Cse352

Artifficial Intelligence

Short Review for Midterm

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Midterm

- Midterm INCLUDES Lectures 1-11 and Homeworks 1,2, Resolution
- LOGIC
- PRODUCTION SYSTEMS
- PROPOSITIONAL RESOLUTION

  (material you needed for Q1)
- CLASSIFICATION
- CLASSIFICATION by Decision TREES

LOGIC: Restricted Domain Quantifiers

Translation for **existential** quantifier

$$\exists_{A(x)} B(x) \equiv \exists x(A(x) \wedge B(x))$$

↑ **restricted** ↑**logic, not restricted**

Example (mathematical formulas):

$\exists\ x{\neq}1\ (x>0 \Rightarrow x + y > 5)$ - restricted

$\exists x\ ((x{\neq}1\ ) \wedge (x > 0 \Rightarrow x + y > 5))$ - not restricted

↑ $B(x, y)$

English statement:

Some students are good.

Logic Translation (restricted domain):

$$\exists_{S(x)} G(x)$$

Predicates are :

S(x) – x is a student

G(x) – x is good

TRANSLATION:

$$\exists x(S(X) \wedge G(x))$$

LOGIC: Restricted Quantifiers

Translation for **universal** quantifier

Restricted Logic (non-restricted)

$\forall_{A(x)} B(x) \quad \Xi \quad \forall x\,(A(x) \Rightarrow B(x))$

Example (mathematical statement)

$\forall x \in N\ (x = 1 \lor x < 0)$ restricted domain

$\Xi\ \forall x\ (x \in N \Rightarrow (x = 1 \lor x < 0))$ – non-restricted

Translations to Logic

Rules:

1. **Identify** the domain: always a set $X \neq \phi$
2. **Identify** predicates (simple: atomic)
3. **Identify** functions (if needed)
4. **Identify** the connectives $\vee, \wedge, \Rightarrow, \neg, \Leftrightarrow$
5. **Identify** the quantifiers $\forall x, \exists x$ or Restricted Quantifiers $\forall P(x), \exists Q(x)$
6. **Write a formula using only symbols for 2 ,3, 4,5**

Use restricted domain quantifier translation rules, where needed to write

7. **Write LOGIC formula** – formula without Restricted Quantifiers

Translation to Logic

- Translations from Natural Language
- **Translate: "No house is red"**

- 1. Domain: $X \neq \phi$
- 2. Predicates: A(x) – x is a House B(y) – y is red
- 3. Functions: (none)
- 4. Connectives: ¬ - "**not**"
- 5. Quantifiers: $\exists_{A(x)}$ – "some houses" (restricted)
- 6. RESTRICTED FORMULA: $\neg \exists_{A(x)} B(x)$
- **7. LOGIC FORMULA:** $\neg \exists x\, (A(x) \wedge B(x))$

PREDICATE LOGIC TRANSLATION

- Translations from Natural Language
- **BE CAREFUL!**
- **YOU MUST ALWAYS DO DIRECT TRANSLATION**
- Never translate some logically EQUIVALENT statements such as
- **“All houses are not red”**
- instead of (via de Morgan Laws)
- **“No house is red”**

Translations Example

Translate: **Some patients like all doctors**

Predicates:

P(x) – x is a patient in the domain $X \neq \phi$, i.e. $x \in \mathbf{X}$

D(y) – y is a doctor in the domain $X \neq \phi$, i.e. $y \in \mathbf{X}$

L(x,y) – x likes y in the domain $X \neq \phi$, i.e. $x,y \in \mathbf{X}$

There is a **patient(x)**, such that for all **doctors(y)**, **x** likes **y**

$$\exists_{P(x)} \forall_{D(y)} L(x,y)$$

Non- restricted quantifiers

$$\exists x(P(x) \land \forall y(D(y) \Rightarrow L(x,y)))$$

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Learning Process

- Short Questions:

- Describe all stages of the Learning Process

- Describe the role of Preprocessing stage and its main methods

- Discuss the Learning Proper stage

Learning Models

- Describe what is Descriptive/ non-Descriptive Learning
- List some Descriptive/ non-Descriptive Models
- How and what decides which type of Learning is the best to use (implement)
- Give examples of types of applications and the best Models (algorithms) for them

Classification

- Describe what is CLASSIFICATION; type of data, goals and applications
- Describe all stages of the classification process
- Describe and discuss basic classification Models and their differences

Classification

- Discuss the Decision Tree Induction and its strengths and weaknesses
- Define a CLASSIFIER
- Describe a process of building a CLASSIFIER

Classification Data and Rules

Given a classification dataset **DB** with a set

A = {*a1, a2,…, an*} of **attributes** and a **class** attribute **C** with values

{*c1, c2,…, ck*} - **k classes**

Definition 1

Any expression ***a1 = v1 & … & ak = vk*** where ***ai* ∈ A** and ***vi*** are corresponding values of attributes from **A**

is called a **DESCRIPTION**

Any expression **C = *ci*** is for ***ci* ∈ {*c1, c2,…, ck*}**

Is called a **CLASS DESCRIPTION**

Classification Data and Rules

Definition 2

A **CHARACTERISTIC FORMULA** is any expression

C = ck => a1 = v1 & … & ak = vk

We write is as

CLASS => DESCRIPTION

Definition 3

A **DETERMINANT FORMULA** is any expression

a1 = v1 & … & ak = vk => C =ck

We write it as

DESCIPTION CLASS

Classification Data and Rules

Definition 4

A characteristic formula

CLASS => DESCRIPTION

is called a **CHARACTERISITIC RULE** of the classification dataset **DB**

iff

it is **TRUE** in **DB**, i.e. when the following holds

{o: DESCRIPTION} /\ {o: CLASS} is a non-empty set

Where

{o: DESCRIPTION}

is the set of all records of DB corresponding to the **DESCRIPTION**

{o: CLASS} is the set of all records of DB corresponding to the **CLASS**

Classification Data and Rules

Definition 5

A discriminant formula

DESCRIPTION => CLASS

is called a **DISCRIMINANT RULE** of **DB**

iff

it is **TRUE in DB,** i.e. the following conditions hold

1. **{o: DESCRIPTION} is a non-empty set**
2. **{o: DESCRIPTION} is included in {o: CLASS}**

PROBLEM 1

Prove

that for any **classification** data base **DB**

and any of its **DISCRIMINANT RULES** of the form

DESCRIPTION ⇒ CLASS

the formula

$\subseteq$

CLASS ⇒ DESCRIPTION

is a **CHARACTERISTIC RULE** of the **DB**

PROBLEM 1 Solution

By **definition 5**, for any database DB :

DESCRIPTION ⇒ CLASS

is a **DISCRIMINANT RULE** **iff**

1. **{o: DESCRIPTION}** **=** **not empty set**

2. **{o: DESCRIPTION}** **is** **included in {o: CLASS}**

Therefore,

{o: DESCRIPTION} /\ {o: CLASS} **=** **not empty set**

and by **Definition 4**

CLASS => DESCRIPTION

Is the **CHARACTERISITIC RULE**

PROBLEM 2

Given a dataset:

Record	a1	a2	a3	a4	C
O1	1	1	1	0	1
O2	2	1	2	0	2
O3	0	0	0	0	0
O4	0	0	2	1	0
O5	2	1	1	0	1

Find the set **{o :DESCRIPTION}**
for the following descriptions

1) a1 = 2 & a2 = 1
2) a3 = 1 & a4 = 0
3) a2 = 0 & a3 = 2
4) c=1
5) c=0

PROBLEM 2 SOLUTION

Find the set **{o :DESCRIPTION}**

for the following descriptions

1) a1 = 2 & a2 = 1 Answer : {o1 }
2) a3 = 1 & a4 = 0 Answer : {o1 , o5}
3) a2 = 0 & a3 = 2 Answer : {o4}
4) c=1 Answer : {o1,o5}
5) c=0 Answer : {o3 ,o5}

PROBLEM 3

For the following formulae use proper definitions to determine (**it means prove**) whether **they are / are not** **DISCRIMINANT / CHARACTERISTIC RULES** of our dataset.

6) $a1 = 1 \ \& \ a2 = 1 \Rightarrow C = 1$

7) $C = 1 \Rightarrow a1 = 0 \ \& \ a2 = 1 \ \& \ a3 = 1$

8) $C = 2 \Rightarrow a1 = 1$

9) $C = 0 \Rightarrow a1 = 1 \ \& \ a4 = 0$

10) $a1 = 2 \ \& \ a2 = 1 \ \& \ a3 = 1 \Rightarrow C = 0$

11) $a1 = 0 \ \& \ a3 = 2 \Rightarrow C = 1$

PROBLEM 3 SOLUTION

For the following formulae use proper definitions to determine (**it means prove**) whether **they are / are not** **DISCRIMINANT / CHARACTERISTIC RULES** of our dataset.

6) a1 = 1 & a2 = 1 ⇒ C = 1
{o1} is a subset of {o1 , o5} so **this is a DISCRIMINANT** rule

7) C =1 ⇒ a1 = 0 & a2 = 1 & a3 = 1
{o: a1 = 0 & a2 = 1 & a3 = 1 } is an empty set so this is **not** a CHARACTERISTIC rule

8) C = 2 ⇒ a1 = 1
As the intersection is empty so this is **not** a **CHARACTERISTIC** rule

9) C = 0 ⇒ a1 = 1 & a4 = 0 ----- {o3 , o4} /\ {o5} is empty set so this is **not a CHARACTERISTIC** rule

10) a1 = 2 & a2 = 1 & a3 = 1 ⇒ C = 0 ----- {o5} is not a subset of {o3 , o4} , so this is **not a DISCRIMINANT** rule

11) a1 = 0 & a3 = 2 ⇒ C = 1 ----- {o4} is not a subset of {o1 , o5} , so this is **not a DISCRIMINANT** rule

Classification

- Describe what is Classification; which is the goal, what data one needs etc….
- Describe all stages of the Classification Process
- Describe basic methods of training and testing
- Describe the process of building a CLASSIFIER
- What is a CLASSIFIER?

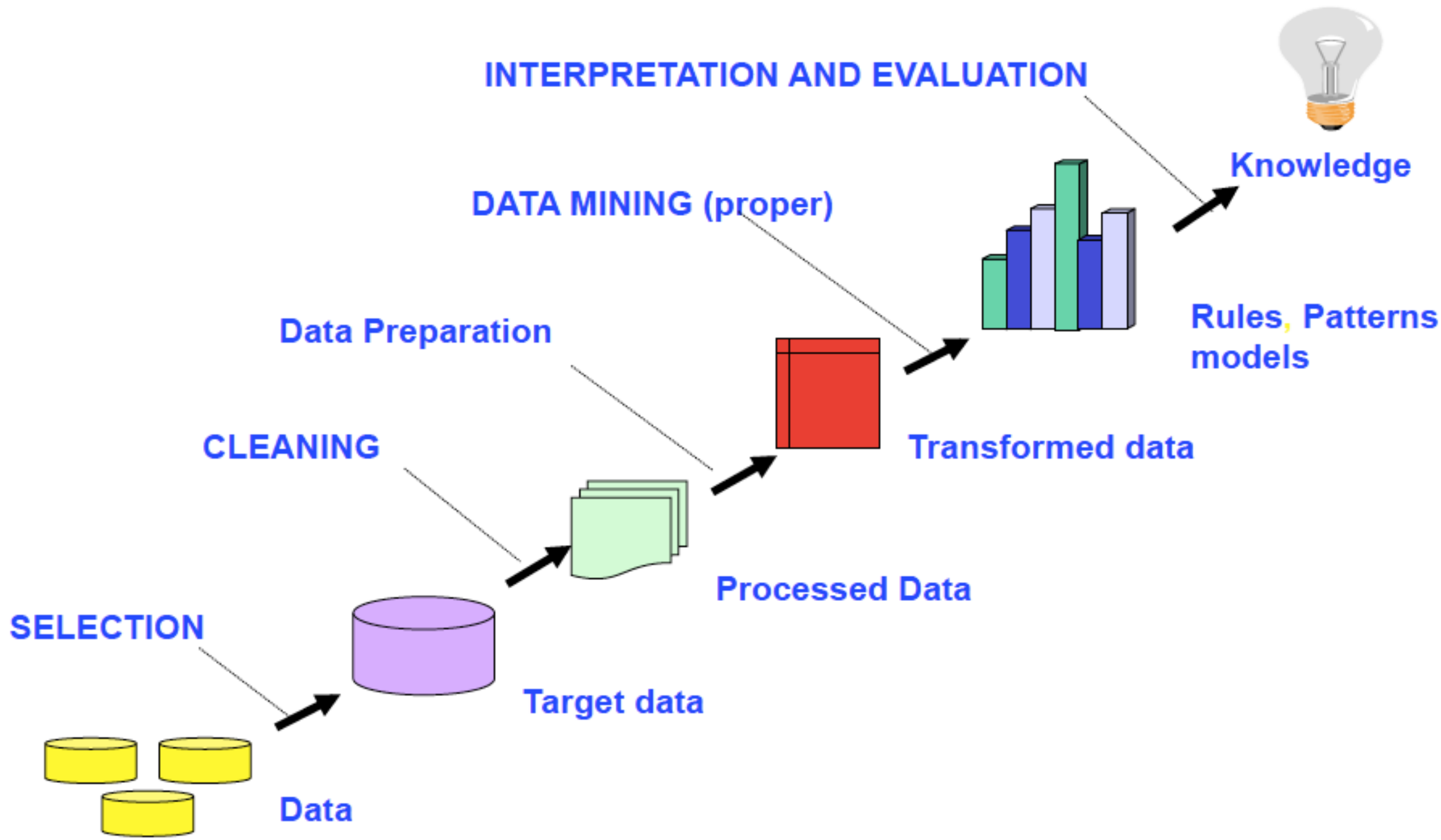
Problem: Classification by DTREE

1. Use the data below build a CLAFSSIFIER by basic DTREE algorithm
2. Use 2 different testing Method of your choice and compare the results

CLASSIFICATION DATA

Record	A1	A2	C
1	1	1	1
2	0	0	0
3	0	1	0
4	0	0	0
5	1	1	1
6	1	1	0
7	0	0	0
8	1	0	1

Data Mining Process



Preprocessing stage

- **Preprocessing:**
- includes all the operations that have to be performed before a learning algorithm is applied

- Data in the real world is dirty: incomplete, noisy and inconsistent.
- Quality decisions must be based on quality Data.

Preprocessing stage

- Data cleaning
- – Fill in missing values, smooth noisy data(binning, clustering, regression), identify or remove outliers, and resolve inconsistencies
- Data integration
- – Integration of multiple databases, data cubes, or files

Preprocessing stage: **Data transformation**

- Data reduction and attribute selection
- Obtains reduced presentation in volume but produces the same or similar analytical results (stratified sampling, PCA, cluster)

- Data discretization
- Part of data reduction but reduces the number of values of the attributes by dividing the values of attributes into intervals (segmentation by natural partition, hierarchy generation) or disjoint subsets (binning)
- Normalization and aggregation

Learning Proper

- **Learning proper** is a step in the LEARNING **process** in which algorithms are applied to obtain patterns in data.

- It can be re-iterated- and usually is

Descriptive / non descriptive models

- Statistical - descriptive
- Statistical data mining uses historical data to predict some unknown or missing numerical values
- Descriptive data mining aims to find patterns in the data that provide some information about what the data contains
- often presents the knowledge as a set of rules of the form IF.... THEN...

Models

- **Discriptive:** Decision Trees, Rough Sets,Association, Classification by Association
- **Statistical:** Neural Networks, Bayesian Networks, Cluster, Outlier analysis, Trend and evolution analysis
- **Optimization method:** Genetic Algorithms – can be descriptive

Classification

- **Classification:**
- Finding models (rules) that describe (characterize) or/ and distinguish (discriminate) classes or concepts for future prediction
- **Classification Data Format**:
- a data table with key attribute removed.
- Special attribute, called a class attribute must be distinguished.
- The values: c1, c2, ...cn of the class atrribute **C** are called **class labels**
- The class label attributes are discrete valued and unordered.

Classification

- **Goal:**
- FIND a minimal set of characteristic and/or discriminant rules, or **other descriptions** of the class C, or all, or some other classes

- We also want the found rules to involve as few attributes as it is possible

Classification and Classifiers

- **An algorithm** (model, method) is called **a** **classification algorithm**

- if it uses the classification data **to build a set of patterns:**
- **discriminant** and /or **characteristic rules**
- or other pattern descriptions

- These **patterns** are **structured** in such a way that **we can use** them to **classify** unknown sets of objects: unknown tuples, records

Classification and Classifiers

- For the reason that
- **we can use** discovered **patterns** to **classify** unknown sets of objects a **classification algorithm** is often called shortly **a classifier**

- **Remember** that the name **classifier** implies **more** than just a **classification algorithm**

- **A classifier** is a **final product** of a **process** that uses **data set** and a **classification algorithm**

Building a Classifier

- **Building** a **classifier** consists of two phases:

training and **testing**

In both phases we use

- **training data set** and **disjoint** with it
- **test data set** for both of which the **class labels** are **known for all** of the records

Building a Classifier

- We use the **training data** set to **create patterns: rules, trees**, or to **train** a **Neural** or **Bayesian** network

- **We evaluate** created **patterns** with the use of the **test data**
- The **measure** for a **trained classifier** is called **predictive accuracy**

- **The classifier is build,** i.e. we **terminate** the process if it has been **trained** and **tested** and the **predictive accuracy** is on an **acceptable level**

Classification Stages

- **Stage 1:** build the basic patterns structure- **training**
- **Stage 2:** optimize parameter settings; can use (N:N) re-substitution- **parameter tuning**
- Re-substitution error rate = training data error rate
- **Stage 3:** use **test data** to compute- predictive accuracy/error rate – **testing**
- **Stage 4:** finish building the **classifier**

Decision Tree

- DECISION TREE
- A flow-chart-like tree structure；
- Internal node denotes an attribute;
- Branch represents the values of the node attribute;
- Leaf nodes represent class labels

DT Basic Algorithm

- The **basic DT algorithm** for decision tree construction is a greedy algorithm that constructs decision trees in a top-down recursive divide-and-conquer manner

- Tree STARTS as a single node representing all training dataset (data table with records called samples)
- **IF** the samples (records in the data table) are all in the same class, **THEN** the node becomes a leaf and is labeled with that class
- The algorithm uses the same process recursively to form a **decision tree** at each partition

DT Basic Algorithm

- The recursive partitioning **STOPS** only when any one of the following conditions is TRUE
- **1.** All records (samples) for the given node belong to the same class
- **2.** There are no remaining attributes on which the samples (records in the data table) may be further partitioned – a **LEAF** is created with **majority vote** for training sample
- **3.** There is no records (samples) left – a **LEAF** is created with **majority vote** for training sample

- **Majority voting** involves converting node N into a leaf and labeling it with the most common class in **D** which is a set of **training** tuples and their associated class labels

Attribute Selection Measures

- **Some Heuristics:**
- **DTree:** some Attribute Selection Measures
- **Information Gain, Gini Index**

- **We use them for selecting the attribute that "best" discriminates the given tuples according to class**

Rule Based Systems REVIEW
Exercise

- **Exercise 1**
- Here are three simple **expert rules**
- **R1:** If your savings are small, then don't invest in stocks
- **R2:** If you have no children and large income, then invest in stocks
- **R3:** If you have children and small income, then invest in savings

Exercise 1

- **Conceptualize** rules **R1, R2, R3**

in **Predicate Form** using predicates

attribute(x, value of attribute)

attribute(object, value of attribute)

WRITE a format of a database TABLE **needed for your conceptualization**

REMARK: In order to express the rules **Predicate Form** , we must first define appropriate ATTRIBUTES and their values

Exercise 1

- **We have the following ATTRIBUTES:**

- **Savings**
  Values: **small, large**
- **Income**
  Values: **small, large**

- **InvestStocks**
  Values: **yes, no**

- **InvestSavings**
- Values: **yes, no**

- **Children**
  Values: **yes, no**

Exercise 1: Predicate Form Conceptualization Data Table Example

Records	Savings	Income	InvesrStocks	InvestSavings	Children
O_1	small	small	yes	yes	yes
O_2	large	small	no	no	no
O_3	small	large	yes	yes	no

Exercise 1: Rules in Predicate Form

- **RULES:**
- **R1:** Savings(x, small) → InvestStock (x, no)
- **R2:** Children(x, no) /\ Income(x, large)→ InvestStocks(x, yes)
- **R3:** Children(x, yes)) /\ Income(x, small)→ InvestSavings(x, yes)
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Exercise 2

- Exercise 2
- **The initial database has the following FACTS**
- F1: Savings(John, small)
- F2: Children(John, no)
- F3: Income(John, large)
- **1.** Are these FACTS true in Exercise 1 Data Table for a record o = John?
- **2.** Design a Data Table 2 in which the above **FACTS** are true
- **3.** Can you deduce InvestStocks(John, yes) on the base of the Data Table 2

Part 3: Exercise 3

- Given rules from **Exercise 1:**
- **R1:** If your savings are small, then don't invest in stocks
- **R2:** If you have no children and large income, then invest in stocks
- **R3:** If you have children and small income, then invest in savings

Exercise 3

- **Conceptualize** rules **R1, R2, R3**

In **Propositional Logic** in two ways:

1. Rules admit **only** atomic formulas; i.e. rules are built from propositional variables only – call the set of rules **PR1**
2. Rules admit atomic formulas and negation of atomic formulas – call obtained set of rules **PR2**

Exercise 3

- Write initial databases B1 and B2

  of facts corresponding to the facts F1, F2, F3 from Exercise 2 for
- (1) propositional conceptualization 1.
- (2) propositional conceptualization 2.
- (3) use corresponding rules from sets

  PR1, PR2 to deduce **all facts** from

  B1 and B2, respectively

  Use **Conflict Resolution** from Busse Handout