





Comparative Evaluation of Approaches to Propositionalization

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Introduction

- Propositionalization:
  largely automatic transformation of relational data
  into a single-table representation
  and application of propositional learners

- In principle less powerful than searching
  full first-order hypothesis space

- In practice often sufficient, efficient, and flexible

- Here: first comparative study using representatives
  of logic-oriented approaches (RSD, SINUS)
  and database-oriented approaches (RELAGGS)

Propositionalization

- An ILP learning task:
  given ground facts of target predicate (examples) and
  clauses of background predicates,
  find hypothesis to explain together with background theory
  some properties of examples

- Complete vs. partial approches,
  general-purpose vs. special-purpose approaches

- Clauses constructed from relational background knowledge
  and structural properties of individuals,
  calls of clauses for individuals produce feature values

RSD

- Declarative bias similar to Progol/Aleph, e.g.

  :-modeb(3,hasCar(+train,-car).

- Step 1: identification of all **closed** feature definitions (Prolog queries) corresponding to declarations

  hasCar(Train,Car), shape(Car,Shape), instantiate(Shape)

- Step 2: instantiation of variables plus feature filtering, e.g.

  hasCar(Train,Shape), shape(Shape,bucket)

- Step 3: creation of propositionalized representation

RSD: Constraints & Pruning

- Language
  - argument modes & types, predicate recall
  - max feature length & variable depth
  - **undecomposability**: *f1 <> f2 & f3*
- Evaluation
  - non-triviality: |*cov(f)*| < |*Data*|
  - relevance: |*cov(f)*| > *min*
  - uniqueness: if *cov(f1)* = *cov(f2)* then discard the longer
- Pruning:
  - large subspaces identified containing only decomposable f.
    - eg. EW Trains: *SearchTime -> +inf as MaxLength -> +inf*
    - with pruning: *SearchTime -> const as MaxLength -> +inf*
  - if |cov(f)| < min then don't refine f

SINUS: Overview

- Developed from LINUS and its feature generation extension
- A modular transformational ILP experimentation platform
  - Automated type construction
  - Feature reduction
  - Invocation of learner and back-translation of induced theory to first-order form.
- Data as flattened Prolog facts + data definition
  - Declarative bias similar to 1BC, e.g.
    train 1 train cwa
    train2car 2 1:train *:#car * cwa
    cshape 2 car #shape * cwa

SINUS: Step by step

- Step 1: construction of instantiated feature definitions, e.g. f_aaaa(A) :- train(A), hasCar(A,B),shape(B,bucket). Recursive left-to-right considering current variable types and bindings.
  - Constraining maximum literals, variable, values in a type and the nature of variable reuse.
- Step 2: feature set reduction (REDUCE)
- Step 3: creation of propositionalized representation
- After learning: result transformation into first-order hypothesis

RELAGGS

- Declarative bias from foreign key relationships
  in relational database schema

- After example identifier propagation to non-target relations:

- Step 1: summarize each non-target relation by example id,
  avg, max, min, sum, stdev, range, quartiles for numeric data,
  count possible values for nominal attributes,
  plus some two-column aggregates

- Step 2: creation of propositionalized representation by
  concatenating aggregate function values to target relation

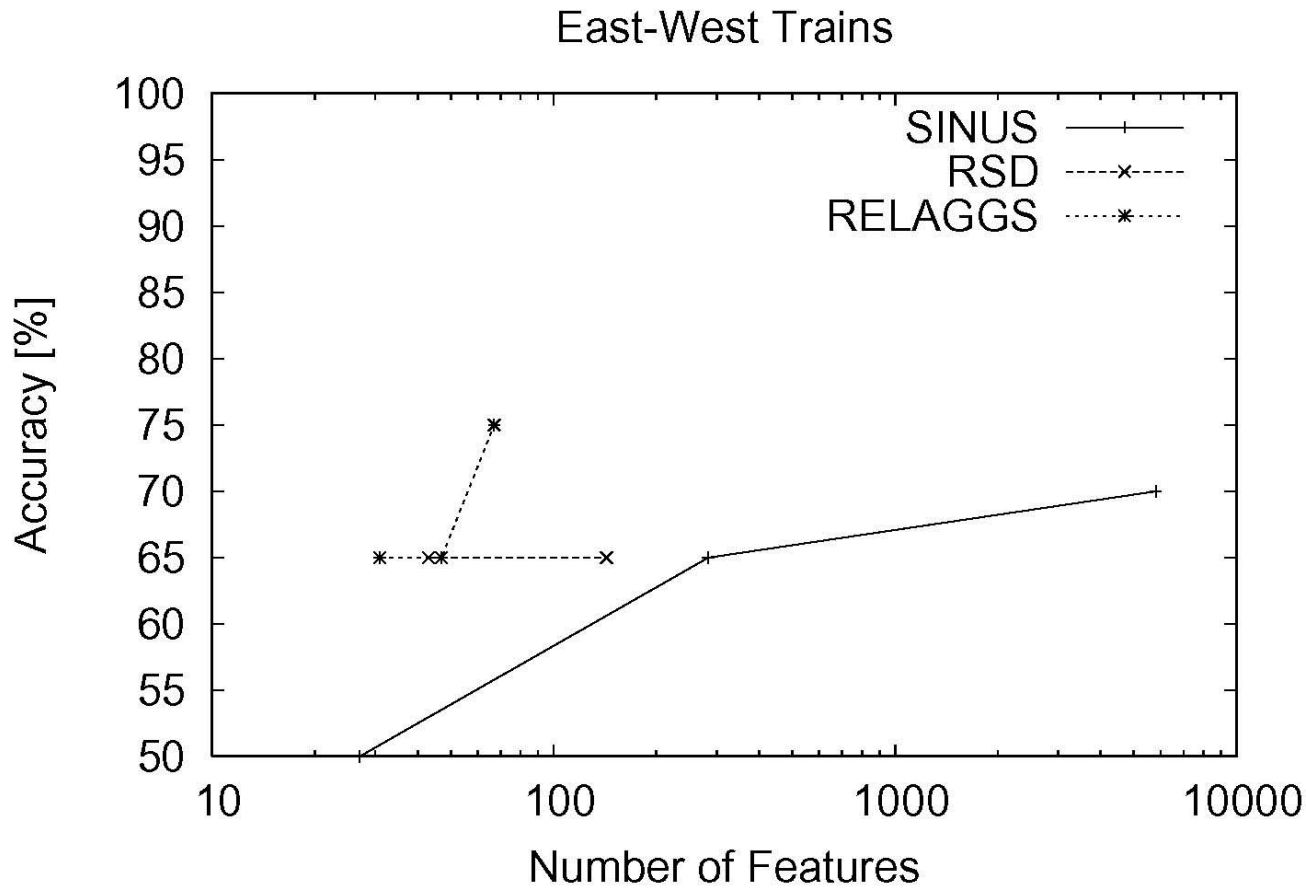
Learning Tasks

- Trains: 20 trains east- or west-bound?
- King-Rook-King: 1000 board states legal or not?
- Mutagenesis: 188 molecules mutagenic or not?
- PKDD Challenges 1999/2000: 682 loans problematic or not?
- KDD Cup 2001: 862 genes/proteins with certain function or not and with certain localization or not?
- Numbers of predicates/relations depend on modeling issues.

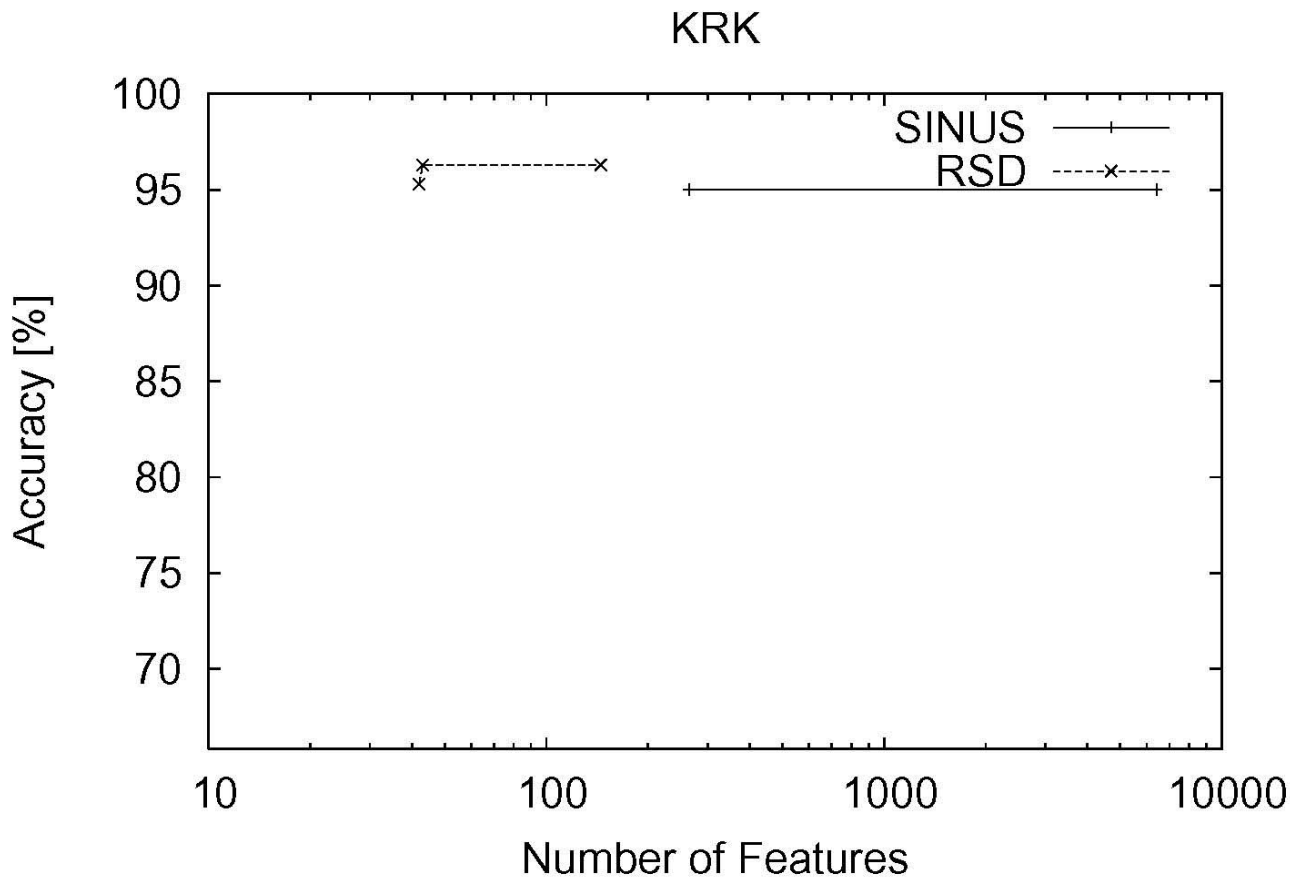
Procedure

- Mostly starting point: Prolog representation of target predicate facts and background predicate definitions, SQL scripts generated from those if necessary
- Manual construction of declarations, propagation of id‘s if necessary
- Application of RSD, SINUS, and RELAGGS to produce single-table representations of relational input data, with different parameter settings to produce feature sets of different sizes
- Application of WEKA‘s J48 (10-fold stratified cross-validation) to those tables

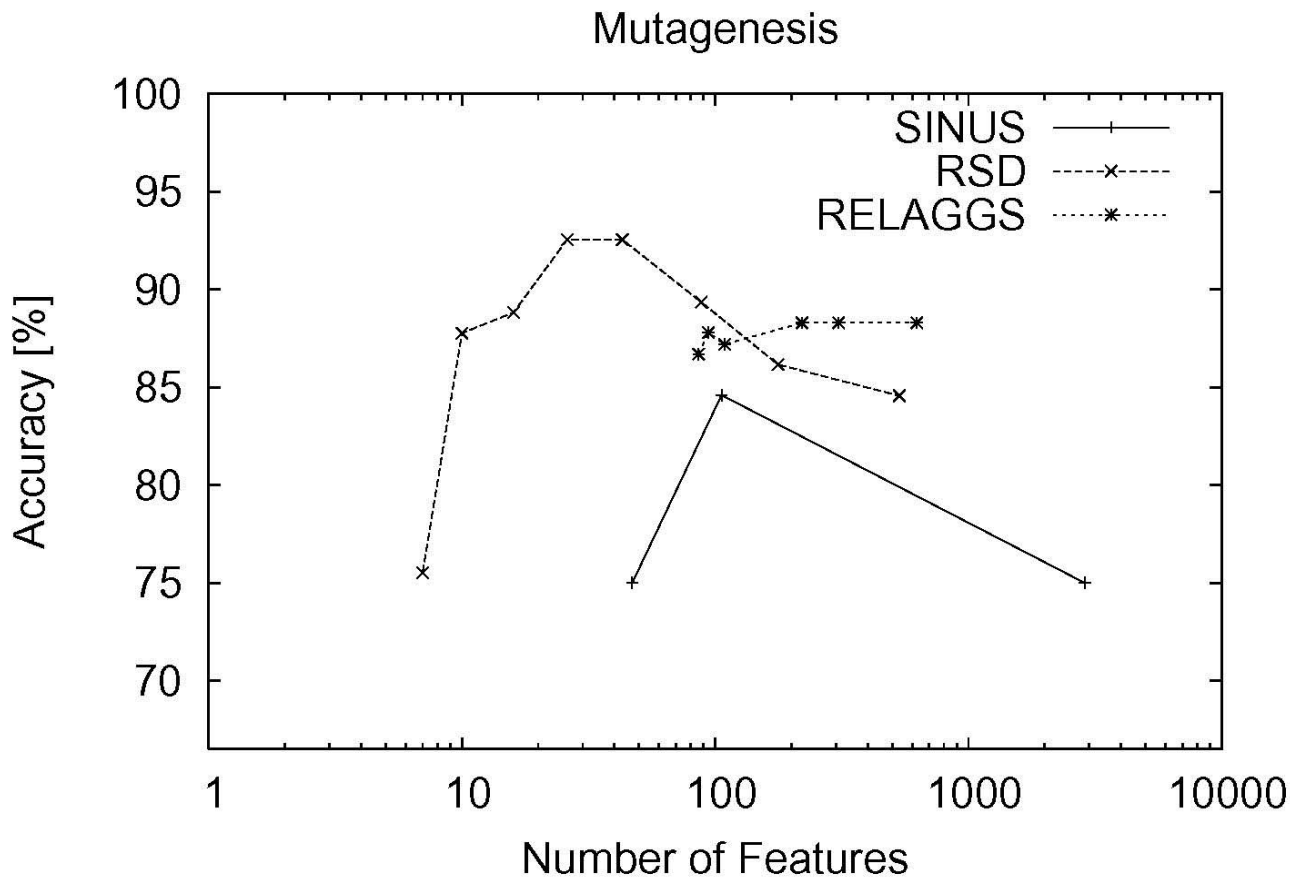
Results: Accuracies (1)



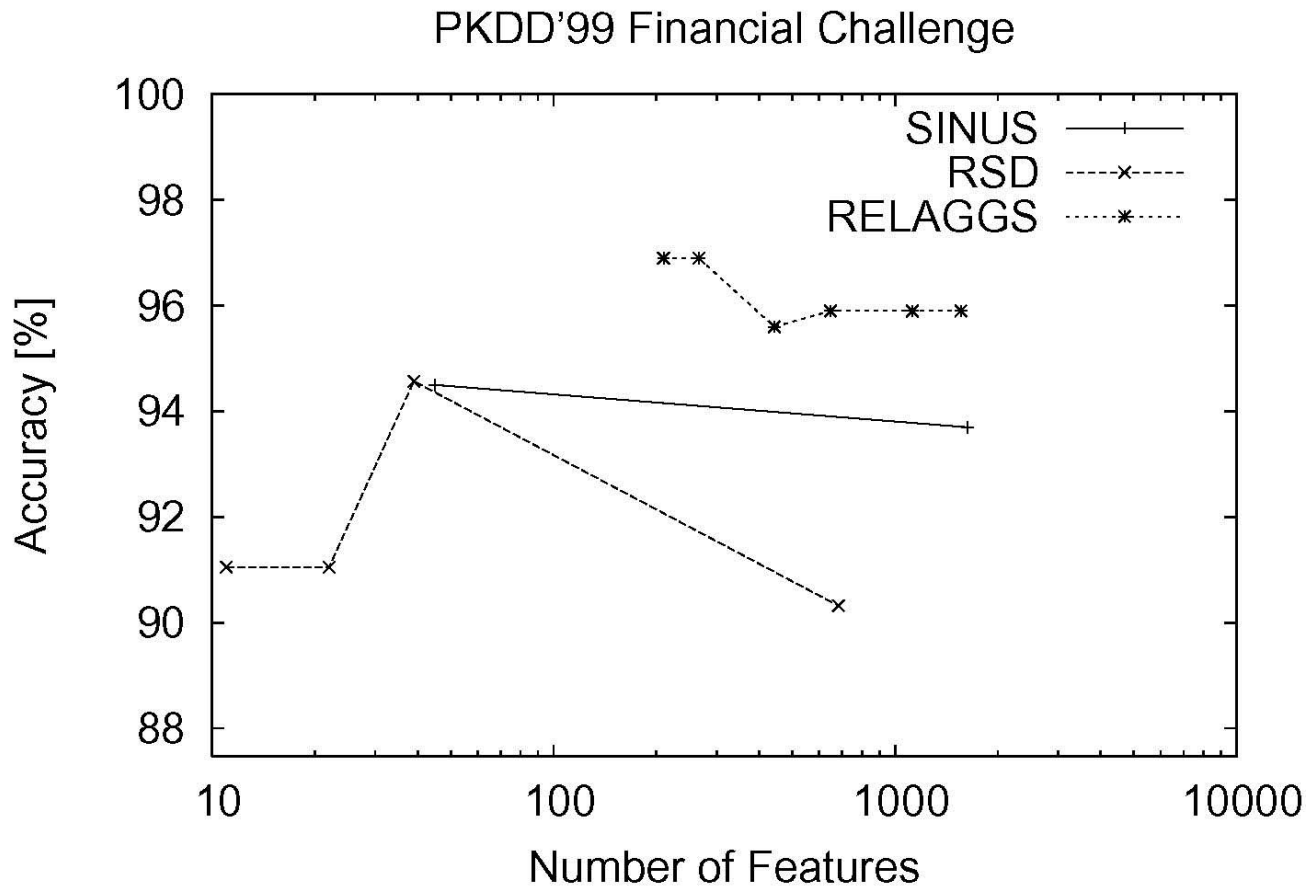
Results: Accuracies (2)



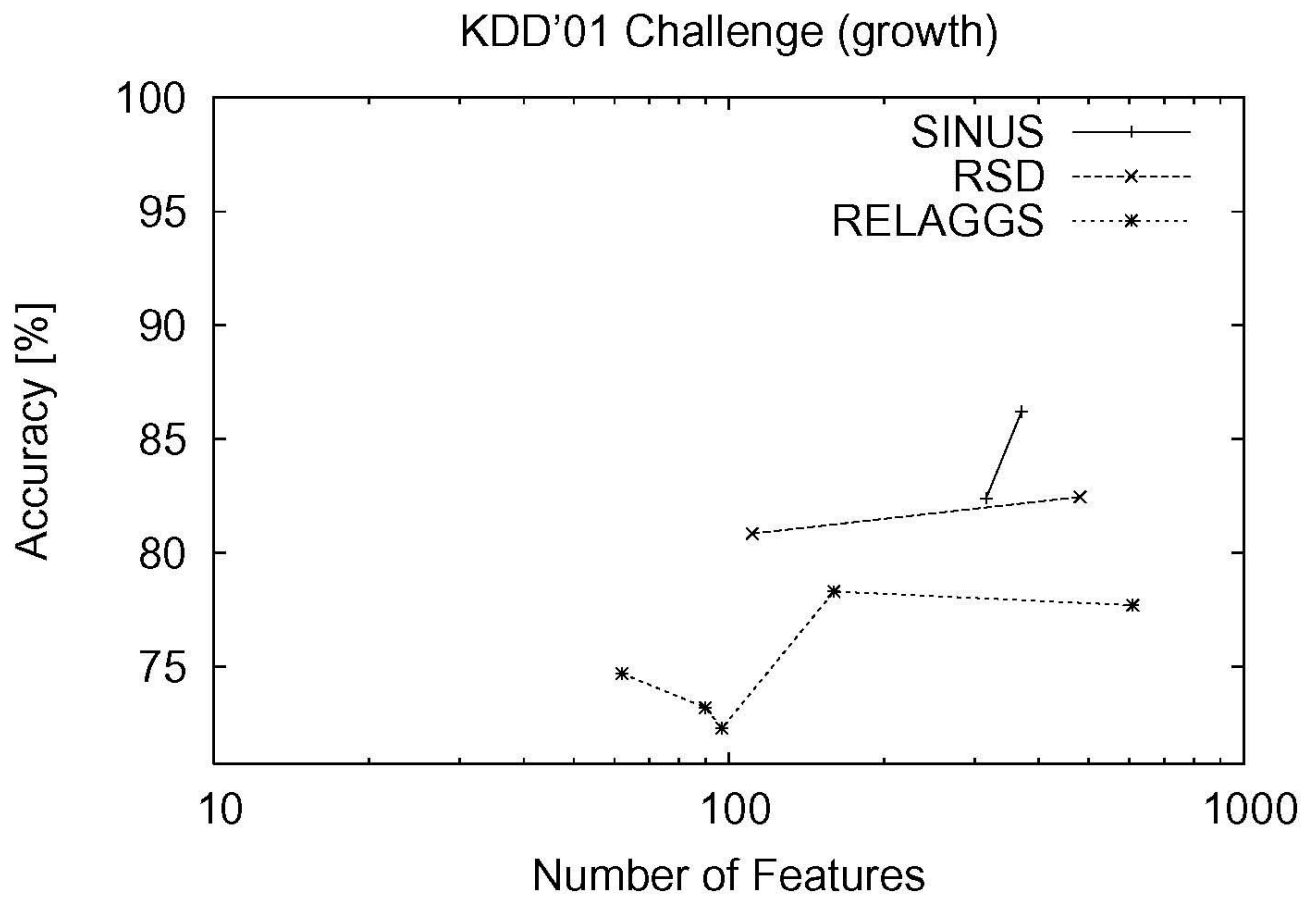
Results: Accuracies (3)



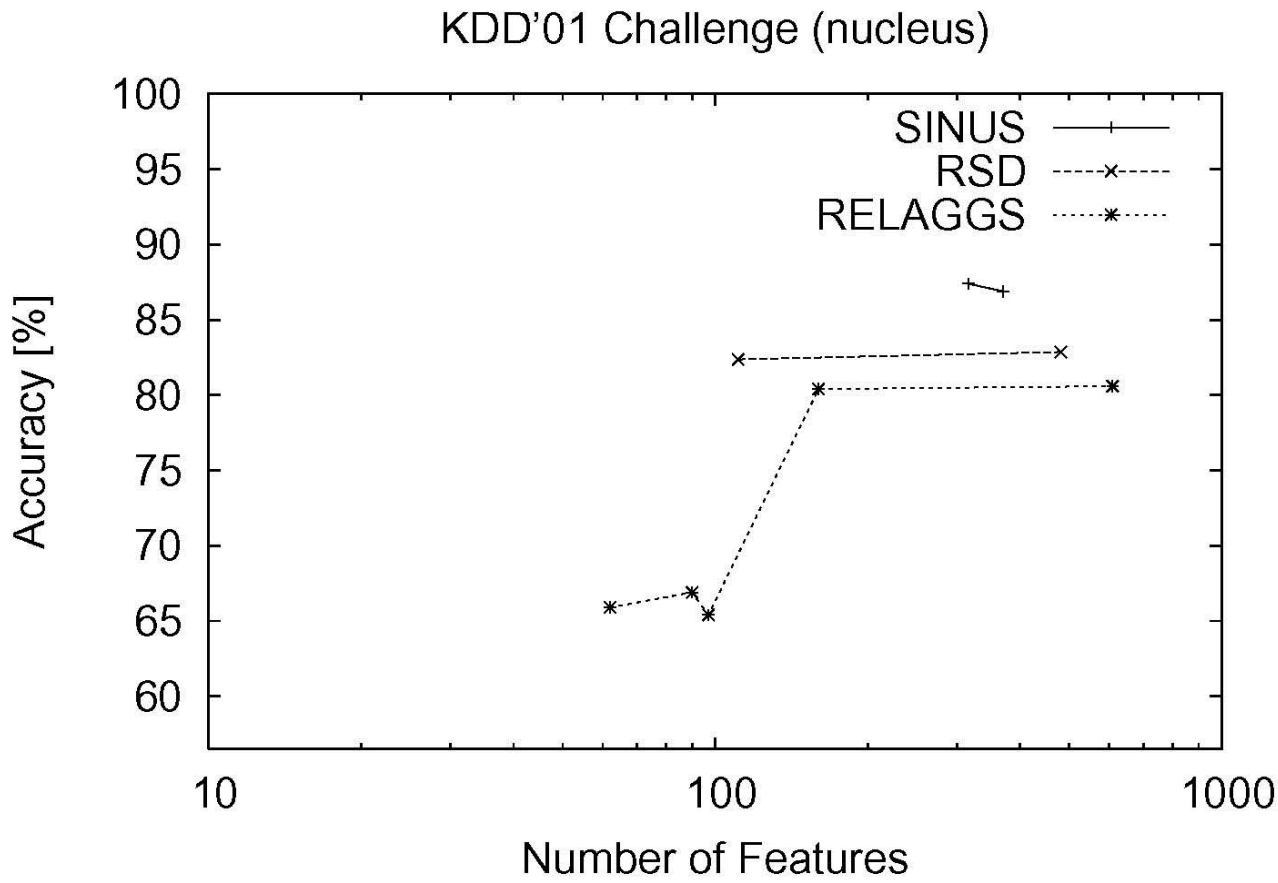
Results: Accuracies (4)



Results: Accuracies (5)



Results: Accuracies (6)



Results: Runtimes

- Different platforms, hence times only indicators
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	RSD	SINUS	RELAGGS
Trains	< 1 sec	2 - 10 min	< 1 sec
King-Rook-King	< 1 sec	2 - 6 min	n. a.
Mutagenesis	5 min	6 - 15 min	30 sec
PKDD99-00	5 sec	2 – 30 min	30 sec
KDD01 fct	3 min	30 min	1 min
KDD01 loc	3 min	30 min	1 min

Discussion

- Not generally conclusive in favor of any approach:
  each winner on two tasks
- Aggregation strong in some domains,
  where counting features are relevant (Trains)
  or many numeric attributes exist in the original data
- Differences between RSD and SINUS mainly due
  to differences in constraining the language bias
- RELAGGS most efficient for many tasks, differences between
  RSD and SINUS possibly caused by pruning or Prolog systems

Related Work

- LINUS/DINUS (Lavrač and Džeroski 1994)
- Stochastic propositionalization (Kramer et al. 1998)
- Bottom-up propositionalization (Kramer 2000)
- Lazy propositionalization (Alphonse and Rouveirol 2000)
- ...

Future Work and Conclusion

- General:
  - Completion of formal framework
  - Comparison to other ILP approaches such as Progol and Tilde
  - Extension of feature subset selection mechanisms
  - Experiments with other propositional learners such as SVMs
  - Combination of the features produced by the approaches here

- RSD: construction of first-order hypotheses
- SINUS: improvements of feature elimination, bias control
- RELAGGS: integration with dynamic relational databases

- Promising approaches with many questions left open!