CL2000 Tutorial
Applications of Inductive Logic Programming

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Overview

Part 1. Introduction to ILP

Part 2. Case studies

Part 3. Summary & new directions

Part 1

Introduction

Motivation

Large databases - genomics, natural language.

Science and industry knowledge-driven.

Procedural or declarative?

Declarative - logical representation.

Inductive logic programming (ILP).

Inductive logic programming

Background knowledge:	B
Examples:	$E = E^+ \wedge E^-$
Hypothesis:	H
Prior consistency:	$B \wedge E^- \not\models \Box$
Prior necessity:	$B \not\models E^+$
Posterior consistency:	$B \wedge H \wedge E^- \not\models \Box$
Posterior sufficiency:	$B \wedge H \models E^+$
	$B \wedge \overline{E^+} \models \overline{H}$

ILP variants

Categorised by deviation from "Standard" model which has:

1. Complete Background Knowledge (BK).
2. Correct BK.
3. Complete set of BK predicates.
4. Minimal set of BK predicates.
5. Noise-free data.
6. Pos+Neg examples.
7. Plentiful example set.
8. Best B,H,E are LPs.
9. Observational predicate learning.

Part 2

Case studies

EX definitions

eastbound(T) :- has_car(T,C), short(C), closed(C).

muta(M) :- atom(M,A,o,40,-0.389), bond(M,B,A,2), bond(M,C,B,1).

Case studies

Mutagenesis

British Telecom library

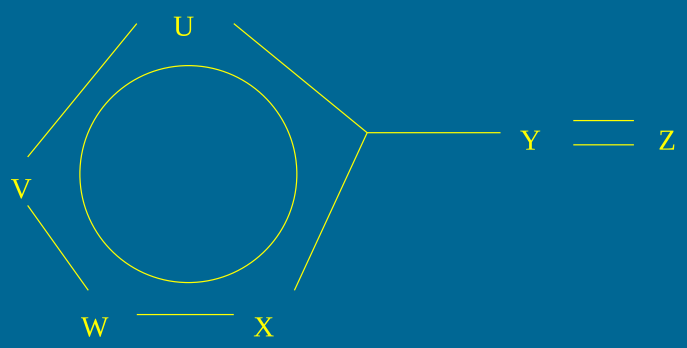
Metabolic Pathways

Mutagenesis

Related to carcinogenicity. Measured by Ames test.
Not always determinable empirically.

New structural alert (42 molecules):

Mutagenic if there exists a double bond
connected to a 5-aromatic ring.



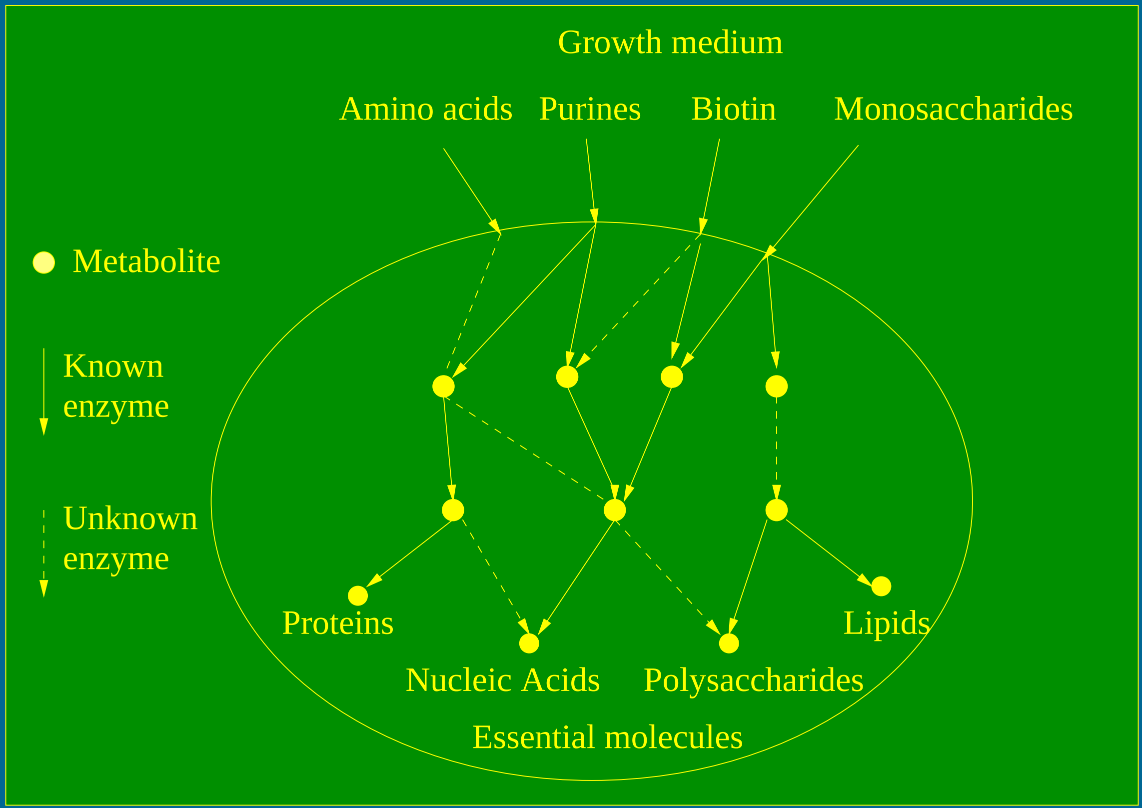
Progol	85.7%
BackProp	64.3%
Regression	66.7%
Default	69.0%

BT library system for Reverse Querying

- INSPEC library database.
- Simple keyword search too many hits.
- Evaluating interactive ILP-based ReQuire system.
- +ve and -ve examples of target.
- Relevant taxonomic background knowledge problem.

```
voice_over_ip(P) :-    has_code(P,C), telephony(C),
                       has_code(P,D), computer_communications(D).
```

Metabolic pathways



McCarthy's appearance/reality challenge

[5] < G >

[0] < C >

[4] < O >

[1] < A >

[3] < D >

[2] < T >

Background knowledge

```
observe(Pos,Ap,Act,Ap1) :-
    act(Act,Pos,Sit,Sit1), appears(Sit,Pos,Ap), appears(Sit1,Pos,Ap1).

appears(Sit,Pos,Ap) :- situation(Sit,Pos,Dial,Ap), letter(Ap),
    not(obscured(Sit,Dial,Pos)).

obscured(Sit,DialN,Pos) :-
    situation(Sit,Pos,DialM,Let), situation(Sit,Pos,DialN,_),
    DialM<DialN, letter(Let).
```

Examples

Example sequence - <0,Left>, <5,Right>

appears(0,0,c). appears(0,1,a). appears(0,2,t).

appears(0,3,d). appears(0,4,o). appears(0,5,g).

appears(1,0,a). appears(1,1,t).

appears(1,3,d). appears(1,4,o). appears(1,5,c).

observe(0,c,left,a). observe(5,c,right,g).

Integrity constraints

:- appears(S,P,L1), appears(S,P,L2), not(L1=L2).

:- situation(S,P,D,L1), situation(S,P,D,L2), not(L1=L2).

Hypothesis

situation(S,P,D,L) :- offset(S,D,O), offby(P,O,P1), dial(D,P1,L).

Part 3

Summary & new directions

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Summary

Name	Motivation	Deviation
Pharmacophores	EX	[2,6]
Mutagenesis	EX subset	[1,4,8]
PTE	EX + reuse	[1,7,8]
BT library	EX	[3,5,7]
Past Tense	EX	[1,4,6]
Folds	EX + novelty	[4,5,6,7]
Grammar learning	EX	[1,4,6,8]
Pathways	Non-observational	[1,2,3,4,5,9]
NeuroPeptides	EX	[1,2,3,4,6,8,9]

Application areas

A. Natural language. Background knowledge - existing large grammars, e.g. Cambridge CLE. Data source - corpora.

B. Genome data. Background knowledge - molecular biology. Data sources - PDB/SCOP and SwissProt.

C. Agents/control. Background knowledge - Dynamics, etc. Data sources - simulators eg. Flight, RoboCup and users.

Research issues

i. Hierarchically structured learning (A,B,C).

ii. Optimal querying/experimentation (A,B,C).

iii. Analysis of comprehensibility (A,B,C).

iv. Multi-agent representation (C).

v. Complex lambda-term structures (A).

vi. Relevance of background knowledge (A).

Computational logic

a. Integration of logic and probability/statistics (vi).

b. Integration of time/-complexity analysis into logic (i,ii,iii,iv).

c. Efficient higher-order representations (i,v,vi).

d. Representation of agency (iv).

Conclusion

- Representation of delarative knowledge.
- Use of background knowledge.
- Applications to scientific discovery and language learning.
- Various possible extensions of representation.

Bibliography

ILP general

Muggleton (1999), *Inductive Logic Programming: issues, results and the LLL challenge*, Artificial Intelligence, 114(1):283-296.

Muggleton and De Raedt (1994), *Inductive Logic Programming: Theory and Methods*, Journal of Logic Programming, 19,20, 629-679.

ILP and Scientific Discovery

Muggleton (1999), *Scientific Knowledge Discovery using Inductive Logic Programming*, Communications of the ACM, 42(11):42-46.