approachs have been used to represent object relations within images. The main motivation for that relies on their invariance to transformations like rotation and translation. From an image collection, firstly, it is necessary to detect all the interest points and, then, cluster the descriptors of the interest points in the feature space. Afterwards, a set of connected graphs is defined in order to generate the visual-word dictionary from the prototypes of the clusters. Using this dictionary we can represent the image, and encode the spatial relationships of visual words. The process to generate the Bags of Visual Graphs descriptor of an image uses the graph-based dictionary to retrieve objects of the image.

3 Proposed Image Retrieval and Classification Method

This section details the proposed method for image retrieval and classification using Bag of Visual Words (BofVW) through the object recognition task in the image, using feature vectors. The structural feature vector consists of SIFT features computed on a regular grid across the image ("dense SIFT") and vector quantized into visual words. The classifier is based on a linear Support Vector Machine (SVM). In image classification, an image is classified according to its visual content. An important application is image retrieval, which consists of searching through an image dataset to obtain (or retrieve) those images with a particular visual content.

The stages of the proposed method are next summarized:

- Stage A: Data Preparation.
  The data consists of various image classes and pre-computed feature vectors for each image. The feature vector consists of SIFT features computed on a regular grid across the image ("dense SIFT") and vector quantized into visual words. This process is summarized in Fig.2:

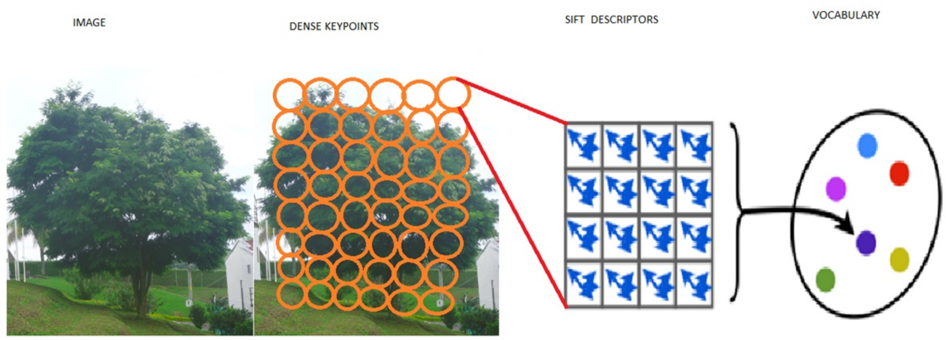

Fig. 2: Data preparation process.

- Stage B: Training the classifier.
  The classifier is a linear Support Vector Machine. We will first assess qualitatively how well the classifier works by using it to rank all the training images.
- Stage C: Classify the test images and assess the performance.
  The trained classifier is applied to the test images. Again, the qualitative performance is analyzed by using the classifier score to rank all the test images.
- Stage D: Train a classifier for each one of the available classes and assess its performance.
  Repeat stages (B) and (C) for each of the classes.

References

[1] J. Sivic, A. Zisserman. Video google : a text retrieval approach to object matching in videos. *in: International Conference on Computer Vision, vol. 2, 2003, pp.14701477.*

[2] K. Mikolajczyk, T.Tuytelaars, C.Schmid, A.Zisserman, J.Matas, F.Schaffalitzky, T.Kadir, L.Gool. A comparison of affine region detectors. *International Journal of Computer Vision 65(2005)4372..*

[3] K.E.A. vande Sande, T. Gevers, C. G. M. Snoek. Evaluating color descriptors for object and scene recognition. *Transactions on Pattern Analysis and Machine Intelligence32(9)(2010)15821596.*

[4] D.G. Lowe Distinctive image features from scale-invariant keypoints. *International Journal of Computer Vision 60(2)(2004)91110.*

[5] Fernanda B. Silva, Siome Goldenstein, Salvatore Tabbone, and Ricardo da S. Torres. Visual Word spatial arrangement for image retrieval and classification.. *IEEE trans. Image Processing.*

Privacy-preserving recommender systems for e-commerce & health services

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1 Introduction

Recommender systems [6] evolve from the field of knowledge discovery in databases (KDD) [7]. Systems for KDD are used by companies to discover understandable patterns within large collections of data, which might help, for example, to save money, make better strategic decisions or sell more products. Collaborative Filtering (CF) [4] is a recommender system that comprises a large family of recommendation methods. The aim of CF is to make suggestions on a set of items (I) (*e.g.* books, music, films, monuments or routes), based on the preferences of a set of users (U) that have already acquired and/or rated some of those items.

In order to make recommendations (*i.e.* to predict whether an item would please a given user) CF methods rely on large databases[2] with information regarding the relationships between sets of users and items. These data take the form of matrices composed by n users and m items, and each matrix cell (i, j) stores the evaluation of user i on item j. The recommendations provided by CF methods are based on the assumption that similar users will be interested in the same items. As a result, items well rated by a user u_a could be recommended to another user u_b, if u_a and u_b are similar.

CF methods are classified into three main categories that depend on the data they use as follows: (i) memory-based methods, which use the full matrix with the users' ratings, (ii) model-based methods, which use statistical models and functions of the data matrix but not the data matrix itself, and (iii) hybrid methods, which combine the previous methods with content-based [8] recommendation methods.

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[2] There are many examples of CF databases [8] referenced in the literature, like Eachmovie, MovieLens, Jester, and Netflix prize data. These databases are frequently used as benchmarks to evaluate the efficiency, quality and robustness of CF methods [5].

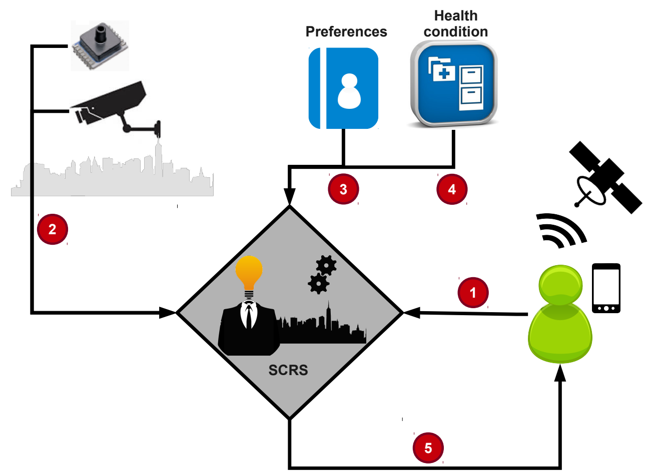

Fig. 1: General scheme and basic operation of a s-health recommender system.

2 Recommender Systems and Smart Health

Nowadays, great efforts are being devoted to build the cities of the future (*i.e.* Smart cities), which will be equipped with full of sensors and actuators (*e.g.* temperature and humidity sensors, pollution and allergens sensors, luminosity sensors or crowds detectors) that would improve the citizens' quality of life. Moreover, the healthcare sector has turned into them to create a powerful symbiosis and create smart health [1] (s-health), which is defined as *the provision of health services by using the context-aware network and sensing infrastructure of smart cities*. Therefore, considering such definition, any application/service that uses the smart city infrastructure to provide healthcare or to promote healthy habits amongst the city population could be considered a smart health application. Hence, great opportunities emerge to consolidate the concept of s-health, for instance, the creation of systems that benefit from this concept and augment it with other powerful well-known information filtering systems such as recommender systems.

It is well-known that many citizens perform physical activities in the city, namely cycling, jogging, running, etc. With the aim to promote these healthy habits, it would be desirable to count with a system that could dynamically adapt to the needs and tastes of the citizens. Within this context, we propose a new way of using the sensing capabilities of smart cities by means of recommender systems that allow citizens/patients to obtain recommendations about the routes that better fit their capacities.

The system would consider real-time constraints and information from several sources: (i) citizens' preferences, (ii) citizens' health conditions and, (iii) real-time information provided by the smart city infrastructure.

An overview of the general scheme of our system architecture and its main actors is shown in Figure 1. Sensors provide real-time environmental information (*e.g.* luminosity, temperature, humidity, pollution) to the Smart City Recommender System (SCRS) through the communication infrastructure of the smart city. Upon the reception of citizen queries, the SCRS checks the health information of citizens and their preferences and cross them with the real-time information of the smart city sensors to finally compute real-time recommendations that are forwarded back to the citizens.

3 Privacy and Collaborative Filtering

The widespread use of CF on the Internet entails great opportunities for both companies and users in multiple contexts. However, the lack of privacy for the contributing users is a major drawback. The relevance of privacy in CF systems is emphasised by the growing pace at which information on each user is collected and stored. Careless management of personal information, apart from being illegal in many countries, has potentially serious consequences for both the users and businesses whose information is disclosed. One of the main problems in CF is that, if customers believe their preferences/profiles may be exposed, they might decide either not to give their assessment on a particular item or to give it incorrectly or inaccurately. Therefore, the feeling of poor privacy protection results in a reduction of the number and quality of evaluations.

Another drawback is that companies can acquire data about the preferences of many users in a given market, getting a big advantage over new competitors if they decide to expand into other markets. Therefore, user profiling through CF promotes in some sense monopolies. Another privacy-related drawback for users comes from the existence of large Internet quasi-monopolies, which massively gather users' preferences and may transfer them within their web of partnered companies in hardly traceable ways, leading to further user profiling.

Whilst privacy preserving CF methods obfuscate and/or hide information on user profiles, sometimes users wish to find other users having similar profiles and form a community. Indeed, communities are very usual in the network, but they can be a double-edged sword. On the one hand, users can conveniently obtain reliable recommendations on items from communities in a particular context. On the other hand, communities can generate a *value homophily* problem in the network, so that recommendations outside the context of the community would give results with little sense, precisely because of the homogeneity of the group.

Therefore, in order to solve the privacy issues raised by the systematic collection of private information on preferences, the Privacy Preserving Collaborative Filtering (PPCF) concept appears [2,3] with the aim to provide quality recommendations without compromising the privacy of users involved.

4 Conclusions and Future Work

Collaborative Filtering is a recommender system used to perform automatic recommendations to users in multiple contexts. Despite the great advantages of using CF, we have highlighted its downside regarding users' privacy, which is probably the most significant challenge to overcome.

Moreover, we have proposed the idea of using recommender systems integrated with the sensing infrastructure of smart cities to provide citizens with routes recommendations that take into account their health conditions and preferences. In addition, the recommendations could be adapted in real-time to the environmental changes of the city.

Future work will focus in the implementation of new PPCF methods that improve the results presented in [3], with the aim to achieve a better privacy/accuracy trade-off.

References

[1] A. Solanas, C. Patsakis, M. Conti, I. Vlachos, V. Ramos, F. Falcone, O. Postolache, P. Pérez-Martínez, R. Di Pietro, D. Perrea, and A. Martínez-Ballesté, Smart health: A context-aware health paradigm within smart cities. *IEEE Communications Magazine*, August. 2014 (In press).

[2] F. Casino, C. Patsakis, D. Puig, and A. Solanas, On privacy preserving collaborative filtering: Current trends, open problems, and new issues. *ICEBE*, pp. 244-249. (2013).

[3] F. Casino, J. Domingo-Ferrer, C. Patsakis, D. Puig, and A. Solanas, Privacy preserving collaborative filtering with k-anonymity through microaggregation. *ICEBE*, pp. 490-497. (2013).

[4] Goldberg, D., Nichols, D., Oki, B. M., Terry, D., *LaTeX User's Guide and Document Reference Manual. Communications of the ACM*, 35(12), 6170. (1992).

[5] Herlocker, J. L., Konstan, J. a., Terveen, L. G., Riedl, J. T., Evaluating collaborative filtering recommender systems. *ACM Transactions on Information Systems*, 22(1), 553. (2004).

[6] Resnick, P., Varian, H., Recommender systems *Communications of the ACM*, 40(3), 5658. (1997).

[7] Sarwar, B., Karypis, GeorgeKonstan., JRiedl, J., Using collaborative filtering to weave an information tapestry. *ACM WebKDD 2000 Web Mining for ECommerce Workshop*, 1625(1), 2648. (2000).

[8] Su, X., Khoshgoftaar, T. M., A Survey of Collaborative Filtering Techniques. *Advances in Artificial Intelligence*,(Section 3) 119. (2009).

Learning Edit Costs for Graph-Matching

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1 Introduction

Graphs refer to a collection of nodes and edges that connect pairs of nodes. Attributed Graphs are graphs in which some attributes are added on nodes and edges to represent local information or characterisation and have been widely used in several fields to represent objects composed of local parts and relations between these parts. More precisely, in Pattern Recognition and Computer Vision, attributed graphs have been used to represent structural objects that have to be identified or classified. These graphs can represent 2D or 3D objects, handwritten characters, proteins, fingerprints and so on [1], [2].

Attributes on the nodes and arcs represent unary and binary relations of local parts of the objects at hand. Before using graphs, the pattern recognition process has to extract them from these objects. This is not a trivial task included in the Image Understanding field since the quality of graphs is crucial for the rest of the process. When attributed graphs have been extracted, a process to compare them is needed, which is called graph matching. Usually, it obtains a similarity value and also a labelling between nodes and arcs of the involved graphs. This labelling between nodes and arcs represents the matching between the local parts that graphs represent. Several similarity measures or distance measures between a pair of attributed graphs have been presented in the literature [3] but probably the most well known distance is the graph edit distance [4] and [6].

The optimal labelling between graphs is going to be different depending on how we consider a node to be an outlier. How we gauge a penalty cost for a node or arc to be an outlier?

In this paper we want to present a method to automatically compute these costs.

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2 Graph Matching Problem

Graph Matching consist in finding the relations between component parts of two graphs. One of the most widely used methods for error-tolerant graph matching is the graph edit distance. The basic idea behind the graph edit distance is to define a dissimilarity measure between two graphs by the minimum amount of distortion required to transform one graph into the other [4], [7]. To this end, a number of distortion or edit operations ε, consisting of insertion, deletion and substitution of both nodes and edges must be defined. Then, for every pair of graphs (G and G), there exists a sequence of edit operations, or edit $path(G, G') = (\varepsilon_1, ..., \varepsilon_k)$ (where each ε_i denotes an edit operation) that transforms one graph into the other. In general, several edit paths may exist between two given graphs. This set of edit paths is denoted by $\vartheta(G, G')$. To quantitatively evaluate which is the best edit path, edit cost functions are introduced. The basic idea is to assign a penalty cost C to each edit operation according to the amount of distortion that it introduces in the transformation. The edit distance between two graphs G and G, denoted by $dist_{K_n,K_e}(G, G')$, is defined as the minimum cost of edit path that transforms one graph into the other given parameters K_n (cost of node insertion or deletion) and K_e (cost of edge insertion or deletion). Several edit paths may obtain the minimum cost. More formally, the edit distance is defined by,

$$dist_{K_n,K_e} = min_{(\varepsilon_1,...,\varepsilon_k)\in\vartheta(G,G')} \sum_{i=1}^{k} C(\varepsilon_i) \tag{1}$$

Optimal [8] and approximate algorithms [9], [10] for the graph edit distance computation have been presented so far. These algorithms obtain the distance value $dist(G, G')$ as well as a labelling y from vertices and arcs of the first graph to vertices and arcs of the second graph. Given any edit path $path(G, G')$, a labelling $y(G, G')$, can be defined univocally.

$$Cost_{K_n,K_e}(G, G', y) = \sum_{i=1}^{k} C(\varepsilon_i) \text{ being } y \text{ related to path } (G, G') = (\varepsilon_1, ..., \varepsilon_k) \tag{2}$$

3 Learning Graph Matching

Usually K_n and K_e are manually set at the validation process and little research has been carried out to automatically set them. Papers [11] and [12] have been presented related to automatically obtaining the weights of attributes. Its aim is to compute the weights such that a classification ratio is maximised whereas the aim of [13] is to compute the substitution weights such that the distance between the automatic obtained labelling and the oracles labelling is minimised. This paper presents a similar problem than the one in [13] but we estimate edit cost instead of substitution weights for the node attributes and it through a different optimisation function.

We approach the problem of learning the weights K_n and K_e for graph matching as a supervised learning problem. The training set is composed of N observations. Each observation is composed of a triplet composed of pair of graphs (G^n, G'^n) and an ideal matching matrix $\hat{y}^n$ (this matrix has to be seen as the ideal labelling provided by an oracle).

Note that the optimal matching matrix $\dot{y}^n_{(K_n,K_e)}$ given a pair of graphs (G^n, G'^n) depends on the weights K_n and K_e but nor it does the ideal matching matrix $\hat{y}^n$. For this reason, the aim of learning graph matching, we purpose, is to search for the weights K_n and K_e such that $\dot{y}^n_{(K_n,K_e)}$ tends to be as close as possible to $\hat{y}^n$ given the training set of the N pairs of graphs (G^n, G'^n) and the ideal set of matching matrices $\hat{y}^n$.

We propose the loss function called *Edit Cost Error*, $\Delta^C_{(K_n,K_e)}$. It gauges how far we are to obtain the cost generated by the ideal matching matrix.

$$\Delta^C_{(K_n,K_e)}(\hat{y}^n, \dot{y}^n_{(K_n,K_e)}) = (Cost_{K_n,K_e}(G^n, G'^n, \hat{y}^n) - Cost_{K_n,K_e}(G^n, G'^n, \dot{y}^n_{(K_n,K_e)}))^2 \quad (3)$$

To minimise equation 3 for K_n and K_e, we propose any quadratic programming algorithm. For instance, nelder-mead method [14].

4 Experimental Validation

Databases	*Initial Costs*			*Learned Costs*		
	K_n	K_e	Accuracy	K_n	K_e	Accuracy
BOAT	1	1	**0.0340**	0.0487	-0.0021	**0.7480**
	0.5	0.5	**0.0340**	0.0487	-0.0021	**0.7480**
	1	0	**0.0900**	0.0487	-0.0021	**0.7480**
	0	1	**0.0340**	0.0487	-0.0021	**0.7480**
EAST PARK	1	1	**0.0260**	0.0190	-0.0017	**0.8160**
	0.5	0.5	**0.0280**	0.0190	-0.0017	**0.8160**
	1	0	**0.0680**	0.0190	-0.0017	**0.8160**
	0	1	**0.0260**	0.0190	-0.0017	**0.8160**

Fig. 1: Accuracy results and learned costs.

The aim of our evaluation is to show the increase of accuracy when learned edit costs are used respect four different usual combinations of edit costs, defined as the average normalised number of nodes that have been correctly mapped: $1-(\sum_{i=1}^{N} d_H(\ddot{f}^i, \dot{f}^i))/(n \cdot N)$, n: number of nodes. We have used the public database called Tarragona Rotation Zoom database [15].

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References

[1] D. Conte, P. Foggia, C. Sansone, M. Vento Thirty Years Of Graph Matching In Pattern Recognition. *International Journal of Pattern Recognition and Artificial Intelligence*, Vol. 18, No. 3 pp: 265-298, 2004.

[2] F. Serratosa, X. Cortés, A. Solé-Ribalta Component Retrieval based on a Database of Graphs for Hand-Written Electronic-Scheme Digitalisation. *Expert Systems With Applications*, 40, pp: 2493-2502 , 2013.

[3] Raveaux, R., J.-C. Burie, and J.-M. Ogier A graph matching method and a graph matching distance based on subgraph assignments. *Pattern Recognition Letters*, 31(5): p. 394-406. 2010.

[4] Sanfeliu, A. and K.-S. Fu A Distance measure between attributed relational graphs for pattern recognition. *IEEE transactions on systems, man, and cybernetics*,13(3): p. 353-362. 1983.

[5] F. Serratosa, A. Solé-Ribalta, X. Cortés Automatic Learning of Edit Costs based on Interactive & Adaptive Graph Recognition. *Graph based Representations*,GbR2011, Munster, Germany, LNCS 6658 pp: 152,163. 2011.

[6] Gao, X, et al A survey of graph edit distance. *Pattern Analysis and applications*, 13(1): p. 113-129. 2010.

[7] Bunke, H., Allerman, G. Inexact graph matching for structural pattern recognition. *Pattern Recognition Letters*,13(3): 1(4), 245253. 1983.

[8] Llads, J., Mart, E., Villanueva, J.J. Symbol Recognition by Error-Tolerant Subgraph Matching between Region Adjacency Graphs. *IEEE Trans. Pattern Anal. Mach. Intell*,23(10), 11371143. 2001.

[9] Gold, S., Rangarajan, A. A Graduated Assignment Algorithm for Graph Matching. *IEEE TPAMI*,18(4), 377388. 1996.

[10] Francesc Serratosa Fast Computation of Bipartite Graph Matching. *Pattern Recognition Letters*, 45, pp: 244250. 2014.

[11] Michel Neuhaus, Horst Bunke Self-organizing maps for learning the edit costs in graph matching. *IEEE Trans. on Sys., Man, and Cybernetics*, Part B 35(3), pp. 503-514. 2005.

[12] Michel Neuhaus, Horst Bunke Automatic learning of cost functions for graph edit distance. *Inf. Sci*, 177(1), pp. 239-247. 2007.

[13] T. S. Caetano, J. J. McAuley, L. Cheng, Q. V. Le, A. J. Smola Learning Graph Matching. *IEEE Trans. Pattern Anal. Mach. Intell*, 177(1), pp. 239-247. 2009.

[14] J.A. Nelder and R. Mead A Simplex Method for Function Minimization. *Computer Journal*, vol 7, pp 308-313. 1965.

[15] http://deim.urv.cat/~francesc.serratosa/SW/

Consensus Based Methodologies for Image Labelling Using Optimisation Functions

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1 Definition

When two or more different strategies decide to solve the assignment problem (finding the labelling or mapping between two sets of elements), differences on the elements mapping may occur. These differences appear due to several factors. For example, one of the strategies gives more importance to some of the element attributes and the other strategy believes other ones are more important. Another factor that influences the elements mapping could be that the elements assignment problem is computed in a suboptimal algorithm, and different non-exact assignments can appear. Although a manual method [1] has been presented to improve the correspondences made by a single matching algorithm, for these cases, a consensus system could intervene as a third party to decide the final elements assignment when discrepancies appear, especially as the number of involved elements increase.

The aim of this work is to present a method to find an accurate consensus that represents the weighted mean labelling of two or more labellings. Assuming two given initial labellings f^a and f^b, the weighted mean condition of a consensus labelling $\bar{f}$ is defined [2] as the accomplishment of the following Hamming Distance [3].

$$d_H(f^a, f^b) = dH(f^a, \bar{f}) + dH(\bar{f}, f^b) \tag{1}$$

Another issue to deal with is that several labellings $\bar{f}$ hold this condition, and amongst them are f^a and f^b. To select the most proper consensus labelling $\bar{f}*$, an option would be a brute force method that obtains all possible combinations and selects the best one from the application point of view. Another option is a standard minimisation approach, to reduce the computational time. Therefore, if we want to find an optimal consensus labelling $\bar{f}*$ we define an empirical risk ∇(f) plus a regularization term Ω(f), weighted by parameters λH and λC respectively [4].

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$$\bar{f}* = argmin_{\forall f:\sum^1 \to \sum^2} \{\lambda_C \bigtriangledown (f) + \lambda_H \Omega(f)\} \quad (2)$$

This function is achieved by using optimisation methods such as the Hungarian Algorithm [5] or the Bipartite Graph Matching [6], which effectively convert the assignment problem into a minimisation problem.

2 Current Results

2.1 Databases

So far, we have been able to test our methodology in two datasets gathered by ourselves. [7]

a) Tarragona Palmprint: We used images contained in the Tsinghua 500 PPI Palmprint Database [8]. This is a public high-resolution palmprint database composed of 500 palmprint images of a resolution of 2040 x 2040 pixels. Eight different palmprint inks are enrolled from each person. We used the first 10 subjects of the database, therefore making our initial dataset composed of 80 palmprints from which we extracted its corresponding 80 minutiae sets using the algorithm presented in [9] and [10]. The average number of extracted minutiae is 1000 per palmprint. To create an oracle labelling, we used a method presented in [11] which is demonstrated to deliver a closely ideal result.

Fig. 1: Example of two inks of the same subject in the Tarragona Palmprint database.

b) Tarragona Exteriors: This database is composed of 5 sequences of images called 'BOAT', 'EAST_PARK', 'EAST_SOUTH', 'RESIDENCE' and 'ENSIMAG' [12]. 11 photos of the same scene are taken, with a different scale and position each. To create our dataset, first from each of the images, we extracted the 50 most reliable salient points using 5 methodologies: FAST, HARRIS, MINEIGEN, SURF (native Matlab 2013b libraries) and

SIFT (own library). To create oracle labellings between any two point sets from two different photos, we used a predefined homography estimation that converts the first image (img00) of the set into the other ones (img01 through img10).

Fig. 2: Example of two photos of the same scene in the Tarragona Exteriors database. A visual representation of the salient points (blue) is also shown, within a labelling represented as red and green lines connecting the two sets.

Both datasets include outlier points (points that must not be matched) which are indicated by a '-1' correspondence in the labelling where they were used.

2.2 Two-labelling consensus

We have successfully created a software that is able to, based on two initial labellings f^a and f^b, enounce a consensus result within a relatively low computational time ($\sim$ 5 seconds for a Tarragona Palmprint image match and $\sim$ 51 second for a Tarragona Exteriors image match). We have also been able to demonstrate that our method achieves a minimum cost as much as possible, as shown in Figure 3.

Fig. 3: Cost (y-axis) of a given $\bar{f}^*_{\lambda_C,\lambda_H}$ in a classical minimisation method (red), a pure consensus (purple) and our method (green) as the number of disagreements (x-axis) increases.

As shown in Figure 4, we are also able to proof that the consensus labelling $\bar{f}^*_{\lambda_C,\lambda_H}$ obtained in our method (green) is more likely to be a weighted mean than one obtained simply with a cost minimisation (red). A pure consensus (purple) will always be a weighted mean, but this doesnt necessarily mean it is the best result.

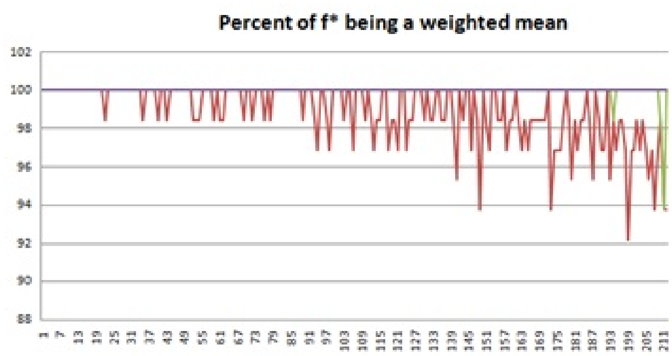

Fig. 4: Percentage of times (y-axis) a given $\bar{f}^*_{\lambda_C,\lambda_H}$ is a weighted mean in a classical minimisation method (red), a pure consensus (purple) and our method (green) as the number of disagreements (x-axis) increases.

This part of the methodology has been successfully submitted to the S+SSPR 2014 Congress to be held in Joensuu, Finland in August. [13]

3 Further Work and Pending Assignments

We have just finished working with more complex comparisons for two-labelling consensus, where we grade our system against more advanced methodologies, i.e. voting and intersection techniques. We also have developed tests that compare different extractors (in the case of the Tarragona Exteriors Database) and combine different features to improve the number of correct correspondences. The results have been submitted to the PAA journal and the results are yet to be announced.

Currently, our most intense work is dedicated to improve the system into a multiple-labelling consensus. This scenario is particularly difficult since, as seen in [14], generating a consensus in with multiple contributions rather than two requires special dedication in the number of variables used and the way we assign the resources. Also, we intend to include a quality factor for each of the multiple labellings participating in the consensus, thus adding extra complexity but improved results to our system.

We are especially interested in working with more datasets and finding application for our system in other study areas.

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References

[1] X. Cortés, Carlos Francisco Moreno-Garca & Francesc Serratosa. Improving the Correspondence Establishment based on Interactive Homography Estimation. Computer Analysis of Images and Patterns. CAIP2013, York, United Kingdom, LNCS 8048, pp: 457-465, 2013.

[2] Franek, F. Jiang, X. & He, C. Weighted Mean of a Pair of Clusterings. Pattern Analysis Applications. Springer-Verlag. 2012.

[3] Solé, A., Serratosa, F. & Sanfeliu, A. On the Graph Edit Distance cost: Properties and Applications. International Journal of Pattern Recognition and Artificial Intelligence. 26, (5). 2012.

[4] C. Papadimitriou and K. Steiglitz. Combinatorial Optimization: Algorithms and Complexity. Dover Publications. July 1998.

[5] Kuhn, H.W. The Hungarian method for the assignment problem Export. Naval Research Logistics Quarterly. 2(1-2), 8397. 1955.

[6] F. Serratosa. Fast Computation of Bipartite Graph Matching. Pattern Recognition Letters. Available online, 2014.

[7] http:deim.urv.catsimfrancesc.serratosadatabases

[8] Jain, A.K., Feng, J. Latent Palmprint Matching. IEEE Transactions on Pattern Analysis and Matching Intelligence, 2009.

[9] Dai, J. and Zhou, J. Multifeature-Based High-Resolution Palmprint Recognition. IEEE Trans. Pattern Analysis and Machine Intelligence. 33(5), pp: 945-957, 2011.

[10] Dai, J., Feng, J., Zhou, J. Robust and Efficient Ridge Based Palmprint Matching. IEEE Transactions on Pattern Analysis and Matching Intelligence. 34 (8), 2012.

[11] Ratha N.K., Karu K., Chen S., and Jain A.K. A Real-Time Matching System for Large Fingerprint Databases. IEEE Trans. on PAMI. 18 (8), pp. 799813, 1996.

[12] http:www.featurespace.org

[13] Carlos Francisco Moreno-García & Francesc Serratosa. Weighted Mean Assignment of a Pair of Correspondences using Optimisation functions. Syntactic and Structural Pattern Recognition. S+SPR2014, Finland.

[14] Franek, L., Jiang, X. Ensemble clustering by means of clustering embedding in vector space. Pattern Recognition. Volume 47, Issue 2, pp. 833-842. Elsevier. 2014.

This proceeding book contains the contributions presented at the 1st URV Doctoral workshop in Computer Science and Mathematics. The main aim of this workshop is to promote the dissemination of the ideas, methods and results that are developed by the students of our PhD program.

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