



# Probabilistic Models of Relational Data

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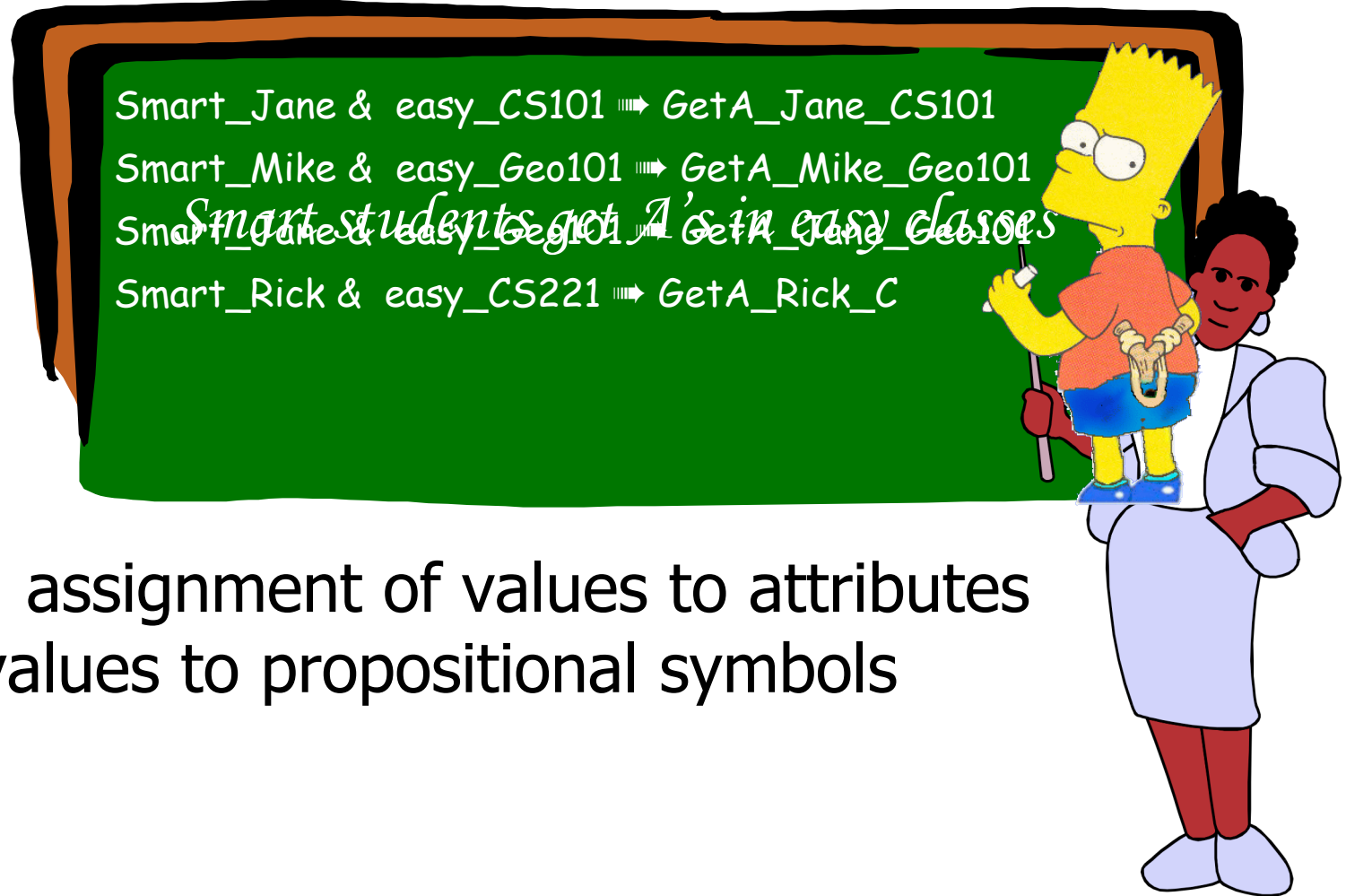
# Why Relational?

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- The real world is composed of objects that have properties and are related to each other
- Natural language is all about objects and how they relate to each other
  - “George got an A in Geography 101”



# Attribute-Based Worlds



- World = assignment of values to attributes / truth values to propositional symbols



# Object-Relational Worlds



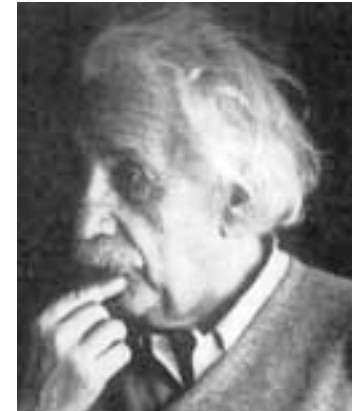
$\forall x,y(\text{Smart}(x) \ \& \ \text{Easy}(y) \ \& \ \text{Take}(x,y) \Rightarrow \text{Grade}(A,x,y))$

- World = relational interpretation:
  - Objects in the domain
  - Properties of these objects
  - Relations (links) between objects



# Why Probabilities?

- All universals are false (almost)
  - Smart students get A's in easy classes
- True universals are rarely useful
  - Smart students get either A, B, C, D, or F



**C student**

The actual science of logic is conversant at present only with things either certain, impossible, or entirely doubtful ...

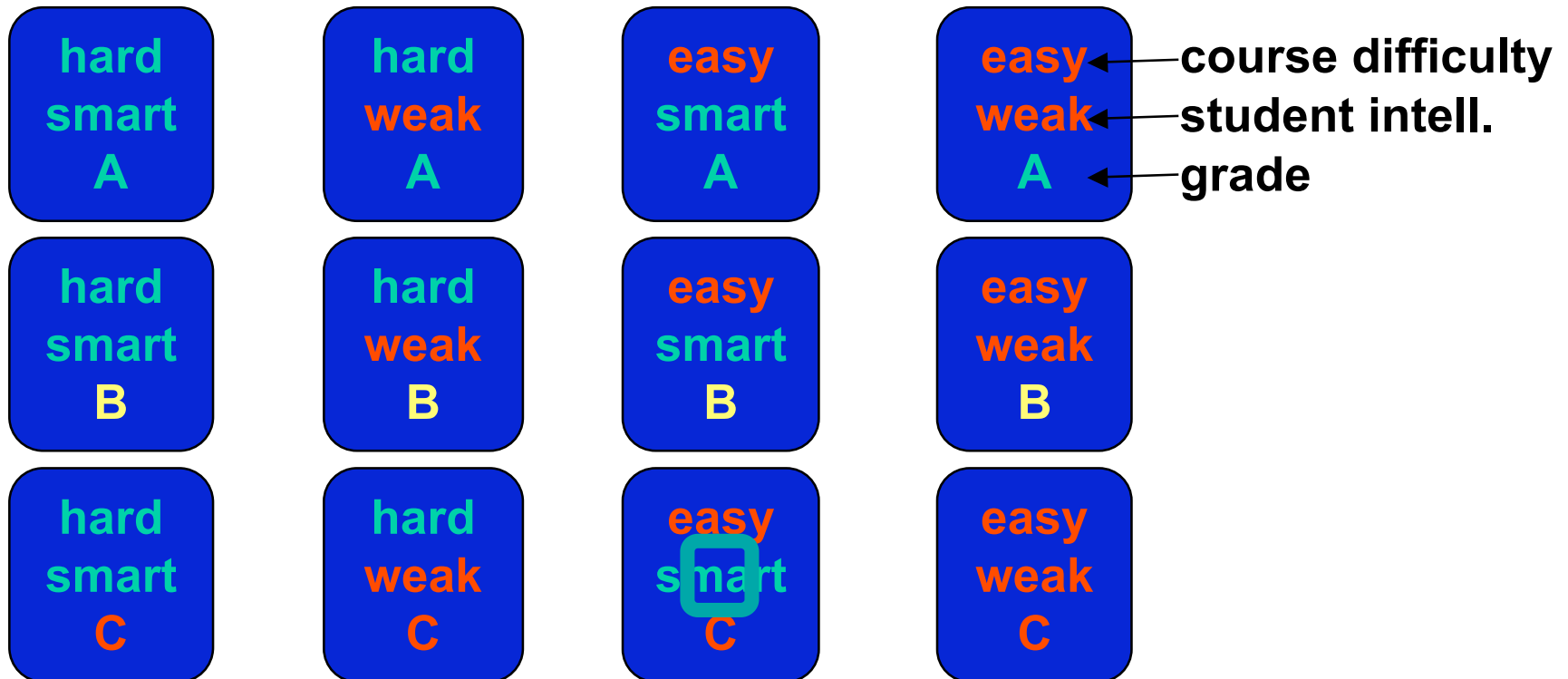
**Therefore the true logic for this world is the calculus of probabilities ...**

James Clerk Maxwell



# Probable Worlds

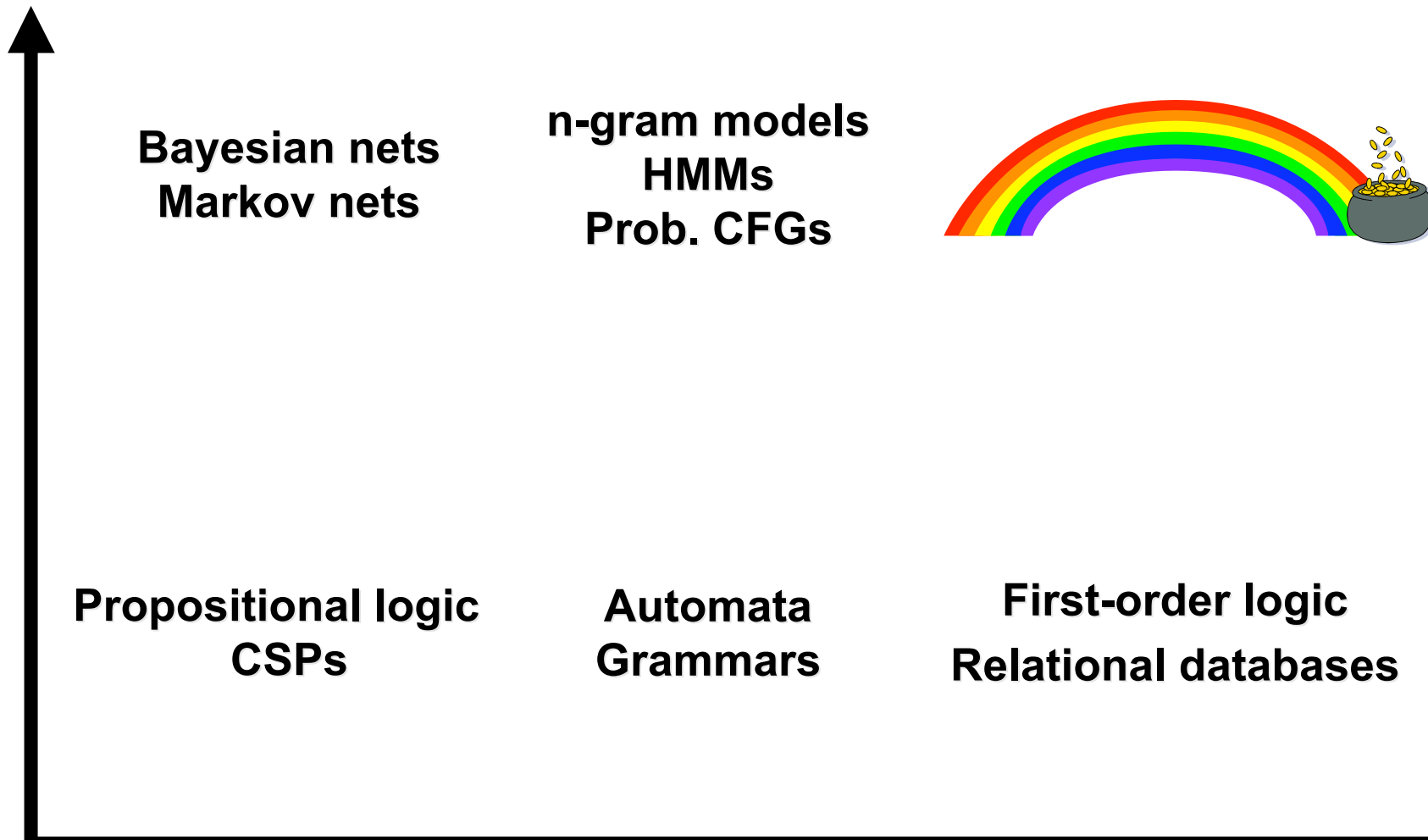
- Probabilistic semantics:
  - A set of possible worlds
  - Each world associated with a probability





# Representation: Design Axes

Epistemic state  
Probabilistic  
Categorical



Attributes

Sequences

Objects

World state



# Outline

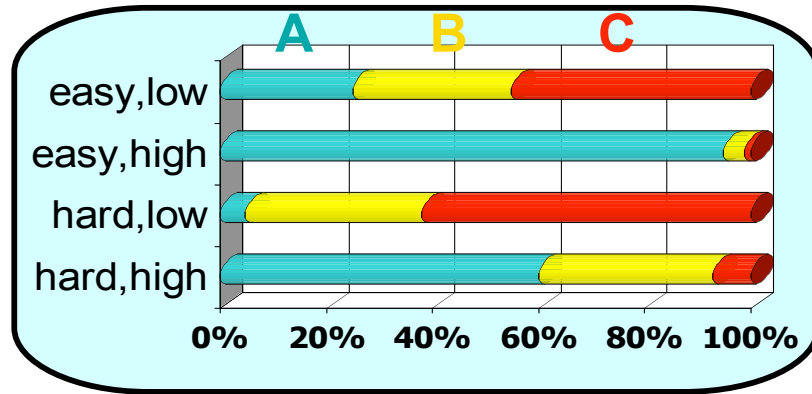
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- **Bayesian Networks**
  - Representation & Semantics
  - Reasoning
- Probabilistic Relational Models
- Collective Classification
- Undirected discriminative models
- Collective Classification Revisited
- PRMs for NLP

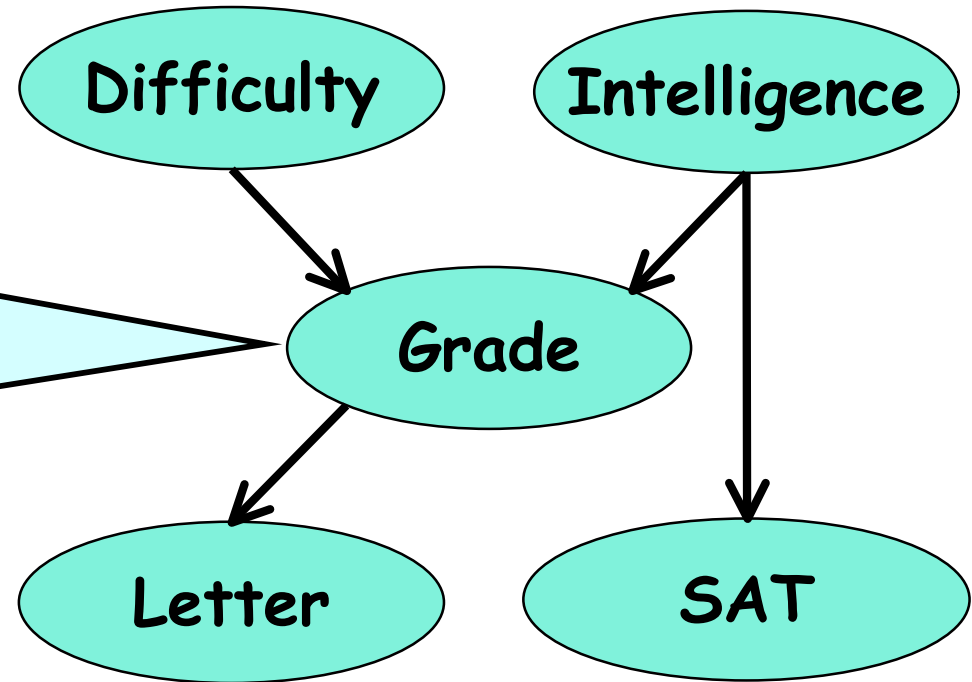


# Bayesian Networks

CPD  $P(G|D,I)$



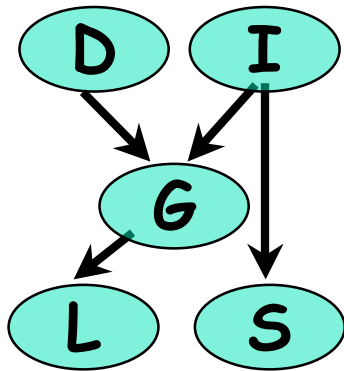
nodes = variables  
edges = direct influence



Graph structure encodes independence assumptions:  
*Letter* conditionally independent of *Intelligence* given *Grade*



# BN semantics



conditional  
independencies  
in BN structure

+ local  
probability =  
models

full joint  
distribution  
over domain

$$P(d,i,g,l,s) = P(d)P(i)P(g | d,i) \\ P(l | g)P(s | i)$$

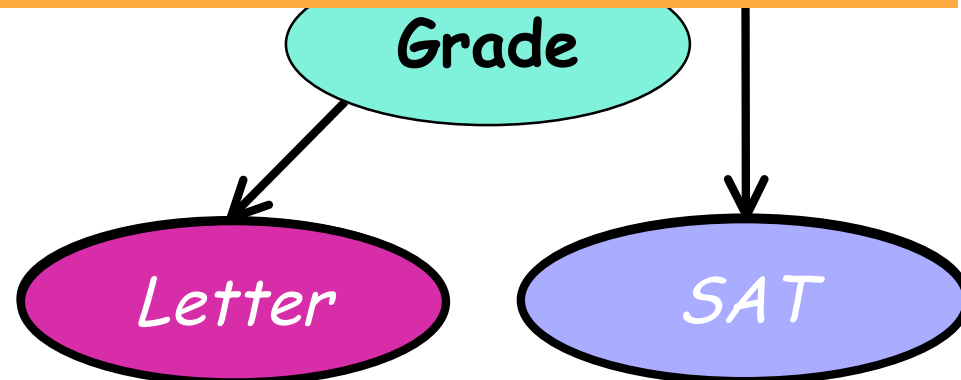
- Compact & natural representation:
  - nodes have  $\leq k$  parents  $\Rightarrow 2^{kn}$  vs.  $2^n$  params
  - parameters natural and easy to elicit



# Reasoning using BNs

Probability theory is nothing but common sense reduced to calculation.

Pierre Simon Laplace



Full joint distribution specifies answer to any query:  
 $P(\text{variable} \mid \text{evidence about others})$



# Outline

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- Bayesian Networks
- **Probabilistic Relational Models**
  - Language & Semantics
  - Web of Influence
- Collective Classification
- Undirected discriminative models
- Collective Classification Revisited
- PRMs for NLP





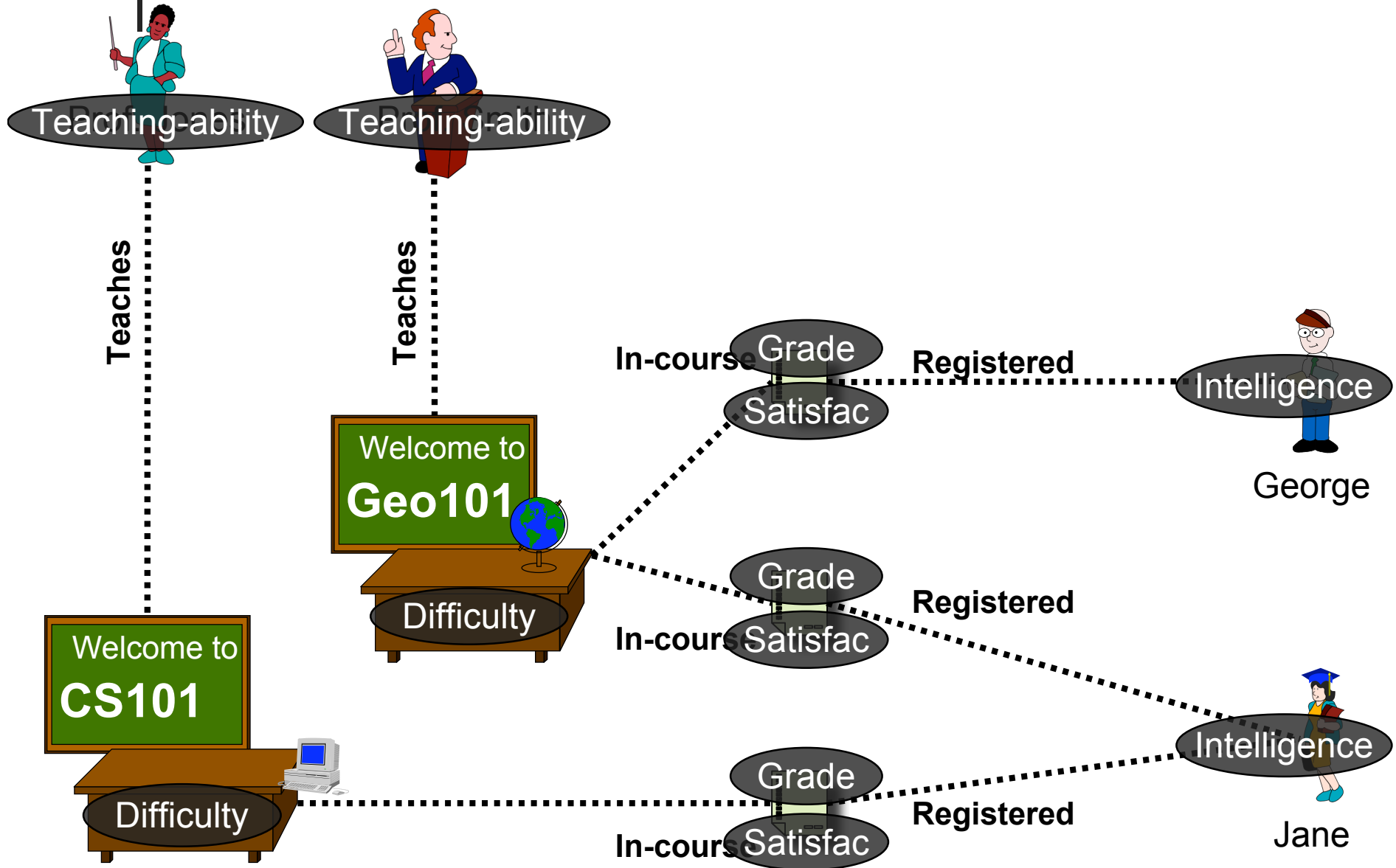
# Probabilistic Relational Models

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- Combine advantages of relational logic & BNs:
  - Natural domain modeling: objects, properties, relations
  - Generalization over a variety of situations
  - Compact, natural probability models
- Integrate uncertainty with relational model:
  - Properties of domain entities can depend on properties of related entities
  - Uncertainty over relational structure of domain



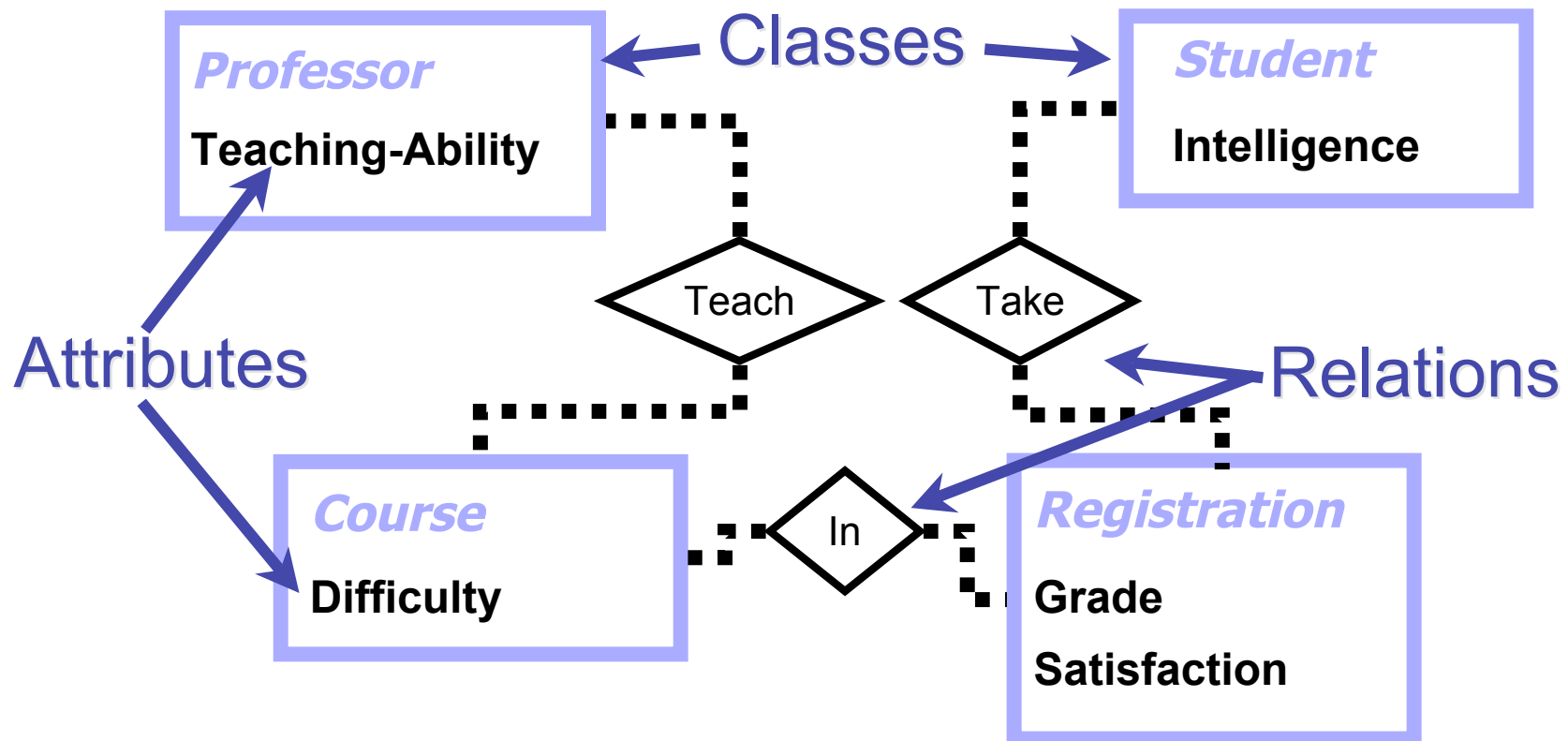
# St. Nordaf University





# Relational Schema

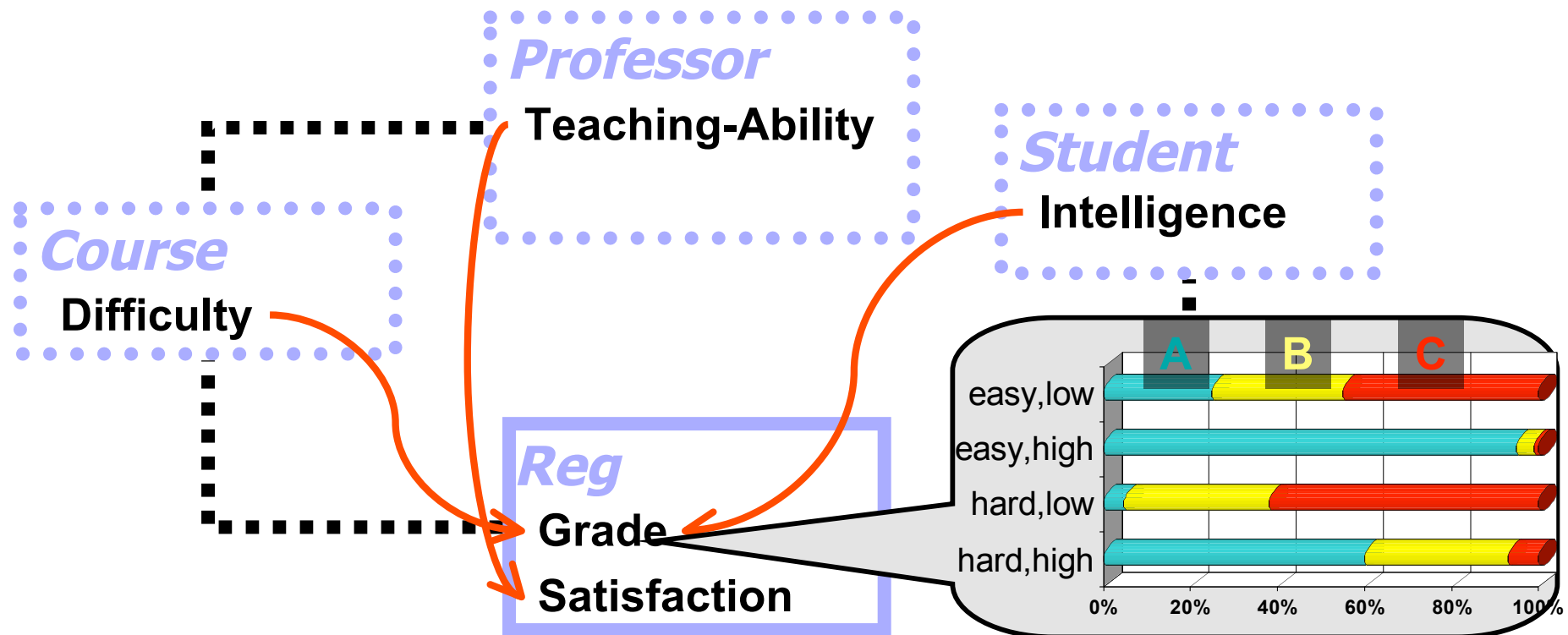
- Specifies types of objects in domain, attributes of each type of object & types of relations between objects





# Probabilistic Relational Models

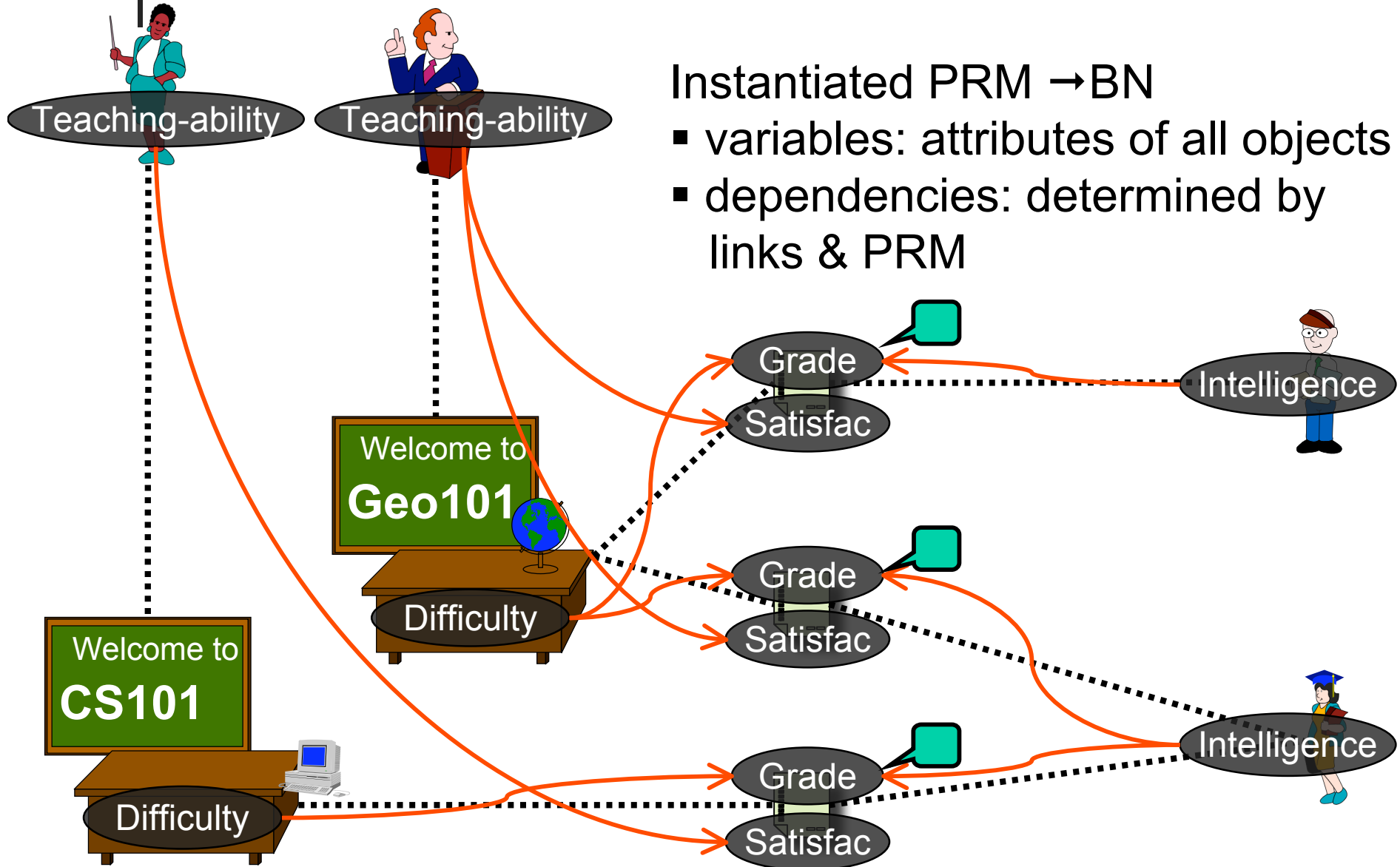
- Universals: Probabilistic patterns hold for all objects in class
- Locality: Represent direct probabilistic dependencies
  - Links define potential interactions



[K. & Pfeffer; Poole; Ngo & Haddawy]



# PRM Semantics





# Discovering Hidden Types

Bookmarks Location: <http://us.imdb.com/Title?0096895>

Back Forward Reload Home Search Netscape Print Security

Search the database for  
All

More searches | Tips

Overview  
main details  
combined details  
full cast and crew  
company credits

Awards & Reviews  
user comments  
external reviews  
newsgroup reviews  
awards & nominations  
user ratings  
recommendations

Plot & Quotes  
plot summary  
plot keywords  
Maltin summary  
memorable quotes

Fun Stuff  
trivia  
goofs  
soundtrack listing  
crazy credits  
alternate versions  
movie connections

Other Info  
merchandising links  
box office & business

## Batman (1989)

Directed by [Tim Burton](#)

Writing credits (WGA)  
[Bob Kane](#) (Batman characters)  
[Sam Hamm](#) (more)

Genre: [Action](#) / [Crime](#) / [Thriller](#) / [Fantasy](#) (more)

Plot Outline: The Dark Knight of Gotham City begins his war on crime with his first major enemy being the clownishly homicidal Joker. (more) (view trailer)

User Comments: Matt's Shoot and Sweet Review... (more)

User Rating: 7.1/10 (14586 votes)

Cast overview, first billed only:  
[Jack Nicholson](#) .... The Joker/Jack Napier  
[Michael Keaton](#) .... Batman/Bruce Wayne  
[Kim Basinger](#) .... Vicki Vale  
[Robert Wuhl](#) .... Alexander Knox  
[Pat Hingle](#) .... Police Commissioner Gordon

amazon.com

## Jack Nicholson

Photo Gallery **NEW**

Birth name  
John Joseph Nicholson

Date of birth (location)  
22 April 1937  
[Neptune, New Jersey, USA](#)

Mini biography  
Abandoned by his father in his childhood, he was raised believing his ... (show more)

Filmography as: [Actor](#), [Writer](#), [Producer](#), [Director](#), [Miscellaneous crew](#), [Notable TV guest appearances](#)

Actor - filmography  
(2000s) (1990s) (1980s) (1970s) (1960s) (1950s)

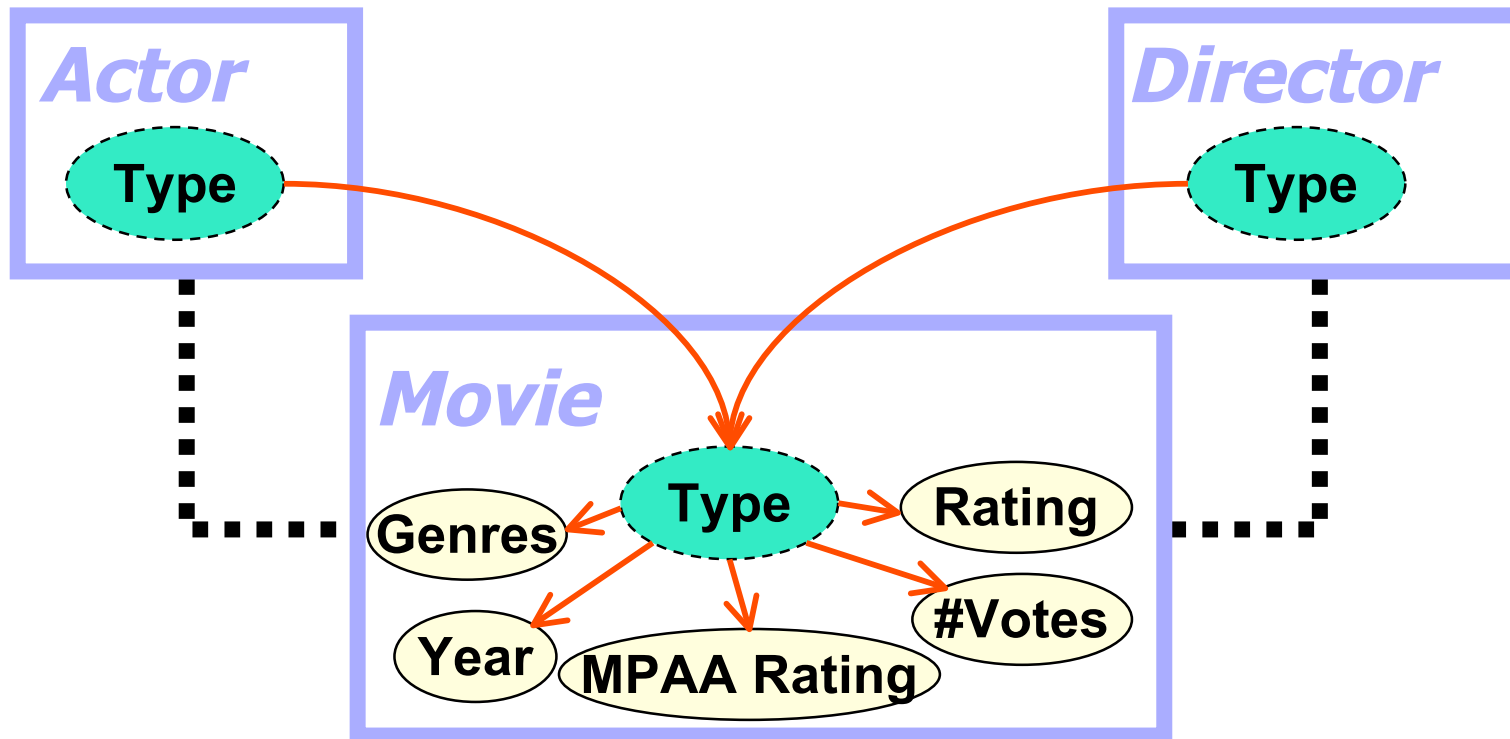
1. [About Schmidt \(2001\)](#) .... Warren Schmidt
2. [Stanley Kubrick: A Life in Pictures \(2001\)](#) .... Himself (Interviewee)
3. [Pledge, The \(2001\)](#) .... Detective Jerry Black
4. [Velocity \(2000\)](#)
5. [Hollywood Rocks the Movies: The Early Years \(1955-1970\) \(2000\)](#) (TV) (uncredited) .... Himself (preproduction footage of

amazon.com

Internet Movie Database  
<http://www.imdb.com>



# Discovering Hidden Types



[Taskar, Segal, Koller]



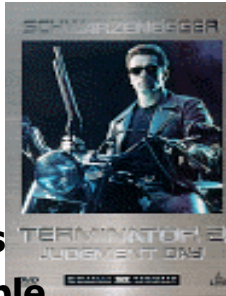
# Discovering Hidden Types

## Movies

Wizard of Oz  
Cinderella  
Sound of Music  
The Love Bug  
Pollyanna  
The Parent Trap  
Mary Poppins  
Swiss Family Robinson



Terminator 2  
Batman  
Batman Forever  
GoldenEye  
Starship Troopers  
Mission: Impossible  
Hunt for Red October



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## Actors

Sylvester Stallone  
Bruce Willis  
Harrison Ford  
Steven Seagal  
Kurt Russell  
Kevin Costner  
Jean-Claude Van Damme  
Arnold Schwarzenegger



Anthony Hopkins  
Robert De Niro  
Tommy Lee Jones  
Harvey Keitel  
Morgan Freeman  
Gary Oldman



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## Directors

Alfred Hitchcock  
Stanley Kubrick  
David Lean  
Milos Forman  
Terry Gilliam  
Francis Coppola



Steven Spielberg  
Tim Burton  
Tony Scott  
James Cameron  
John McTiernan  
Joel Schumacher

