



BOOSTING HUMAN EXPERTISE WITH SUBGROUP DISCOVERY

Speakers. Adnene Belfodil & Aimene Belfodil

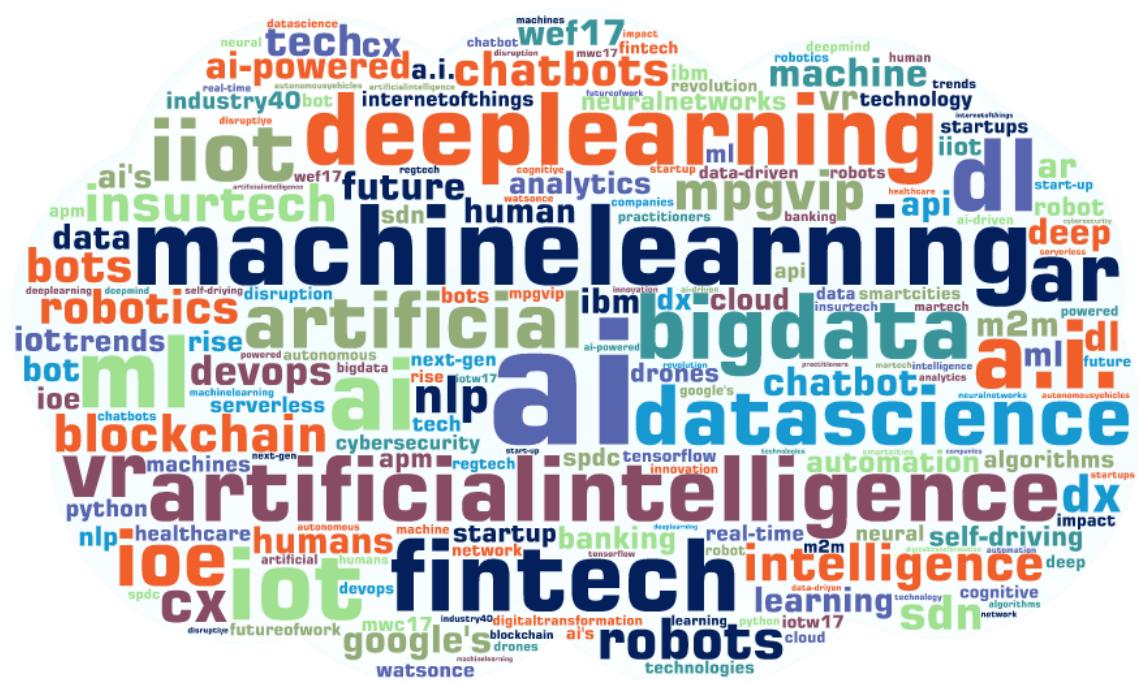


INTRODUCTION

ARTIFICIAL INTELLIGENCE AND KNOWLEDGE DISCOVERY

“AI [ed. Artificial Intelligence] currently encompasses a huge variety of subfields, ranging from the general (learning and perception) to the specific, such as playing chess, proving mathematical theorems, writing poetry, driving a car on a crowded street, and diagnosing diseases. AI is relevant to any intellectual task; it is truly a universal field.”

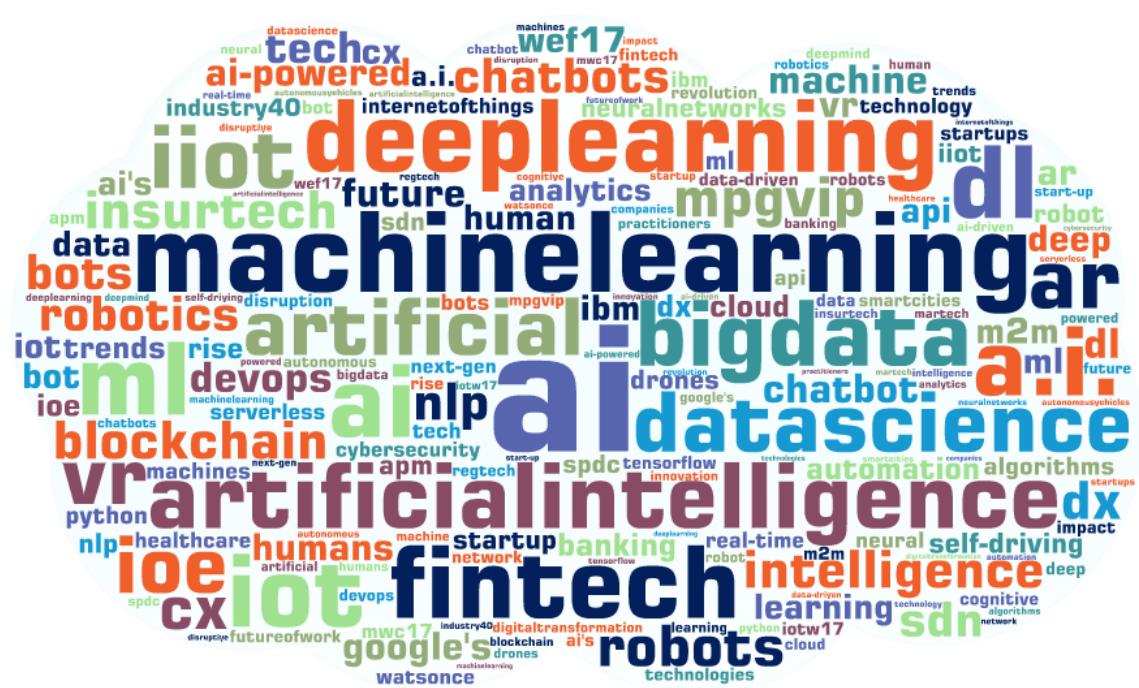
Stuart J. Russell and Peter Norvig. 2010
[*Artificial Intelligence A Modern Approach*]



<https://iiot-world.com/wp-content/uploads/2017/05/word-cloud.png>

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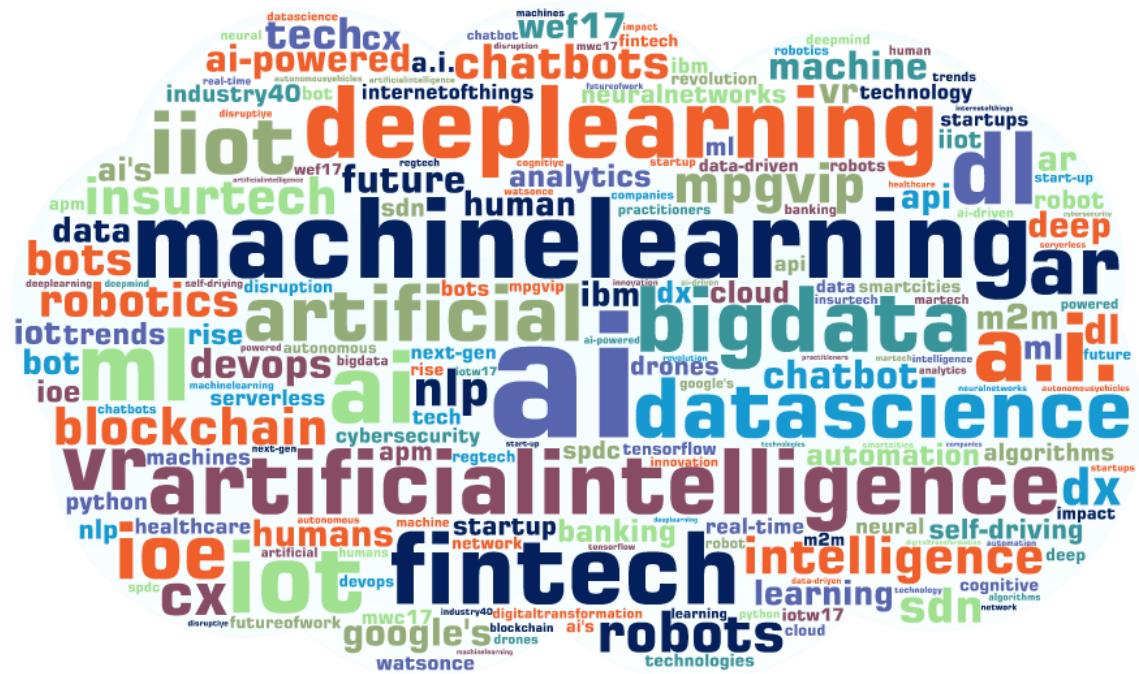
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Artificial Intelligence (AI) is an umbrella term that simply means making computers act intelligently. It refers to computer software that can reason and adapt based on sets of rules. AI technologies include, but are not limited to,

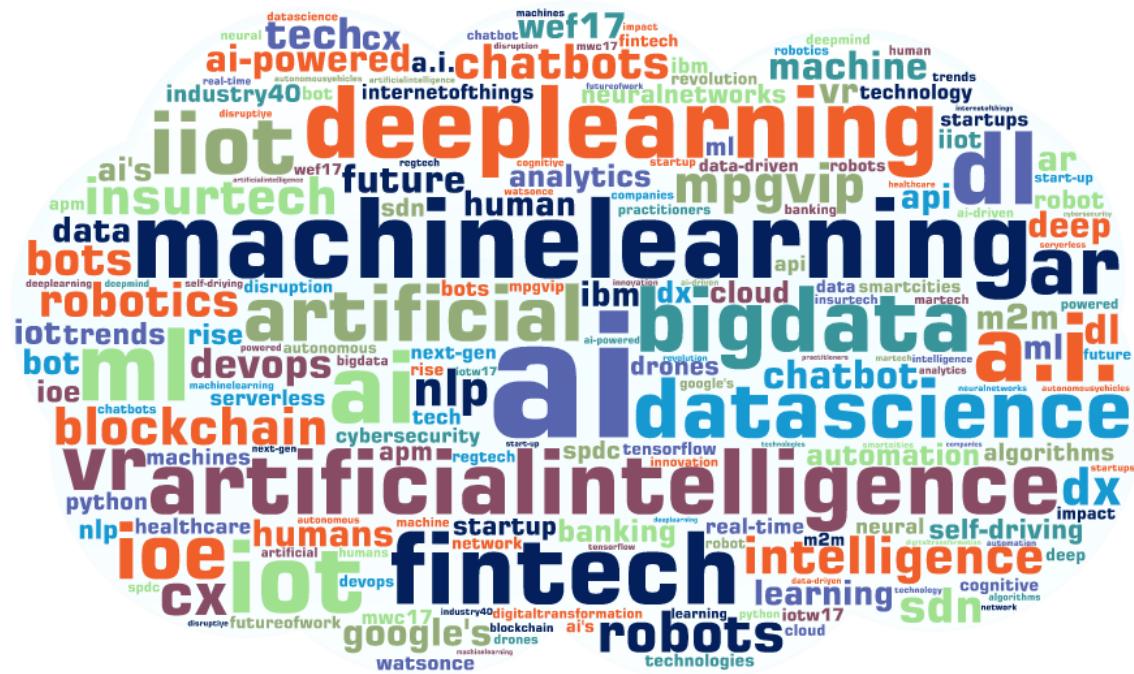
- NLP,
 - automated reasoning,
 - machine learning,
 - expert systems,
 - robotics,
 - computer vision,
 - multi-agent systems,
 - knowledge discovery.



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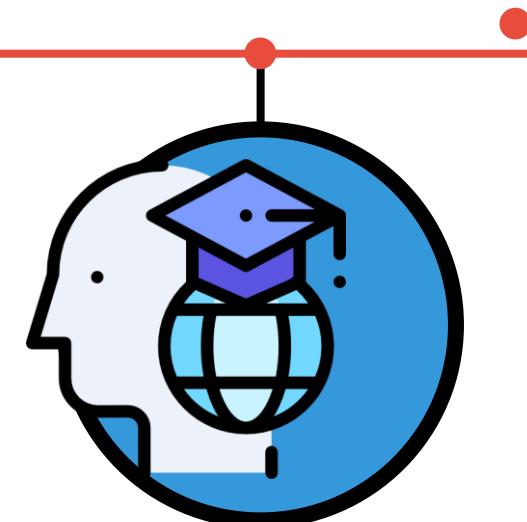
The ultimate purpose of the **Machine Learning** is automatization. i.e., to use a machine to **substitute human cognition**.

e.g.: for autonomously driving a car based on sensor inputs.

V.S.

In contrast, the purpose of **(exploratory) data analysis** is to use machine discoveries to **synergistically boost human expertise**.

e.g.: for understanding relationships between physicochemical properties of odorant molecules and their odors.



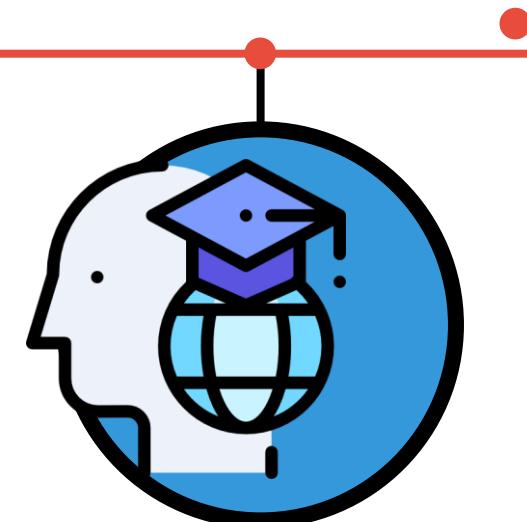
ed. Boley M. [realKD Blog, 2017]



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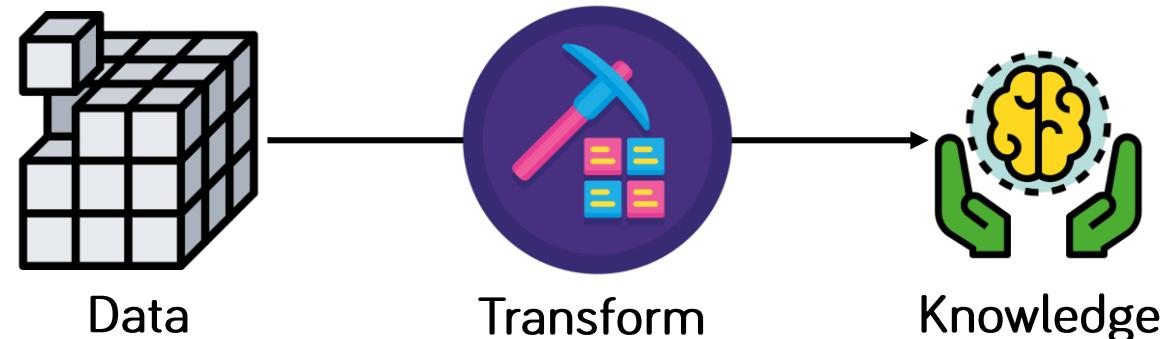
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Data Analysis: “Procedures for analyzing data, techniques for interpreting the results of such procedures, ways of planning the gathering of data to make its analysis easier, more precise or more accurate, and all the machinery and results of (mathematical) statistics which apply to analyzing data.”

Tukey, J.W. 1961

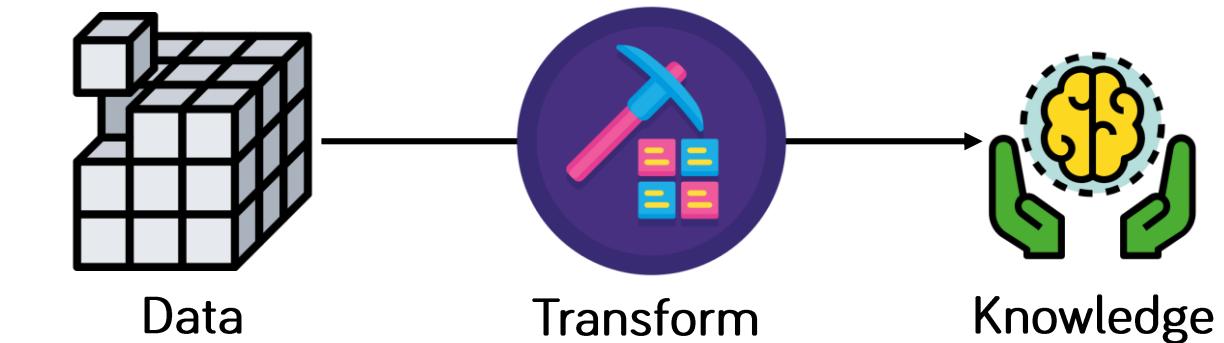


Knowledge Discovery in Databases: “The nontrivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data.”

Fayyad U., Piatetsky-Shapiro G., Smyth P. 1996

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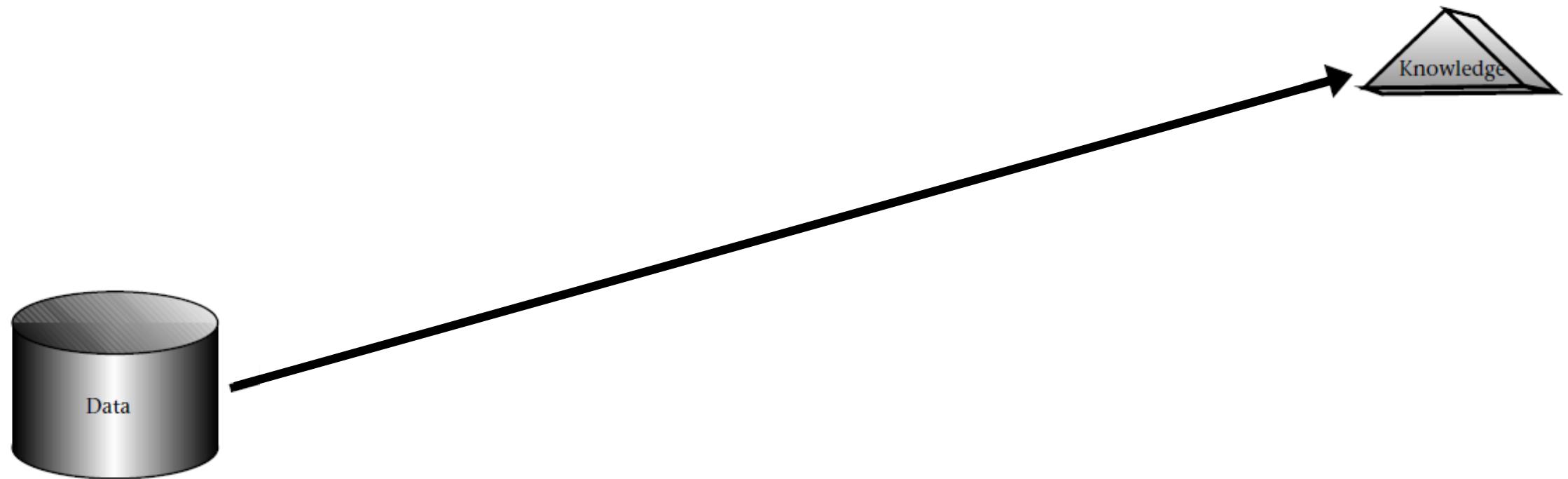
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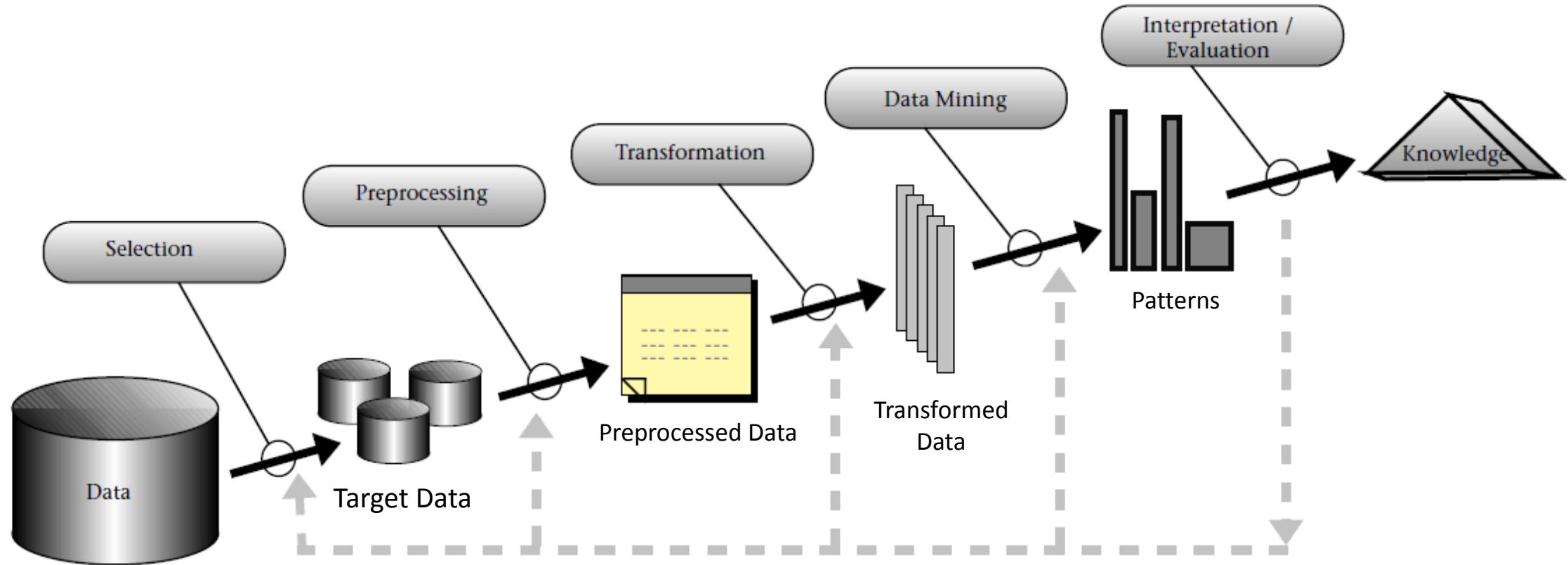
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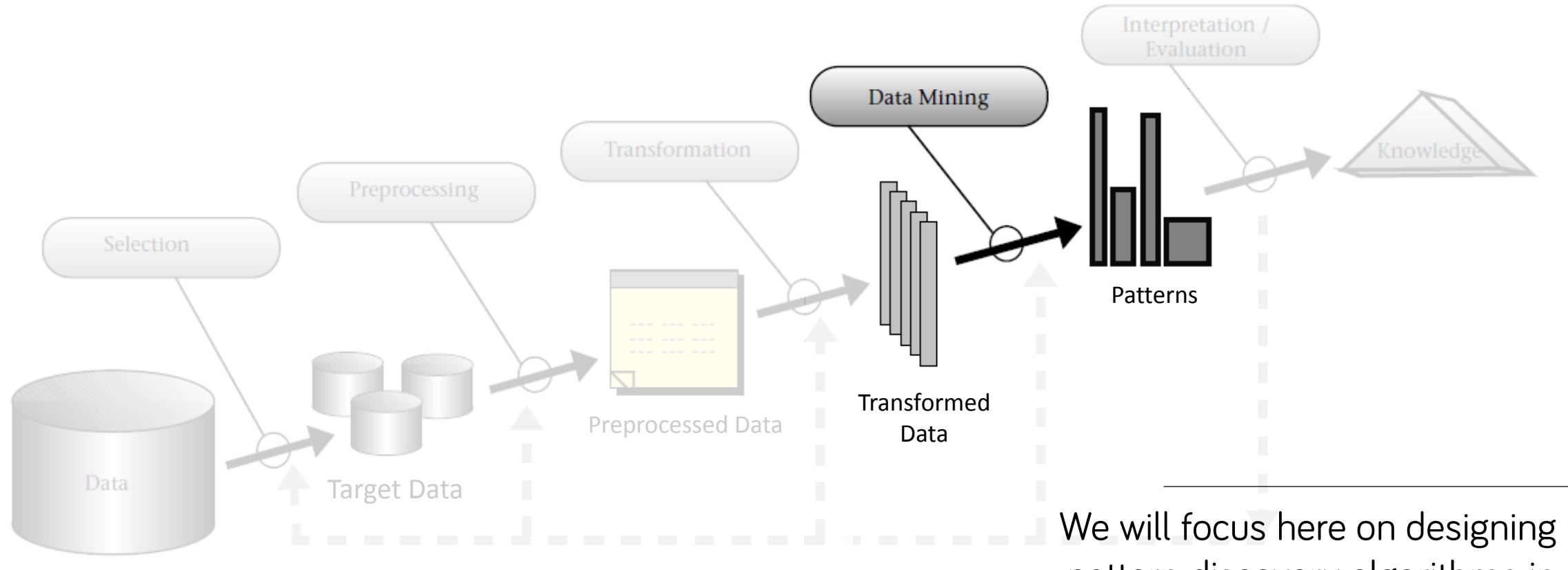


Knowledge Discovery in Databases – A Process

Fayyad U., Piatetsky-Shapiro G., Smyth P. [AAAI, 1996]



Fayyad U., Piatetsky-Shapiro G., Smyth P. [AAAI, 1996]

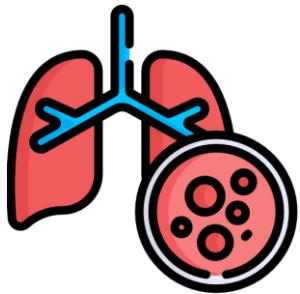


We will focus here on designing pattern discovery algorithms in prepared data.



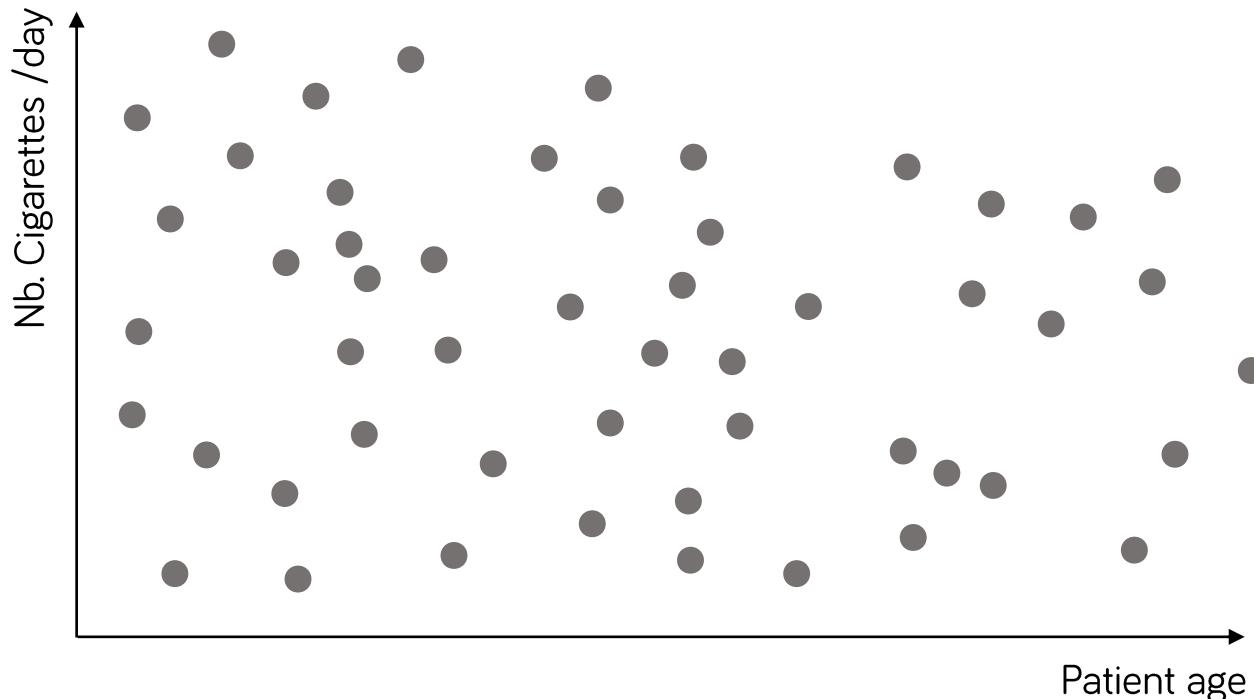
SUBGROUP DISCOVERY

WHAT IS IT ABOUT?

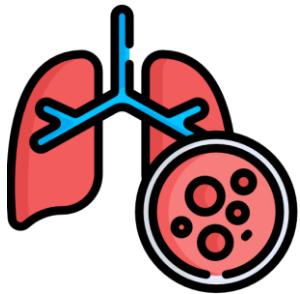


Subgroup Discovery*

The problem of finding **statistically unusual subgroups** in a given database



* S. Wrobel. An Algorithm for Multi-relational Discovery of Subgroups. In PKDD 1997.



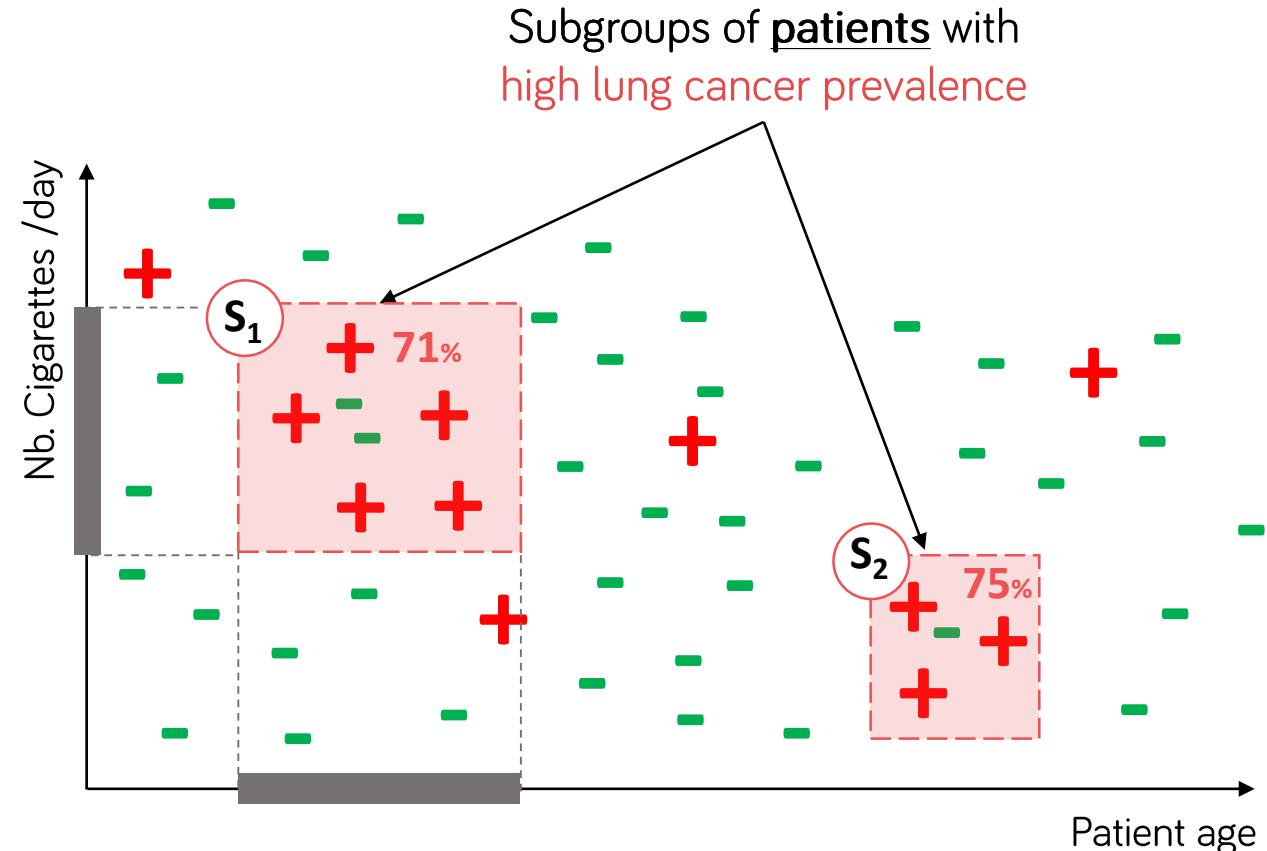
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- Subgroups are **subsets** of individuals
- Subgroups are **interesting**
- Subgroups are **described** using **individuals attributes**



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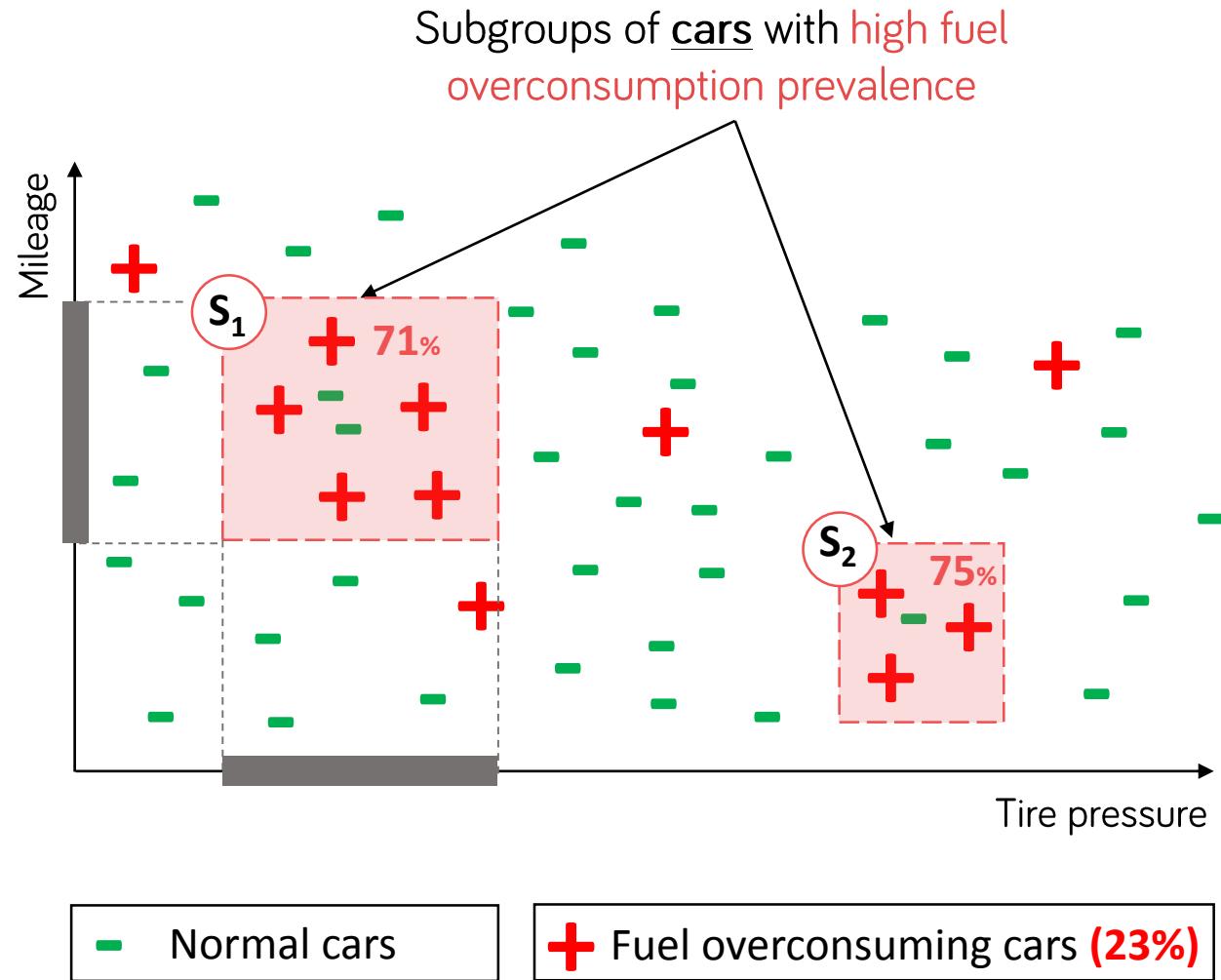
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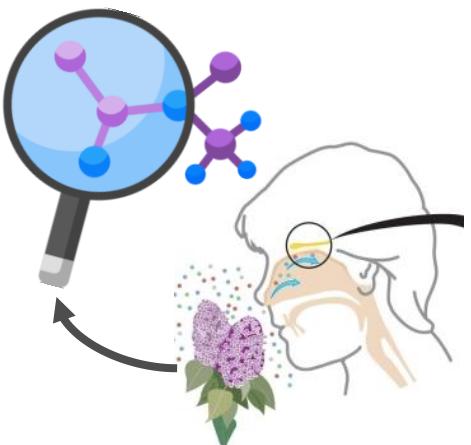


C. C. Licon, G. Bosc, M. Sabri, M. Mantel, A. Fournel, C. Bushdid, J. Golebiowski, C. Robardet, M. Plantevit, M. Kaytoue, M. Bensafi. Chemical features mining provides new descriptive structure-odor relationships. *PLOS Computational Biology* 2019



Collaboration between Computer Scientists, Neuroscientists and Chemists

Find relationships between the physicochemical properties of odorant molecules and their olfactory qualities



PLOS COMPUTATIONAL BIOLOGY

RESEARCH ARTICLE

Chemical features mining provides new descriptive structure-odor relationships

Carmen C. Licon^{1,2*}, Guillaume Bosc^{3,4†}, Mohammed Sabri^{1,5‡}, Maryam Mantel¹, Amaud Fournel⁵, Caroline Bushdid⁶, Jerome Golebiowski^{5,7}, Celine Robardet⁸, Marc Plantevit^{9,10*,}, Mehdi Kaytoue^{10,11}, Moustafa Bensafi^{10,12}

¹ Lyon Neuroscience Research Center, University Lyon, CNRS UMR6292, France, ² Food Science and Nutrition Department, California State University, Fresno, California, United States of America, ³ INSA Lyon, CNRS, LIRIS UMR6205, France, ⁴ Infologic, Bourg-lès-Valence, France, ⁵ Ecole Nationale Polytechnique d'Oran—Maurice Audin, Département de Mathématiques et Informatique, Oran, Algérie, ⁶ Institute of Chemistry of Nice, CNRS UMR7272, Université Côte d'Azur, Nice, France, ⁷ Department of Brain & Cognitive Sciences, DGIST, Daegu, Republic of Korea, ⁸ Université Lyon 1, CNRS UMR6205, France

* These authors contributed equally to this work.
† These authors are joint first authors on this work.
* moustafa.bensafi@onm.fr

Abstract

An important goal in researching the biology of olfaction is to link the perception of smells to the chemistry of odorants. In other words, why do some odorants smell like fruits and others like flowers? While the so-called stimulus-percept issue was resolved in the field of color vision some time ago, the relationship between the chemistry and psycho-biology of odors remains unclear up to the present day. Although a series of investigations have demonstrated that this relationship exists, the descriptive and explicative aspects of the proposed models that are currently in use require greater sophistication. One reason for this is that the algorithms of current models do not consistently consider the possibility that multiple chemical rules can describe a single quality despite the fact that this is the case in reality, whereby two very different molecules can evoke a similar odor. Moreover, the available datasets are often large and heterogeneous, thus rendering the generation of multiple rules without any use of a computational approach overly complex. We considered these two issues in the present paper. First, we built a new database containing 1689 odorants characterized by physicochemical properties and olfactory qualities. Second, we developed a computational method based on a subgroup discovery algorithm that discriminated perceptual qualities of smells on the basis of physicochemical properties. Third, we ran a series of experiments on 74 distinct olfactory qualities and showed that the generation and validation of rules linking chemistry to odor perception was possible. Taken together, our findings provide significant new insights into the relationship between stimulus and percept in olfaction. In addition, by automatically extracting new knowledge linking chemistry of odorants and psychology of smells, our results provide a new computational framework of analysis enabling scientists in the field to test original hypotheses using descriptive or predictive modeling.

OPEN ACCESS

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Data Availability Statement: The data underlying the results presented in this study are available from <https://doi.org/10.1371/journal.pcbi.1006945>.

Funding: This work was supported by a joint French-German research program from both the French National Agency of Research (<http://www.agence-nationale-recherche.fr>) and the German Research Foundation (<https://www.dfg.de>) (ANR-DFG SISI FRAL program; MEROD Project, ANR-15-FRAL-0002) to MB, and a grant from the Institut hospitalier des systèmes complexes (H2O).

PLOS Computational Biology | <https://doi.org/10.1371/journal.pcbi.1006945> April 25, 2019

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Subgroup Discovery : A Real Use Case

X	MW	nAT	nC	...	Vanillin	Woody	...
1	150	21	11	...	x	x	...
2	128	24	9
3	136	29	10	...		x	...
4	152	23	11	...		x	...
5	151	27	12	...	x		...
6	154	27	10	...	x		...
...

Data: 1689 Molecules, 82 Properties, 74 Odors

Subgroup
 $MW(X) \in [128, 151] \wedge nAT(X) \in [20, 27] \wedge nC(X) \in [9, 12] \rightarrow Vanillin$

*Molecules with such physicochemical attributes are likely to smell Vanillin



The “Likely” is quantified by some interestingness measure

Subgroup Discovery : More Use Cases

AI4ALL.TALK
Adnene Belfodil and Aimene Belfodil

DEVIANT: Discovering Significant Exceptional (Dis-)Agreement Within Groups [Tech. Report]

Adnene Belfodil¹ , Wouter Duivesteijn², Marc Pfantein³, Sylvie Cormann⁴, and Philippe Balmer⁵

¹ Univ Lyon, INSA Lyon, CNRS, LIRIS UMR 5205, F-69621, Lyon, France

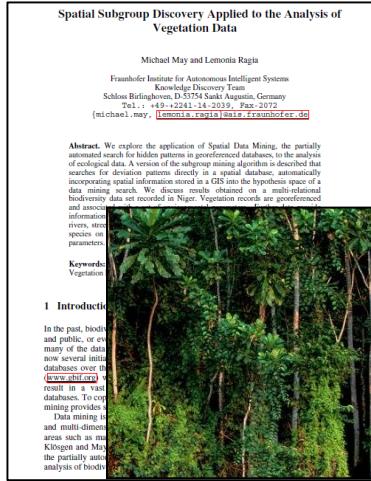
² Technische Universität Eindhoven, Eindhoven, the Netherlands

³ Univ Lyon, CNRS, LIRIS UMR 5205, F-69621, Lyon, France

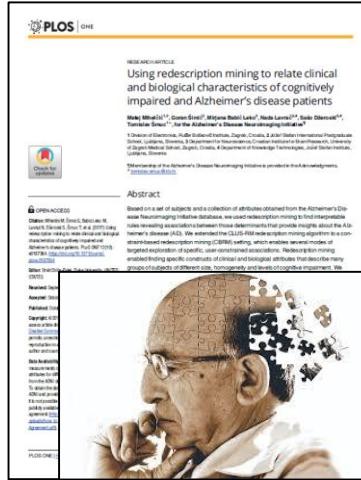
Abstract. We strive to find contexts (i.e., subgroups of entities) under which two individuals (e.g., political parties, countries, individuals, institutions) performing observable actions (e.g., votes, ratings) on entities (e.g., other individuals, countries, documents) agree or disagree. This is a generalization of the well-known problem of discovering statistically significant exceptional contextual items in itemset mining. In this paper, we propose a novel approach for solving this problem by combining subgroup discovery and rating data, we use Krippendorff's Alpha measure for assessing the agreement among individuals. We derive a branch-and-bound algorithm for efficiently finding all the subgroups of the data that satisfy both closure operation and tight optimistic estimate. We derive analytic approximations for the confidence interval (CI) associated with each pattern for a computationally efficient agreement measurement. We prove that those approximate CIs are nested along specificities of patterns. The results show that the proposed approach (DEVIANT) can quickly discard non-significant patterns. Empirical study on several datasets demonstrate the efficiency and the usefulness of D-EVANT.



Find exceptional disagreements within groups of individuals.



Find dependencies of a plant species on other plant species and environmental parameters.



Find relationships between biological and clinical attributes of cognitively impaired and Alzheimer's disease patients.

A. Belfodil, W. Duivesteijn et al. DEViANT: Discovering Significant Exceptional (Dis-) Agreement Within Groups. In ECML/PKDD 2019.



M. May, L. Ragia. Spatial subgroup discovery applied to the analysis of vegetation data. In PAKM 2002.



M. Mihelčić, G. Šimić et al. Using redescription mining to relate clinical and biological characteristics of cognitively impaired and Alzheimer's disease patients. In PLOS One 2017.

Subgroup Discovery : More Use Cases

AIK4ALL.TALK
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Abstract. We strive to find contexts (i.e., subgroups of entities) under which two individuals, or groups of individuals, have different opinions, in any type of data featuring individuals (e.g., politicians, companies, institutions) performing observable actions (e.g., votes, ratings) on entities (e.g., countries). This work is related to subgroup discovery, but it solves the problem of discovering statistically significant exceptional contextual items (i.e., subgroups) that are in agreement with the majority of the data, ignoring non-existing individuals. We derive a branch-and-bound algorithm that finds all significant exceptional (dis-)agreements in the data, using both closure operators and tight optimistic estimates. We derive analytic approximations for the p-values of the discovered patterns (CI), assuming that patterns are statistically independent. We prove that these approximate CIs are nested along specificities of patterns. The results of our experiments show that D-EViANT can quickly discard non-significant patterns. Empirical study on several datasets demonstrate the efficiency and the usefulness of D-EViANT.



Find exceptional disagreements within groups of individuals.

Spatial Subgroup Discovery Applied to the Analysis of Vegetation Data

Michael May and Lemona Ragia

Fraunhofer Institute for Autonomous Intelligent Systems
Knowledge Discovery Team
Sachsen-Bergbaustr. 13, D-85748 Asbach-Auerbach, Germany
Tel.: +49-9124-1420-2000; Fax: +49-9124-1420-2072
(michael.may, lemona.ragia)@fraunhofer.de

Abstract. We explore the application of Spatial Data Mining, the partially automated search for hidden patterns in georeferenced databases, to the analysis of vegetation data. We propose a spatial subgroup discovery approach that searches for deviation patterns directly in a spatial database, automatically interpreting spatial subdeviations stored in a GIS into the hypothesis space of a data mining system. We apply this approach to a vegetation dataset from a biodiversity data set recorded in Niger. Vegetation records are geo-referenced and associated with environmental information such as rivers, tree species, and environmental parameters.

Keywords:
Vegetation
1 Introduction

In the past, biodiversity and public, or even more private, interest in nature has led to now several initial databases over the globe (www.iucn.org). There are also many smaller databases. To cope with this situation, data mining provides a powerful tool. Data mining is a broad and multi-dimensional area such as machine learning, knowledge discovery, and the partially automated analysis of biodiversity.

M. May, L. Ragia. Spatial subgroup discovery applied to the analysis of vegetation data. In PAKM 2002.

Find dependencies of a plant species on other plant species and environmental parameters.

PLOS

ONE

RESEARCH

Using redescription mining to relate clinical and biological characteristics of cognitively impaired and Alzheimer's disease patients

Maša Mihelčić^{1,2*}, Goran Šimić³, Adnene Belfodil⁴, Lydia Oberndorfer⁵, Tanja Bošnjak⁶, for the Alzheimer's Disease Neuroimaging Initiative

¹ Institute of Biostatistics, University of Regensburg, Regensburg, Germany, ² Institute of Mathematics, University of Regensburg, Regensburg, Germany, ³ Institute of Mathematics, University of Regensburg, Regensburg, Germany, ⁴ Institute of Mathematics, University of Regensburg, Regensburg, Germany, ⁵ Institute of Mathematics, University of Regensburg, Regensburg, Germany, ⁶ Institute of Mathematics, University of Regensburg, Regensburg, Germany

Abstract. Alzheimer's disease (AD) is a neurodegenerative disease that primarily affects memory and cognitive function. It is characterized by progressive cognitive decline, memory loss, and behavioral changes. The disease is often accompanied by physical symptoms such as depression, anxiety, and hallucinations. The exact cause of AD is not fully understood, but it is believed to be a combination of genetic, environmental, and lifestyle factors. One of the key features of AD is the presence of beta-amyloid plaques and neurofibrillary tangles in the brain. These plaques and tangles disrupt the normal functioning of neurons and lead to progressive cognitive decline. The goal of this study was to use redescription mining to identify clinical and biological characteristics that are associated with cognitive impairment in AD patients. Redescription mining is a data mining technique that identifies associations between variables in a dataset. In this study, we used redescription mining to identify associations between clinical and biological characteristics of AD patients. We found that there were significant associations between cognitive impairment and clinical and biological characteristics such as age, gender, education level, and cognitive function. These findings suggest that redescription mining can be a useful tool for identifying associations between clinical and biological characteristics of AD patients.

Methodology. We used redescription mining to identify associations between clinical and biological characteristics of AD patients. We used a dataset of AD patients from the Alzheimer's Disease Neuroimaging Initiative (ADNI) study. The dataset contains information about cognitive function, clinical history, and biological markers such as brain scans and blood tests. We used a redescription mining algorithm to identify associations between clinical and biological characteristics of AD patients. The algorithm identified associations between cognitive impairment and clinical and biological characteristics such as age, gender, education level, and cognitive function. These findings suggest that redescription mining can be a useful tool for identifying associations between clinical and biological characteristics of AD patients.

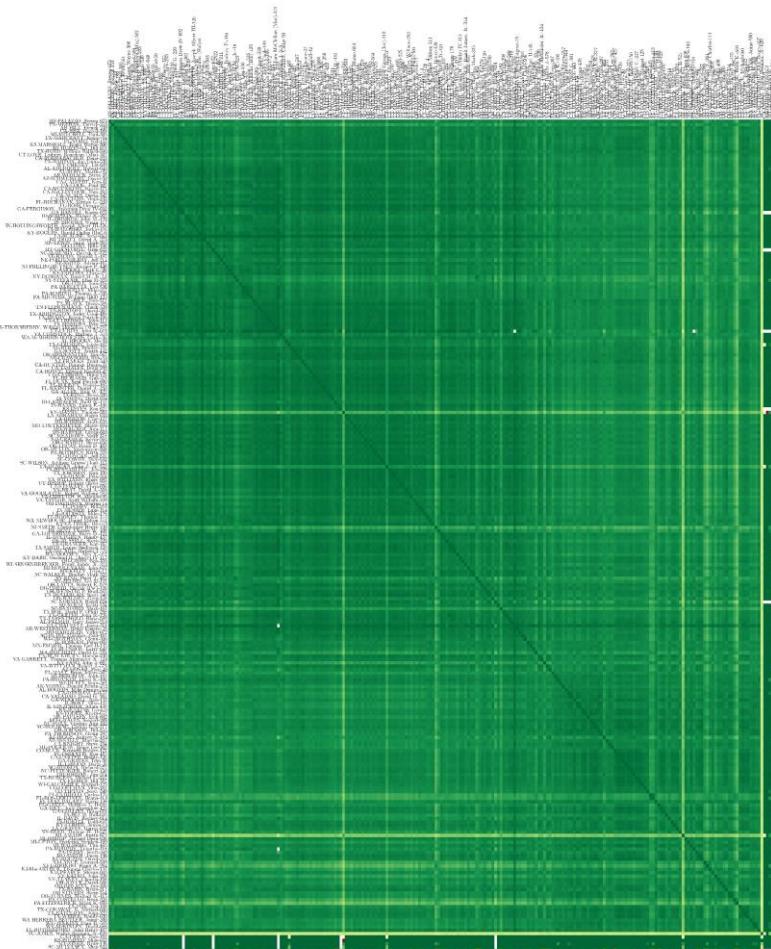
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Find relationships between biological and clinical attributes of cognitively impaired and Alzheimer's disease patients.

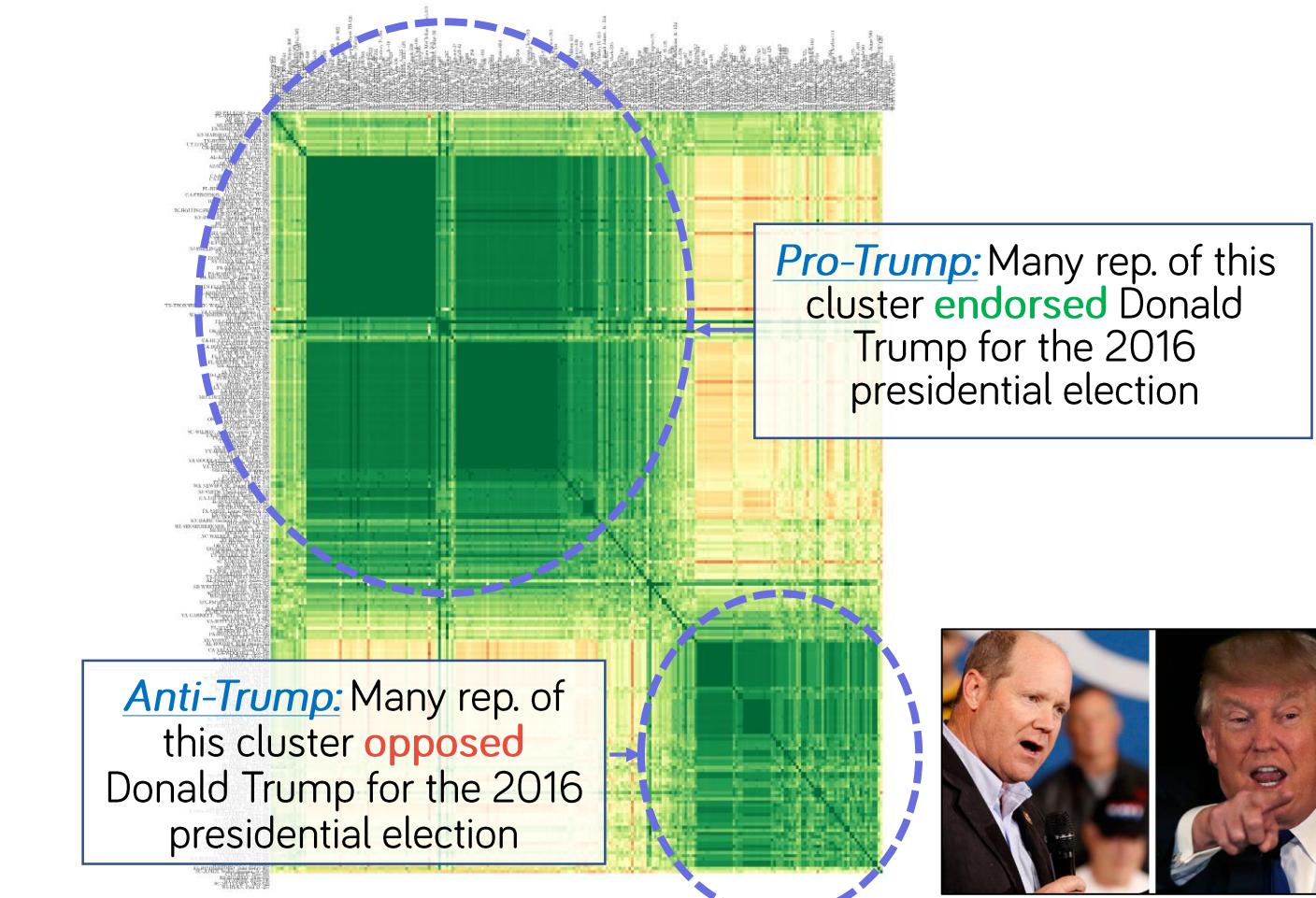


A. Belfodil, W. Duivesteijn et al. DEViANT: Discovering Significant Exceptional (Dis-)Agreement Within Groups. In ECML/PKDD 2019.

Subgroup Discovery : A Use Case in the US Congress



Overall **intra-agreement**
between **Republicans**
Group



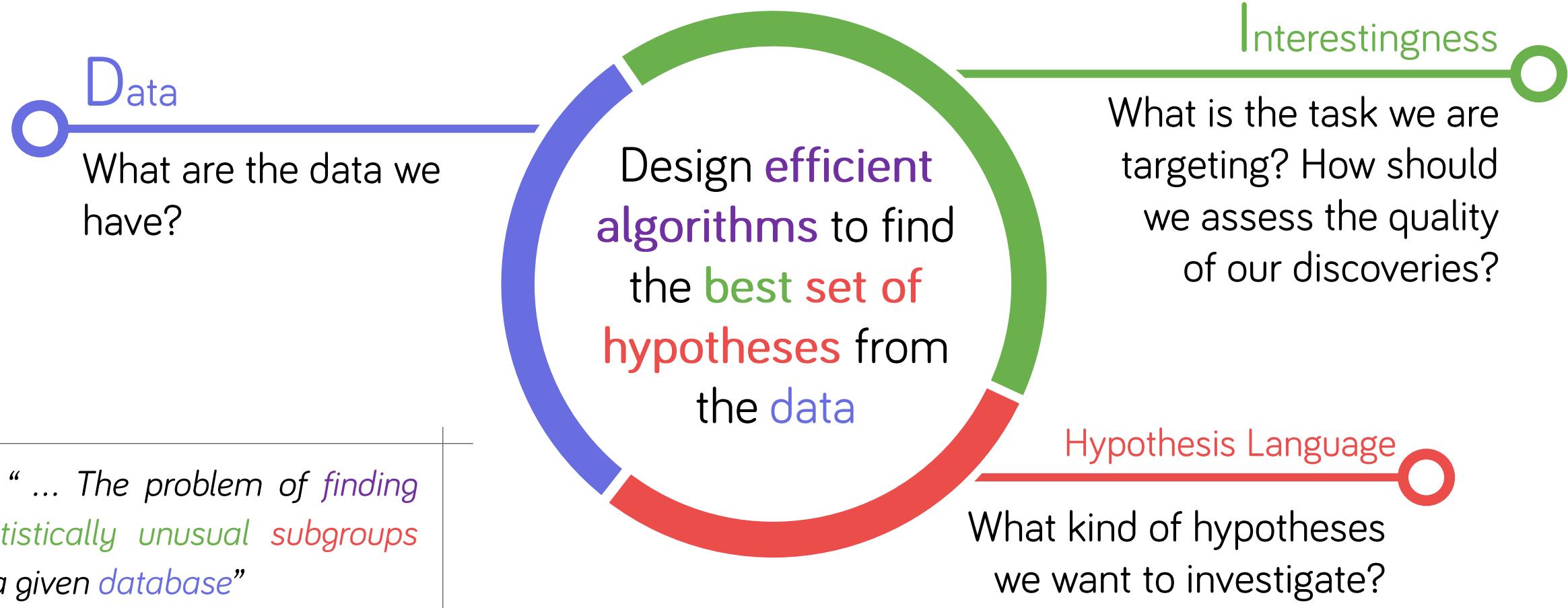
Contextual **intra-agreement** between **Republicans** in
Government and Administrative Issues related voting sessions
Context



SUBGROUP DISCOVERY

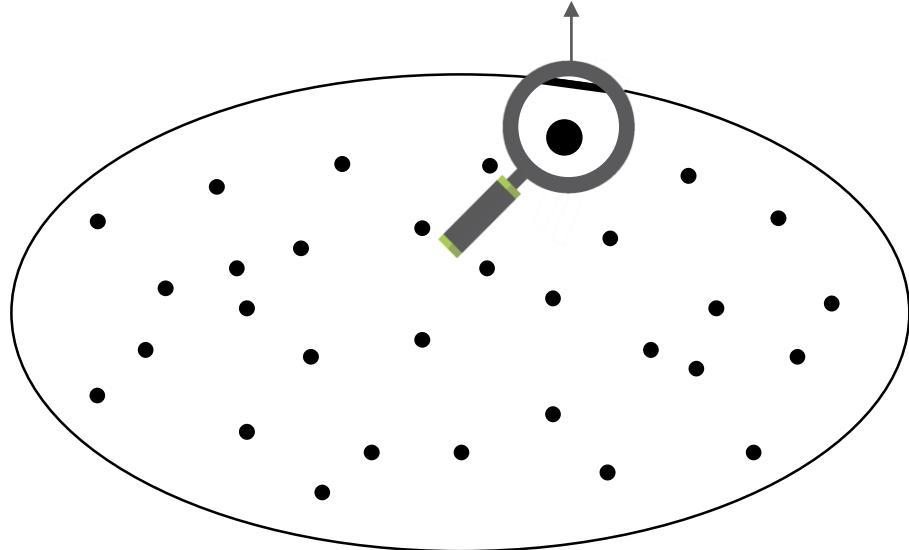
HOW DOES IT WORK?

Subgroup Discovery: A generic framework



Hypotheses Spaces

Patient Age = Young and Number of Cigarettes per day < 15



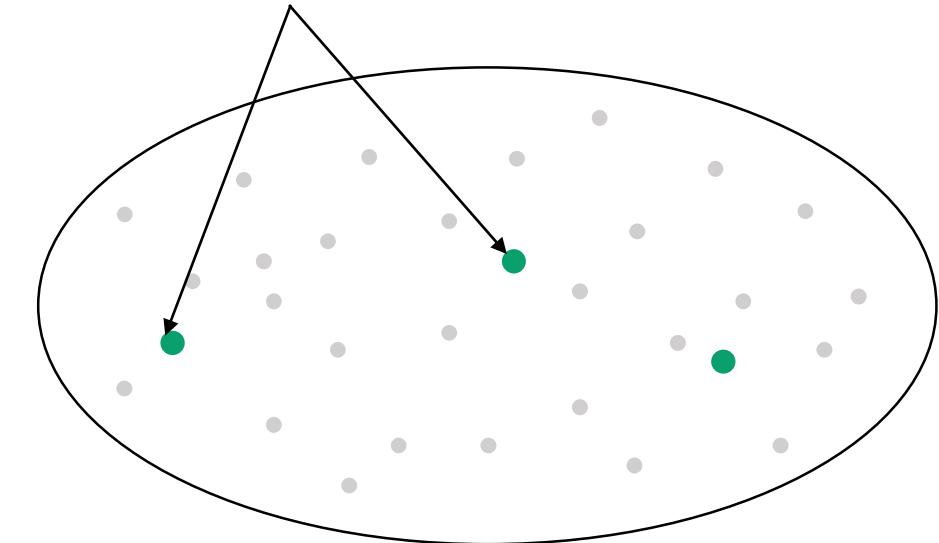
Hypotheses Search Space

Algorithm

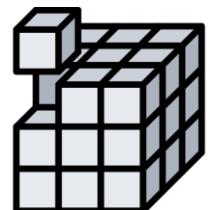
Elicit the interesting hypotheses out from the data



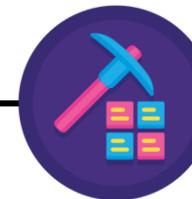
Interesting Hypotheses



Collection of interesting hypotheses (subgroups)



Data

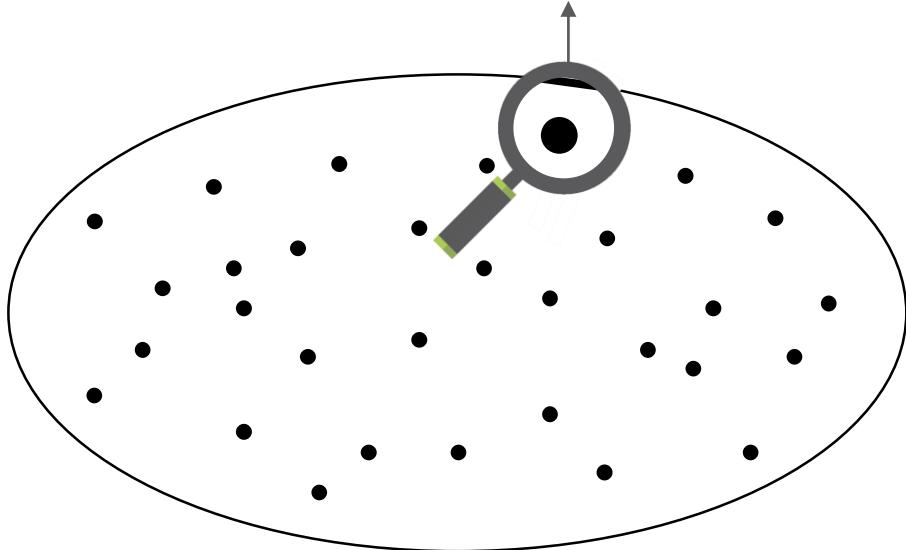


Knowledge



Hypotheses Spaces

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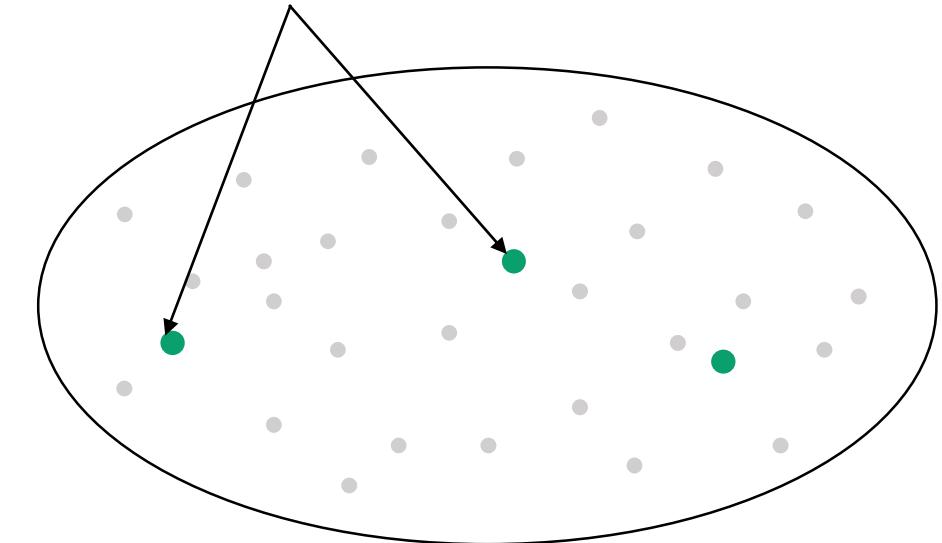
Hypotheses Search Space

Algorithm

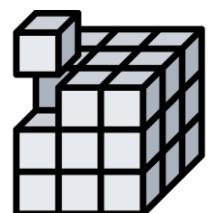
Elicit the interesting hypotheses out from the data



Interesting Hypotheses



Collection of interesting hypotheses (subgroups)



Data



Knowledge



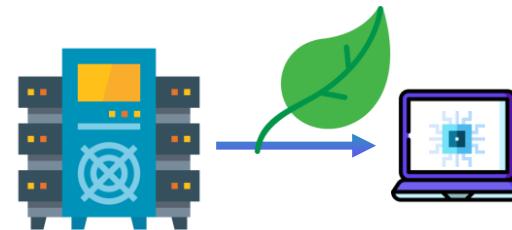


Subgroup Discovery Algorithmic Challenges



Interactivity

Algorithms need to be fast for better interactivity



Efficiency

Algorithms need to avoid consuming too much resources

Understand the **theory** lying behind subgroup discovery



A. Belfodil, M. Kaytoue, M. Kaytoue and A. Napoli. On Ordered Sets in Pattern Mining. An ECML/PKDD Tutorial in 2019.



A. Belfodil, M. Kaytoue and S. O. Kuznetsov. On Pattern Setups and Pattern Multistructures. In Arxiv 2019.

Provide **efficient** and fast algorithms



A. Belfodil, A. Belfodil and M. Kaytoue. Anytime Subgroup Discovery in Numerical Domains with Guarantees. In ECML/PKDD 2018.



A. Belfodil, A. Belfodil et al. FSSD – A Fast and Efficient Algorithm for Subgroup Set Discovery. In DSAA 2019.

Provide **practical tools** to end users



A. Belfodil, S. Cazalens et al. Identifying exceptional (dis) agreement between groups. In DMKD Journal 2019 (to appear).



A. Belfodil, W. Duivesteijn et al. DEViANT: Discovering Significant Exceptional (Dis-) Agreement Within Groups. In ECML/PKDD 2019.

IT Thesis Work

Aimene Belfodil



An Order-Theoretic Point of View on Subgroup Discovery (2019)

Adnene Belfodil



Exceptional Model Mining for Behavioral Data Analysis (2019)

Understand the theory lying behind subgroup discovery

Provide efficient and fast algorithms

Provide practical tools to end users



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Thesis Work

Aimene Belfodil



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Adnene Belfodil

Exceptional Model Mining for Behavioral Data Analysis (2019)

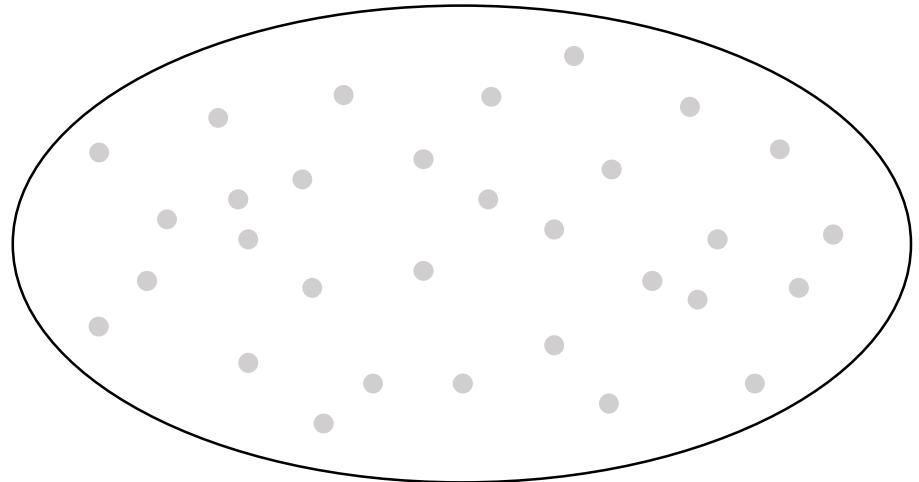


SUBGROUP DISCOVERY

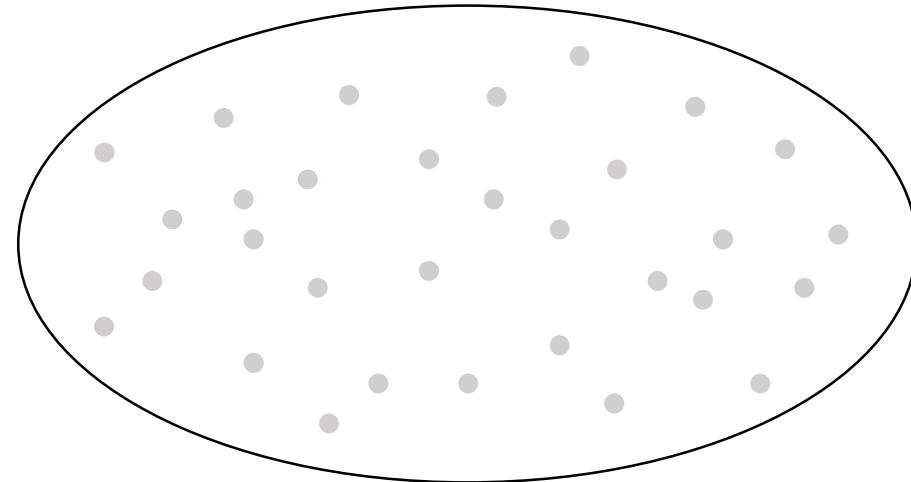
TOWARD FAST ALGORITHMS

Exhaustive VS Heuristic Search Paradigm

Paradigm I

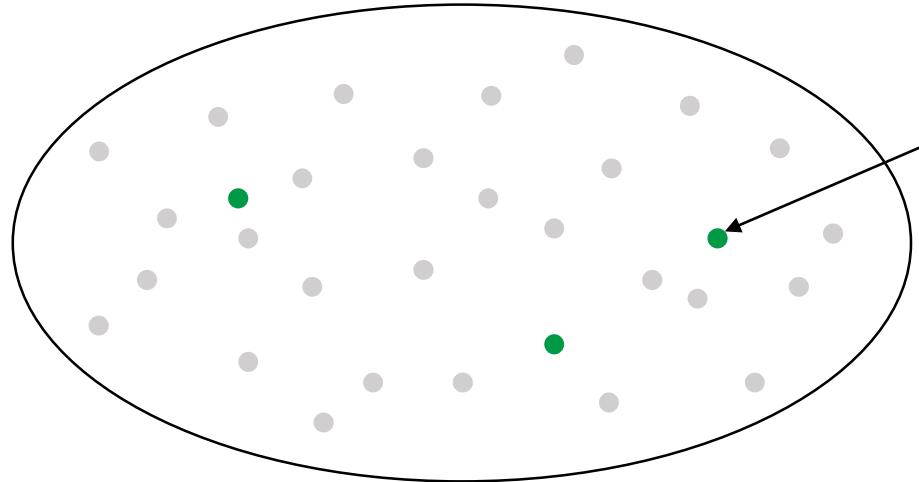


Paradigm II



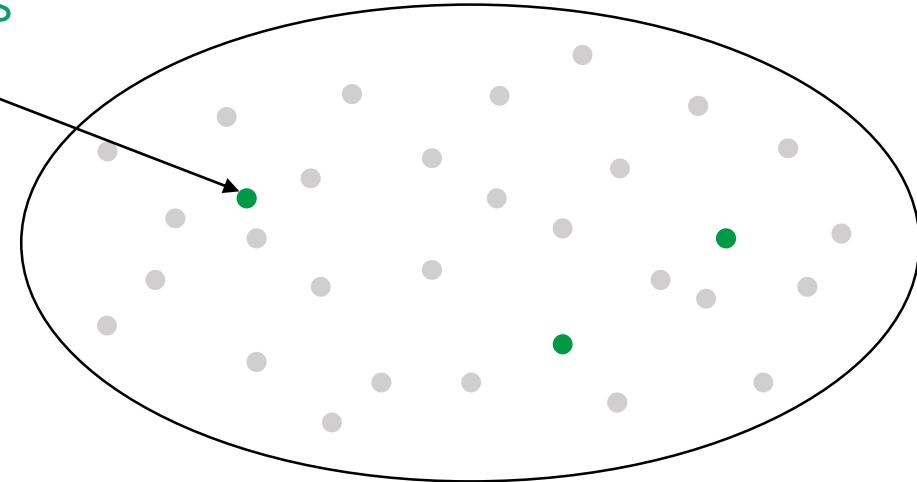
Exhaustive VS Heuristic Search Paradigm

Paradigm I



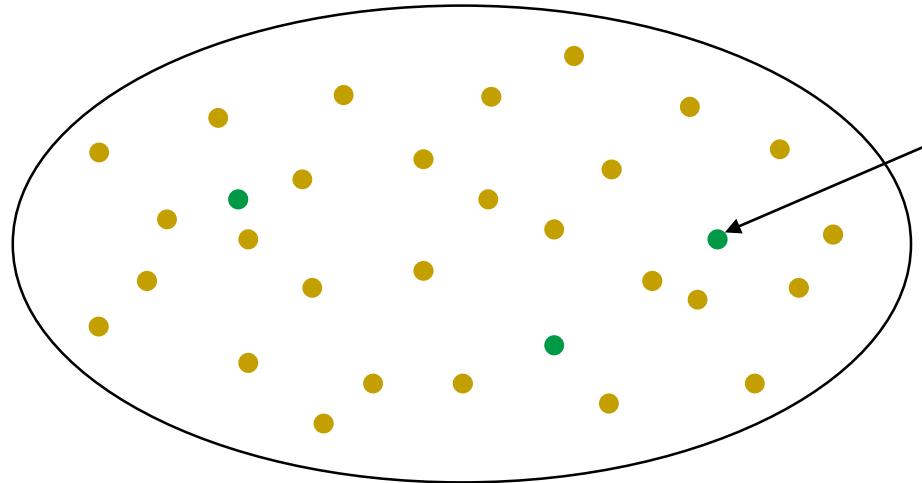
Interesting
Hypotheses

Paradigm II



Exhaustive VS Heuristic Search Paradigm

Exhaustive Search Paradigm



All subgroups are looked for and then post-processed to obtain the best subgroups



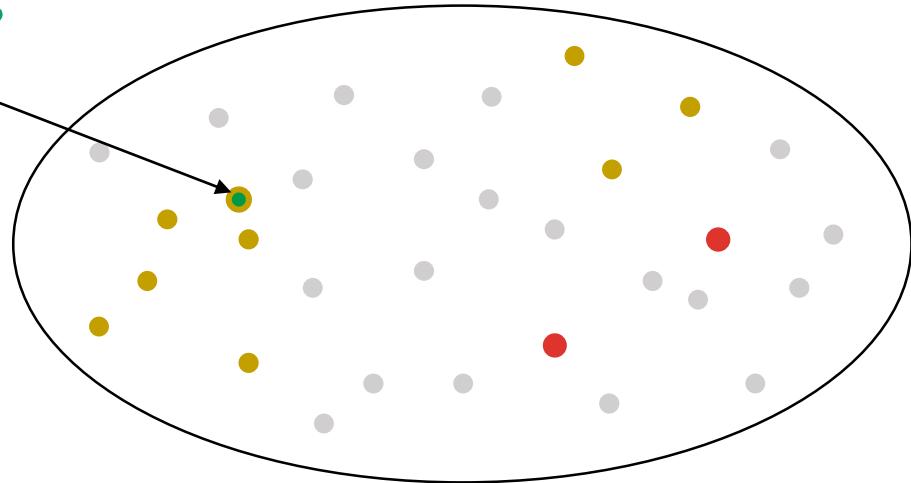
Guarantees to find the **best** subgroups



Time and resources consuming

Interesting Hypotheses

Heuristic Search Paradigm



Only few subgroups are looked for and then post-processed to obtain the best subgroups



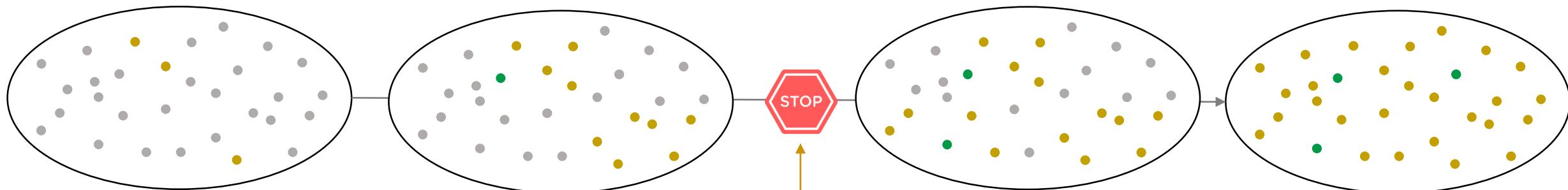
Efficient algorithms: fast and not resource greedy



Lack of exhaustivity: some (to most) interesting subgroups can be **ignored**



Good trade-off between
the two paradigms



Few patterns
after 5"

More patterns
after 1'

Many patterns
after 20'

All patterns
after the End

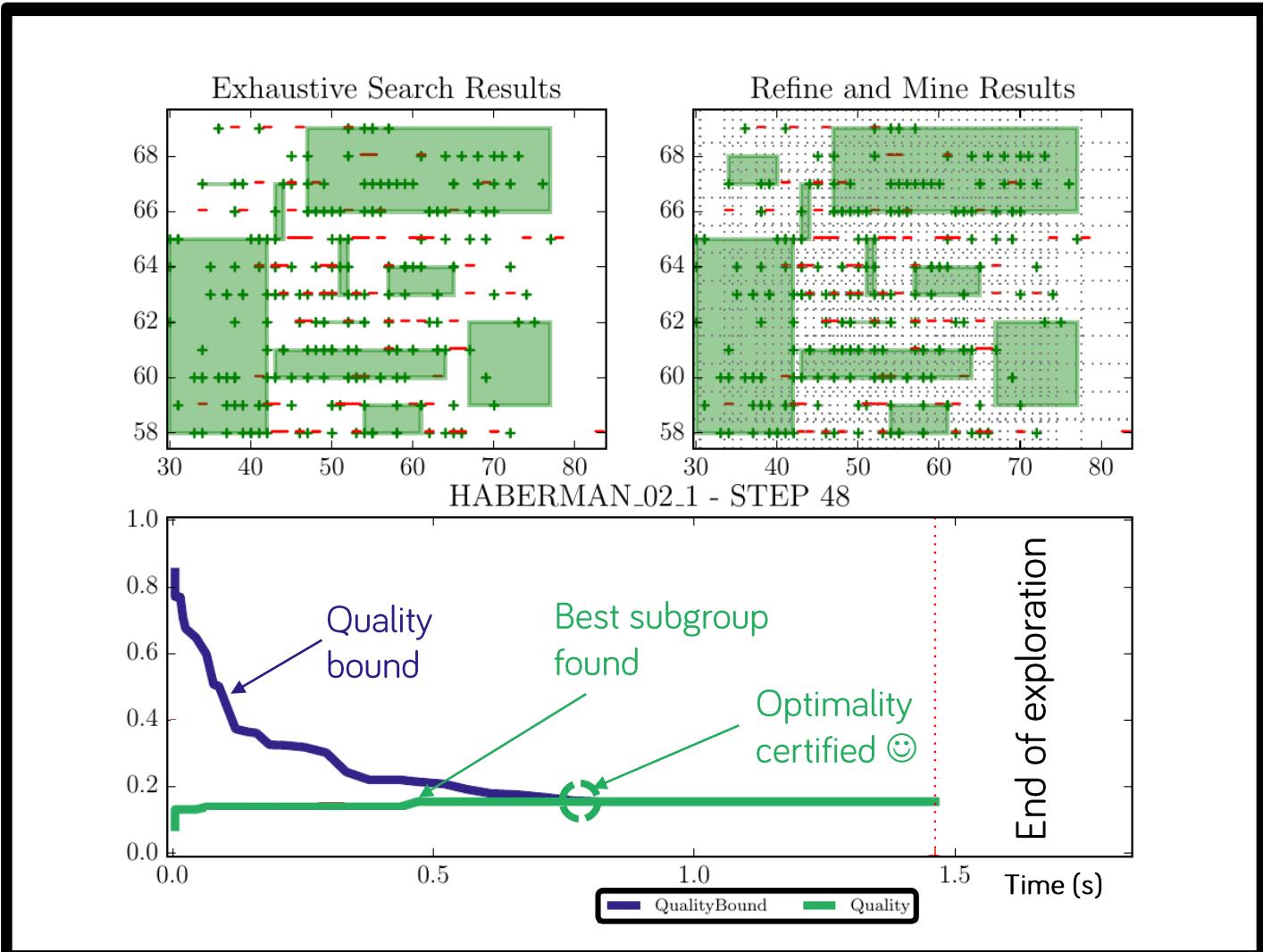


A. Belfodil, A. Belfodil and M. Kaytoue. Anytime Subgroup Discovery in Numerical Domains with Guarantees. In ECML/PKDD 2018.

Awarded as the best data mining paper in ECML/PKDD 2018



Propose Refine&Mine, an Anytime algorithm which yields progressively interesting subgroups whose quality improves over time.

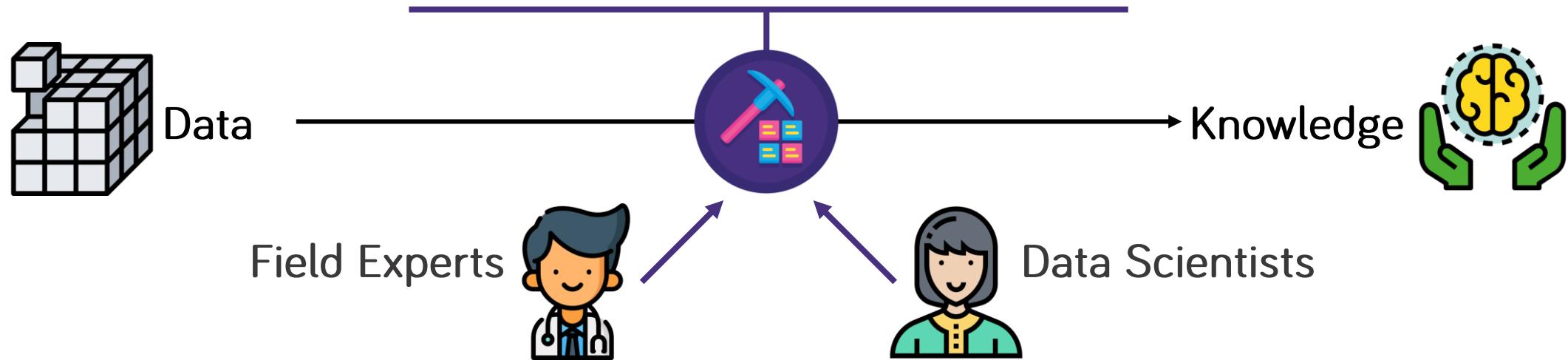




CONCLUDING REMARKS

WHAT SHOULD WE TAKE HOME?

Subgroup Discovery is a generic framework that can be used to **enhance human expertise** by exploiting the data.



How can we leverage subgroup discovery framework to **facilitate the discovery of interesting hypotheses** from **clinical data**?



GRAÇIAS

THANKS FOR YOUR TIME

GO RAIBH MAITH AGAT

MULŞUMIRI

Ευχαριστώ

AČIŪ

AČIŪ

GO RAIBH MAITH AGAT

TAK

DZIĘKI

GRAÇIAS

TACK

благодаря

PALDIES

GRAZIE

AČIŪ

DĚKUJI

DANKE

HVALA

BEDA

OBRIGAD

KIITOS

VĐAKA



QUESTIONS

AITÄH

MERCI

Contact : adnene.belfodil@gmail.com
aimene.belfodil@gmail.com