Using analogical complexes to improve human reasoning and decision making in Electronic Health Record Systems

Christian Săcărea, Diana Șotropa, **Diana Cristea (Troancă)**

csacarea@cs.ubbcluj.ro, diana.halita@ubbcluj.ro, **dianat@cs.ubbcluj.ro**

Table of contents

Motivation

- Traditional models of healthcare services are inefficient and expensive;
- Electronic Health Record Systems (EHR) may reduce human error & improve patient safety;
- Identify valid, novel, useful & understandable **patterns from medical data**;
- Reduce costs for **decision support systems**;
- **Minimize unwanted biases**, **errors** and excessive medical costs due to intuition;
- Support & enhance the medical system;

Purpose

- Enhance Electronic Health Record Systems with an analogical reasoning component;
- Improve the accuracy of the decision process;
- Prove the effectiveness of formal concept analysis & analogical reasoning as a suitable mechanism through which EHRS might be improved, offering thus a valuable reasoning and decision making support for medical experts.

Methodology

- Data mining results are usually difficult to interpret;
- For a user-friendly visualization we used:
  - Analogical Reasoning (AR) – a powerful tool for classification;
  - Formal Concept Analysis (FCA) – a well known for effective knowledge discovery algorithms.

Formal Concept Analysis

- Basic notions of Formal Concept Analysis (FCA):
  - **Formal context** consisting of a set of object and attributes with an incidence relation;
  - **Formal concepts** representing maximal clusters of objects containing attributes;
  - **Concept lattice** – the conceptual structure defined on the formal concepts.

Proportional Analogies (AP) for formal concepts

- Reasoning by analogy has been recently improved and formalized;

$$x : y :: z : t$$

$$x \text{ is to } y \text{ as } z \text{ is to } t$$

eg. **Annecy is to ICCS 2016 what Edinburgh is to ICCS 2018**

- Properties:
  - Symmetry of "as": $x : y :: z : t \Leftrightarrow z : t :: x : y$
  - Exchange of means: $x : y :: z : t \Leftrightarrow x : z :: y : t$

Proportional Analogies (AP) for formal concepts

- Four elements (formal concepts) (x,y,z,t) of a lattice are in *Weak Analogical Proportion* (WAP) iff

$$x \vee y = y \vee z \text{ and } x \wedge t = y \wedge z$$

$$\Leftrightarrow$$

$$A_x \cap A_t = A_y \cap A_z \text{ and } O_x \cap O_t = O_y \cap O_z;$$

- A full analogical proportion (FWAP) is a WAP iff the four concepts are incomparable for $\leq$ and the quadruples (x, z, y, t) and (x, z, y, t) are not WAPs.

Proportional Analogies (AP) for formal concepts

- A proportional analogy between concepts is a relation $\updownarrow$ defined on B(G) x B(M) x B(G) x B(M) derived from a full analogical proportion written as:

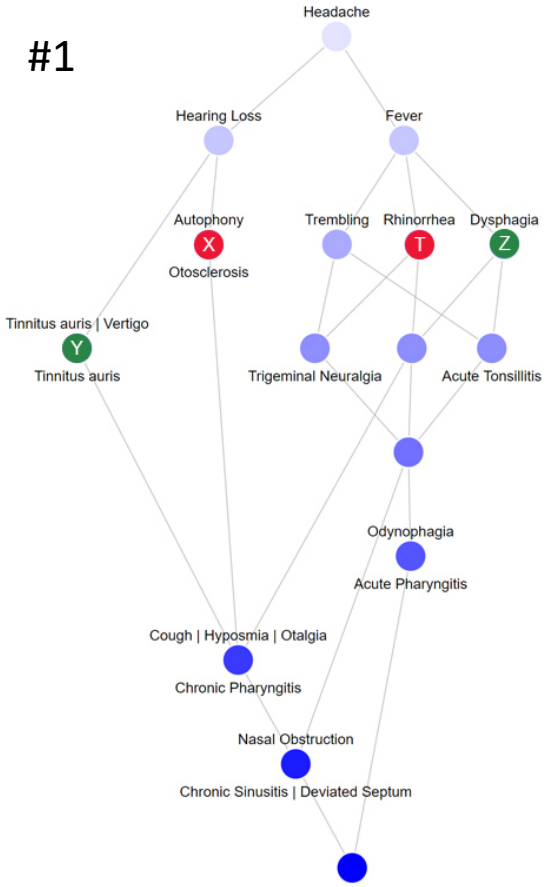
$$(O_x \backslash O_y) \updownarrow (A_x \backslash A_y) \updownarrow \updownarrow (O_y \backslash O_x) \updownarrow (A_y \backslash A_x)$$

- We consider proportional analogies derived from all analogical proportions.

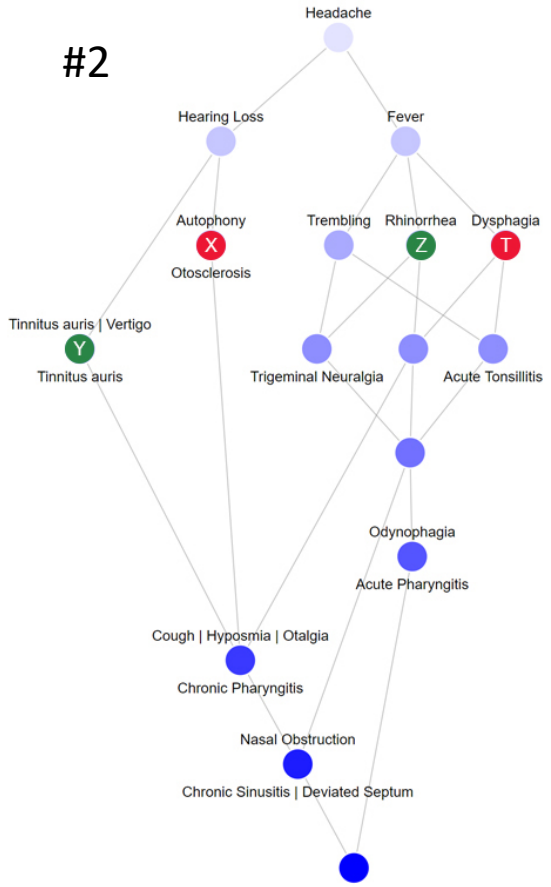
Experiments

Diagnostics in relation with symptoms with focus on Deviated Septum as principal diagnostic and Chronic Sinusitis as secondary diagnostic

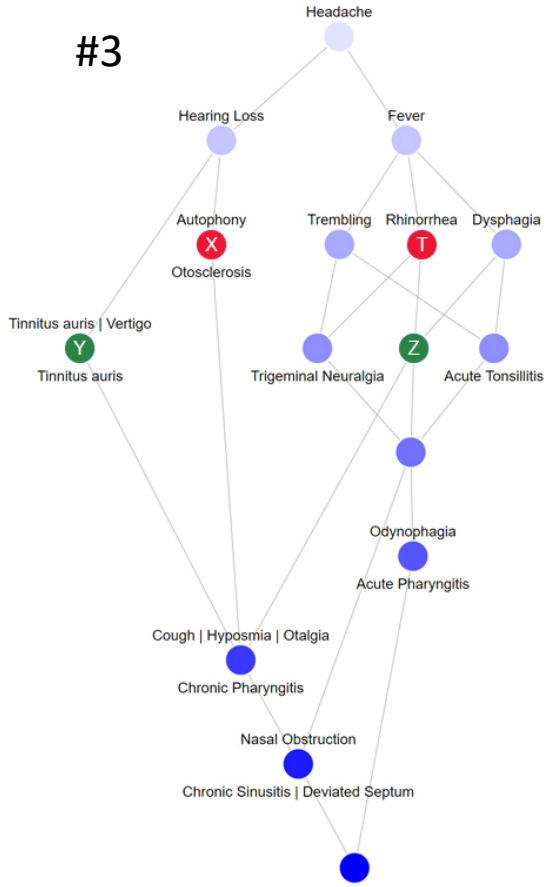
#1



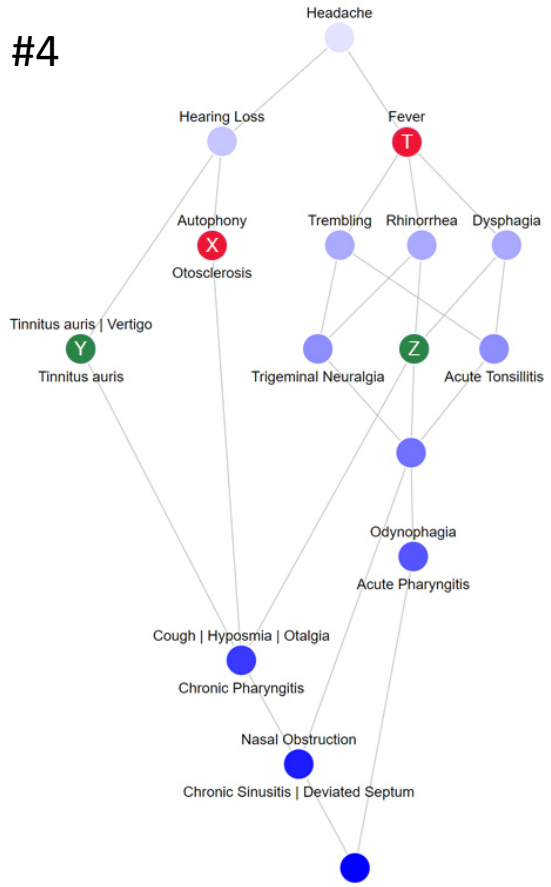
#2



#3



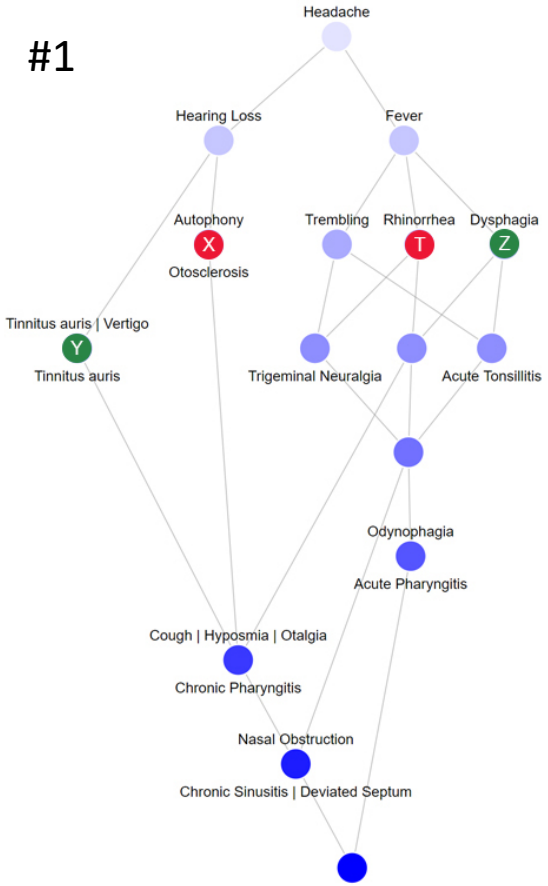
#4



Experiments

Diagnostic: Deviated Septum - concepts in analogical relation - WAP1

#1

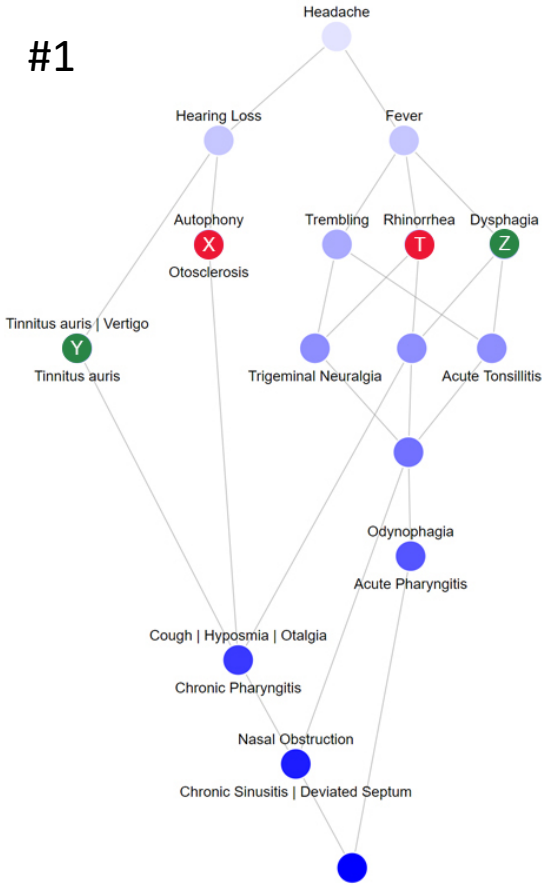


Concept	Extent	Intent
X	Ostosclerosis, Chronic Pharyngitis, Chronic Sinusitis, Deviated Septum	Autophony, Headache, Hearing Loss
Y	Chronic Pharyngitis, Chronic Sinusitis, Deviated Septum, Tinnitus	Headache, Hearing Loss, Tinnitus, Vertigo
T	Acute Pharyngitis, Chronic Pharyngitis, Chronic Sinusitis, Deviated Septum, Trigeminal Neuralgia	Fever, Headache, Rhinorrhea
Z	Acute Pharyngitis, Acute Tonsillitis, Chronic Pharyngitis, Chronic Sinusitis, Deviated Septum	Dysphagia, Fever, Headache

Experiments

Diagnostic: Deviated Septum - proportional analogies - WAP1

#1



	Extent1 \ Extent 2	Intent1 \ Intent 2	Extent2 \ Extent 1	Intent 2 \ Intent1
(x,y)	Ostosclerosis	Autophony	Tinnitus	Tinnitus, Vertigo
(x,z)	Ostosclerosis	Autophony, Hearing Loss	Acute Pharyngitis, Acute Tonsillitis	Dysphagia, Fever
(y,t)	Tinnitus	Hearing Loss, Tinnitus, Vertigo	Acute Pharyngitis, trigeminal Neuralgia	Fever, Rhinorrhea

Experiments - Observations

- For instance, we observed that the pair of objects and attributes *{{Ostoclerosis}, {Autophony, Hearing Loss}}* is repeated for different WAPs, however the second part of the analogy is different;
- Hence, one can infer knowledge from enhancing the chain of similarities;
- Another observations is that replacing a single symptom can lead to a different diagnostics.

Experiments - Scenario

1. Patients come to the hospital presenting a list of symptoms recorded in the system;
2. Some symptoms are principal, while others are secondary;
3. Based on a previous data **preprocessing phase, conceptual landscapes are built**, enabling navigation in a dyadic or triadic setting;
4. The analogical reasoning component presents quadruples of concepts in a weak analogical proportion and mines all analogical relations;
5. Based on a previously built knowledge base, **eventual inconsistencies can be highlighted**;
6. The clinician can give a diagnostic to the patient **and investigates some of the highlighted analogical relations**;
7. Based on the entire set of analogies, the clinician may dig deeper into relations between symptoms and diagnostics.

Conclusions

- EHRs proved to be a significantly aid in health improvement;
- We addressed health care system‘s shortcomings;
- We proved the positive impact on a patient welfare;
- Decrease medical errors due to analogies between symptoms and diagnostics.

Future work

- Develop a recommendation system based on the confidence of an analogy;
- Assign a grading to the recommendation according to the percent of concepts in which the pair (object, attribute) is present out of all concepts which contain the object in their extent.