Collective Classification

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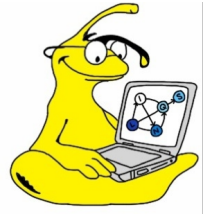
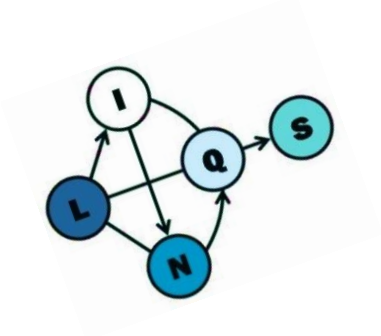
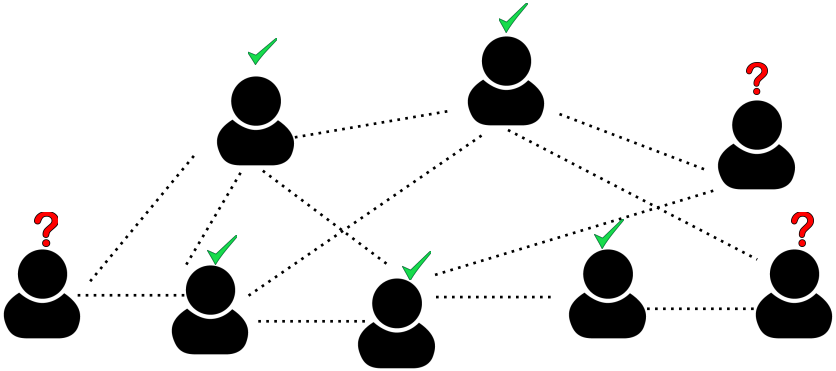
UC Santa Cruz
MLTrain 2018



psl.linqs.org
github.com/linqs/psl

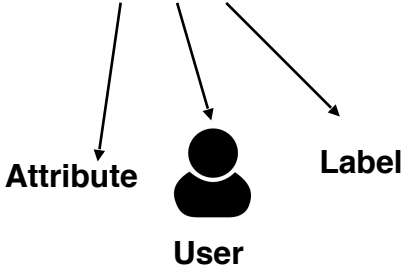


What is Collective Classification?

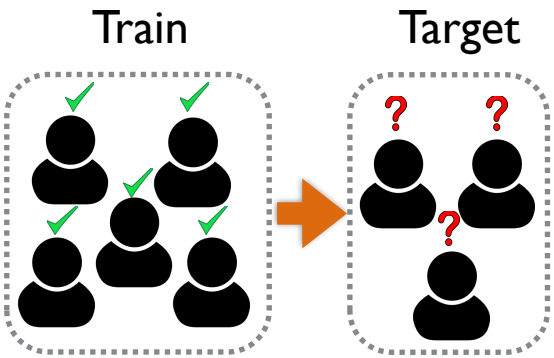


Attribute "**A**" of User "**U**" **is** Labeled "**L**"

```
Is(A,U,L)
```



What is Collective Classification?



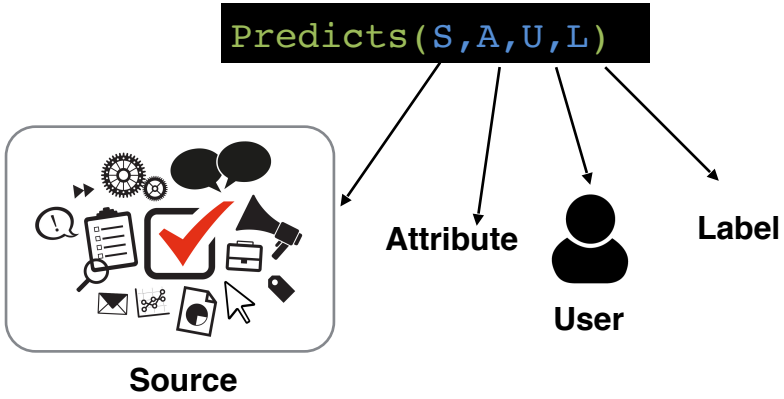
example:

```
Is(Gender,Alice,Female)
```

```
Is(Age,Bob,Young)
```

```
Is(Personality,Carol,Introvert)
```

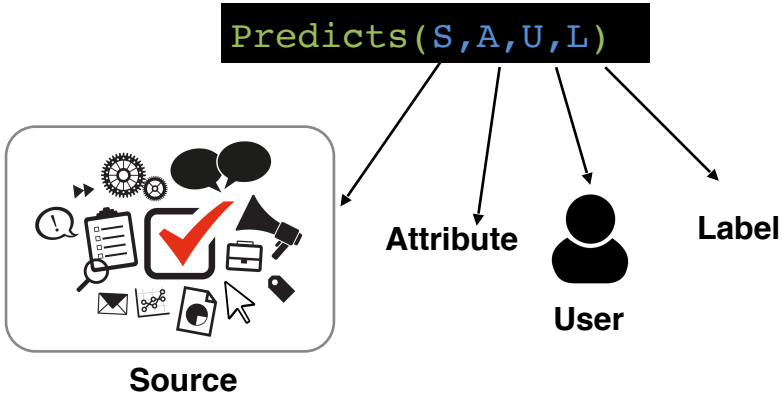
Local Predictor Rule



Source "**S**" **Predicts** Attribute "**A**" of User "**U**" **is** Labeled "**L**"

```
Predicts(S,A,U,L) -> Is(A,U,L)
```

Local Predictor Rule

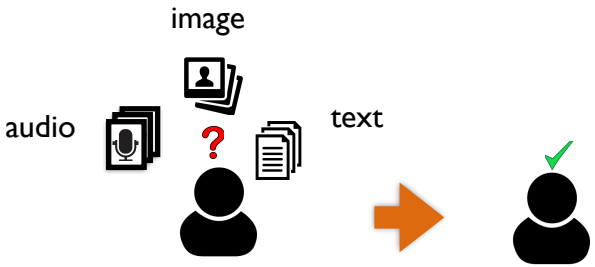


We collect training data to learn a predictive model, e.g. logistic regression

T_U	L_U
	0
⋮	⋮
	1

$$P(L|T)$$

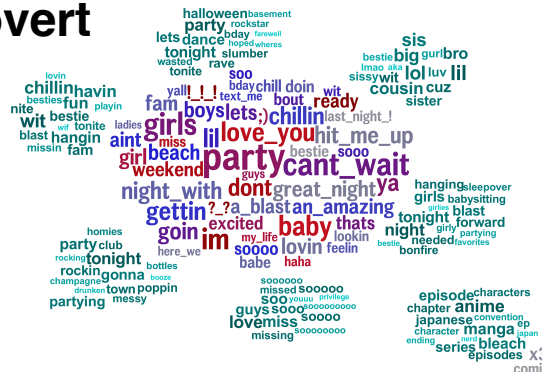
Local Predictor Rule



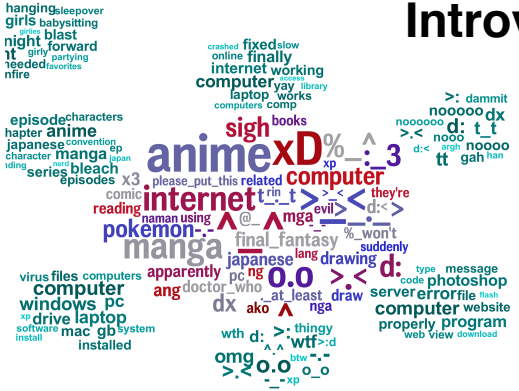
example:

```
Predicts(Txt,Personality,Alice,Int)
                    -> Is(Personality,Alice,Int)
```

Extrovert

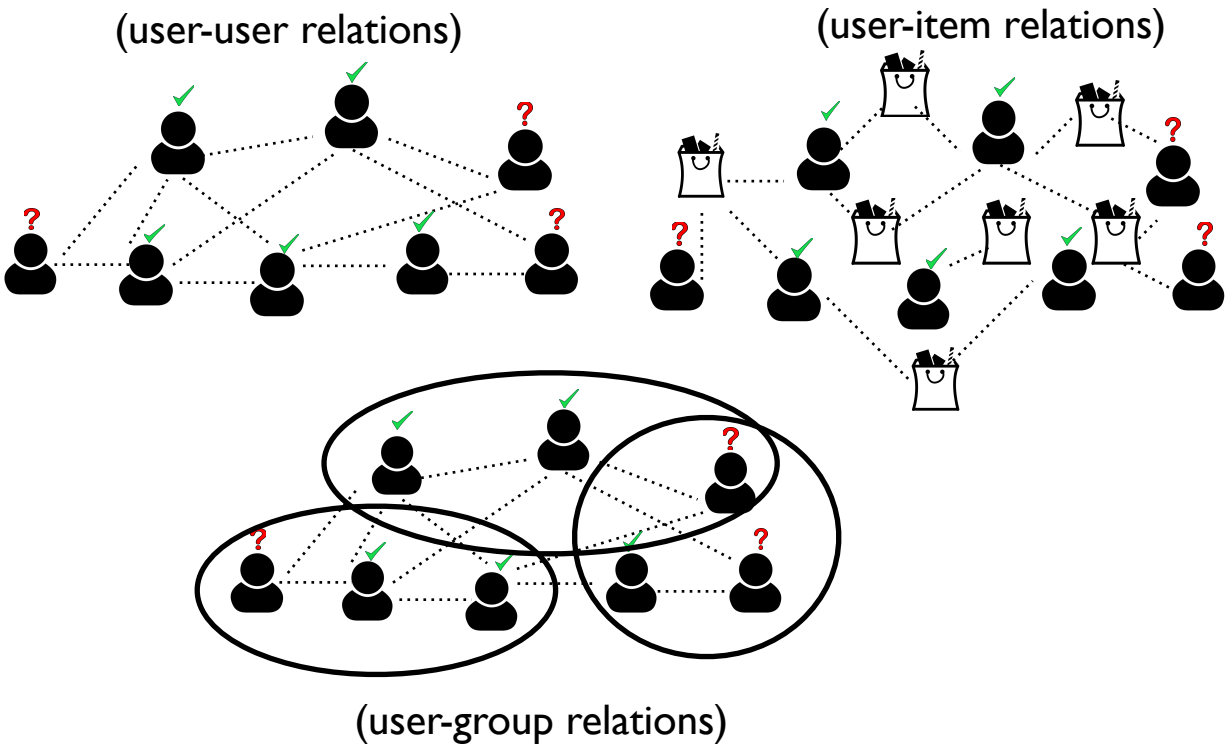


Introvert

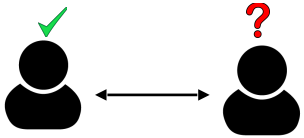


Park G, Schwartz HA, Eichstaedt JC, Kern ML, Kosinski M, Stillwell DJ, Ungar LH, & Seligman ME (2014). Automatic Personality Assessment Through Social Media Language. Journal of Personality and Social Psychology

Collective Rule



Collective Rule (1/3) (user-user relations)

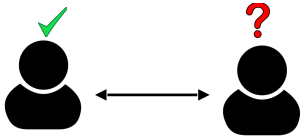


- Friend
- Follower
- Neighbour
- Spouse
- Idol
- Coauthor
- Colleague

u1	u2
u2	u3
…	…
un	u22

	u1	u2	…	un
u1	1	1		0
u2	1	1	..	1
…	…	…		…
un	0	1	…	1

Collective Rule (1/3) (user-user relations)



- Friend
- Follower
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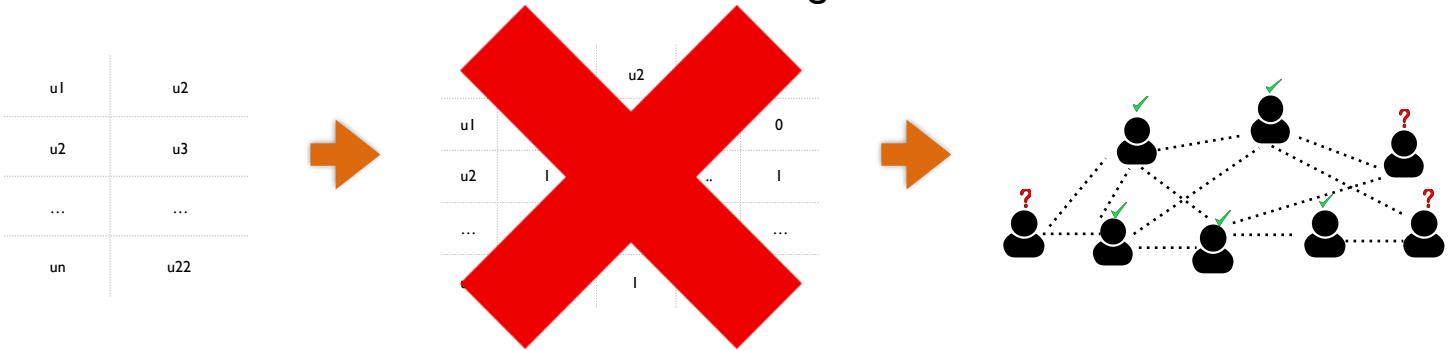
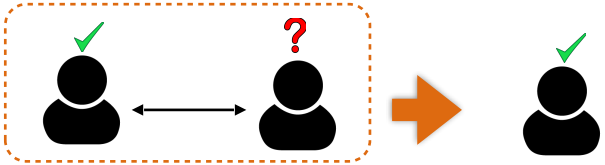
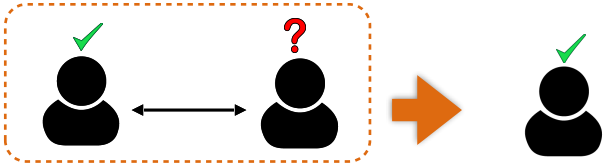


Collective Rule (1/3) (user-user relations)



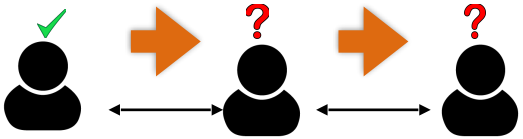
```
Friend(U1,U2) & Is(A,U1,L)-> Is(A,U2,L)
```

Collective Rule (1/3) (user-user relations)

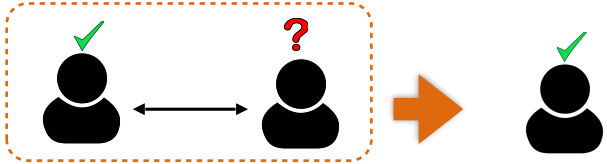


```
Friend(U1,U2) & Is(A,U1,L) -> Is(A,U2,L)
```

Open predicate



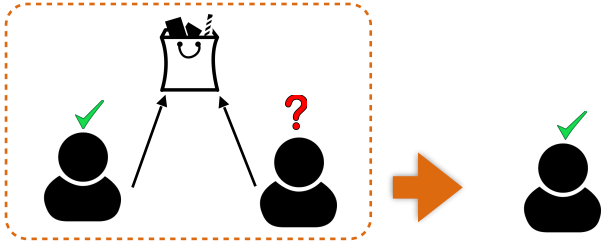
Collective Rule (1/3) (user-user relations)



example:

```
Friend(Alice,Carol) & Is(Personality,Carol,Ext)
                                -> Is(Personality,Alice,Ext)
```

Collective Rule (2/3) (user-item relations)



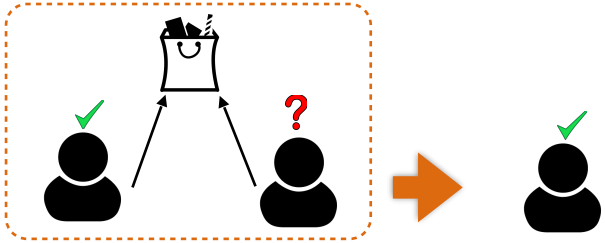
- Page likes
- Item rating
- Movie ratings

u1	I1
u2	I7
…	…
un	I8

	I1	I2	…	In
u1	1	1		0
u2	1	1	..	1
…	…	…		…
un	0	1	…	1

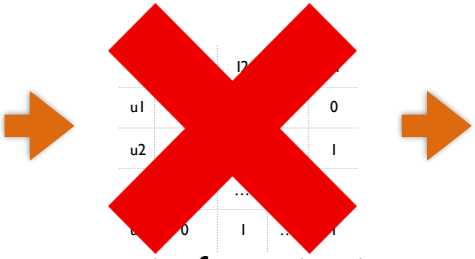
matrix-factorisation

Collective Rule (2/3) (user-item relations)

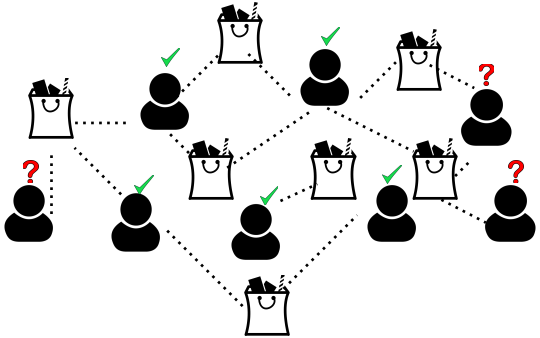


- Page likes
- Item rating
- Movie ratings

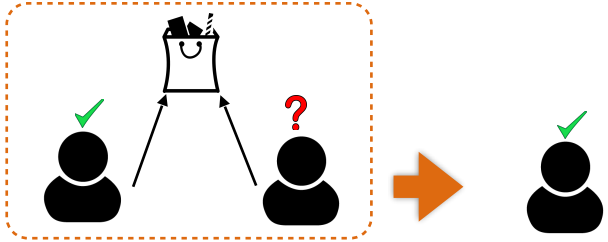
u1	I1
u2	I7
…	…
un	I8



matrix-factorisation

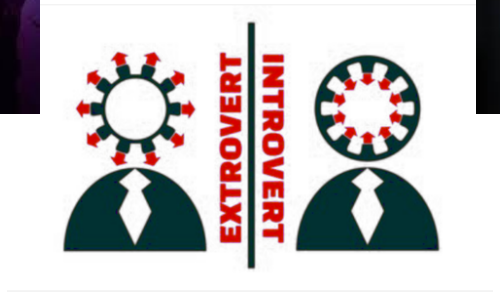


Collective Rule (2/3) (user-item relations)



```
Likes(U1,I) & Likes(U2,I) & Is(A,U1,L)-> Is(A,U2,L)
```

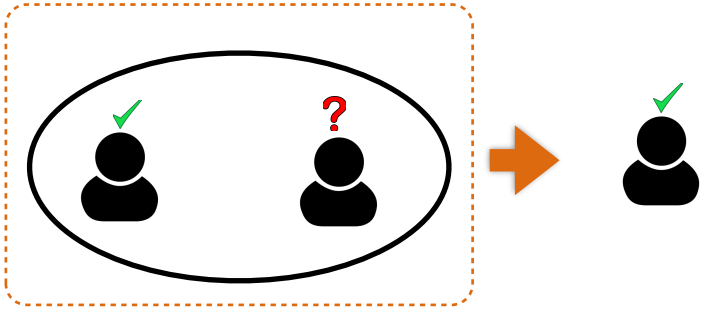
Collective Rule (2/3) (user-item relations)



example:

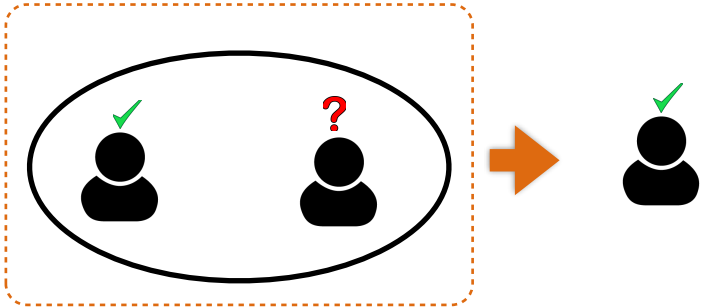
```
Likes(Alice,Partying) & Likes(Carol,Partying) &
     Is(Personality,Carol,Ext)-> Is(Personality,Alice,Ext)
```

Collective Rule (3/3) (user-group relations)



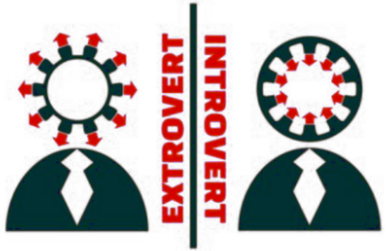
- groups
- clusters

Collective Rule (3/3) (user-group relations)



```
Joins(U1,G) & Joins(U2,G) & Is(A,U1,L)-> Is(A,U2,L)
```

Collective Rule (3/3) (user-group relations)



example:

```
Joins(Carol,Action-Movies) & Joins(Alice,Action-Movie) &
    Is(Personality,Carol,Ext)-> Is(Personality,Alice,Ext)
```

Hands on

- **Data**: Synthetic data, friendship links is a network whose degree distribution follows a power law, with 100 users, two local predictors, one set of joins relations and one set of likes relations.

- git clone https://github.com/linqs/psl-examples.git
- cd psl-examples/user-modeling/cli
- git checkout uai18

- Models
    - Local predictor (Text and Image)
    - Friendship
    - Likes
    - Joins
    - all

PSL Model for User Modeling

```
//Priors from local classifiers
  1: Has(U,S) & Predicts(S,A,U,L)-> Is(A,U,L)
  1: Has(U,S) & ~Is(A,U,L) -> ~Predicts(S,A,U,L)

//Collective Rules for relational signals

  1: Friend(U,V) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(U,V) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Friend(V,U) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(V,U) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & Is(A,V,L) -> Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & ~Is(A,V,L) -> ~Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & Is(A,V,L) -> Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & ~Is(A,V,L) -> ~Is(A,U,L)

//Ensure that user has one attribute
  1: Is(A,U,+L) = 1
```

Data file for User Modeling

predicates:

Predicts/4: closed
Friend/2: closed
Likes/2: closed
Joins/2: closed
Has/2: closed
Is/3: open

observations:

Predicts: ../data/local_predictor_obs.txt
Has: ../data/has_obs.txt
Friend: ../data/friend_obs.txt
Likes : ../data/likes_obs.txt
Joins : ../data/joins_obs.txt
Is : ../data/user_train.txt

targets:

Is : ../data/user_target.txt

truth:

Is : ../data/user_truth.txt

PSL Model for User Modeling

```
//Priors from local classifiers
  1: Has(U,S) & Predicts(S,A,U,L)-> Is(A,U,L)
  1: Has(U,S) & ~Is(A,U,L) -> ~Predicts(S,A,U,L)

//Collective Rules for relational signals

  1: Friend(U,V) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(U,V) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Friend(V,U) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(V,U) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & Is(A,V,L) -> Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & ~Is(A,V,L) -> ~Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & Is(A,V,L) -> Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & ~Is(A,V,L) -> ~Is(A,U,L)

//Ensure that user has one attribute
  1: Is(A,U,+L) = 1
```

local predictor

PSL Model for User Modeling

```
//Priors from local classifiers
  1: Has(U,S) & Predicts(S,A,U,L)-> Is(A,U,L)
  1: Has(U,S) & ~Is(A,U,L) -> ~Predicts(S,A,U,L)

//Collective Rules for relational signals

  1: Friend(U,V) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(U,V) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Friend(V,U) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(V,U) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & Is(A,V,L) -> Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & ~Is(A,V,L) -> ~Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & Is(A,V,L) -> Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & ~Is(A,V,L) -> ~Is(A,U,L)

//Ensure that user has one attribute
  1: Is(A,U,+L) = 1
```

Friend

PSL Model for User Modeling

```
//Priors from local classifiers
  1: Has(U,S) & Predicts(S,A,U,L)-> Is(A,U,L)
  1: Has(U,S) & ~Is(A,U,L) -> ~Predicts(S,A,U,L)

//Collective Rules for relational signals

  1: Friend(U,V) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(U,V) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Friend(V,U) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(V,U) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & Is(A,V,L) -> Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & ~Is(A,V,L) -> ~Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & Is(A,V,L) -> Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & ~Is(A,V,L) -> ~Is(A,U,L)

//Ensure that user has one attribute
  1: Is(A,U,+L) = 1
```

Likes

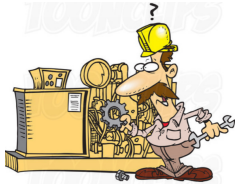
PSL Model for User Modeling

```
//Priors from local classifiers
  1: Has(U,S) & Predicts(S,A,U,L)-> Is(A,U,L)
  1: Has(U,S) & ~Is(A,U,L) -> ~Predicts(S,A,U,L)

//Collective Rules for relational signals

  1: Friend(U,V) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(U,V) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Friend(V,U) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(V,U) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & Is(A,V,L) -> Is(A,U,L)
  1: Likes(U,T) & Likes(V,T) & ~Is(A,V,L) -> ~Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & Is(A,V,L) -> Is(A,U,L)
  1: Joins(U,G) & Joins(V,G) & ~Is(A,V,L) -> ~Is(A,U,L)

//Ensure that user has one attribute
  1: Is(A,U,+L) = 1
```

Joins

Evaluation Result (Personality prediction-synthetic data)

Type of the model	AUC
Random	0.5
Local Predictor	0.811655
Friendship links	0.528963
Likes	0.724014
Joins	0.865880
All	0.777315



Rules' weights?

PSL Model for User Modeling

```
//Priors from local classifiers
  50: Has(U,S) & Predicts(S,A,U,L)-> Is(A,U,L)
  50: Has(U,S) & ~Is(A,U,L) -> ~Predicts(S,A,U,L)

//Collective Rules for relational signals

  1: Friend(U,V) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(U,V) & ~Is(A,V,L)-> ~Is(A,U,L)
  1: Friend(V,U) & Is(A,V,L)-> Is(A,U,L)
  1: Friend(V,U) & ~Is(A,V,L)-> ~Is(A,U,L)
  10: Likes(U,T) & Likes(V,T) & Is(A,V,L) -> Is(A,U,L)
  10: Likes(U,T) & Likes(V,T) & ~Is(A,V,L) -> ~Is(A,U,L)
  100: Joins(U,G) & Joins(V,G) & Is(A,V,L) -> Is(A,U,L)
  100: Joins(U,G) & Joins(V,G) & ~Is(A,V,L) -> ~Is(A,U,L)

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```

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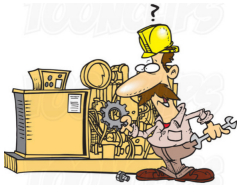
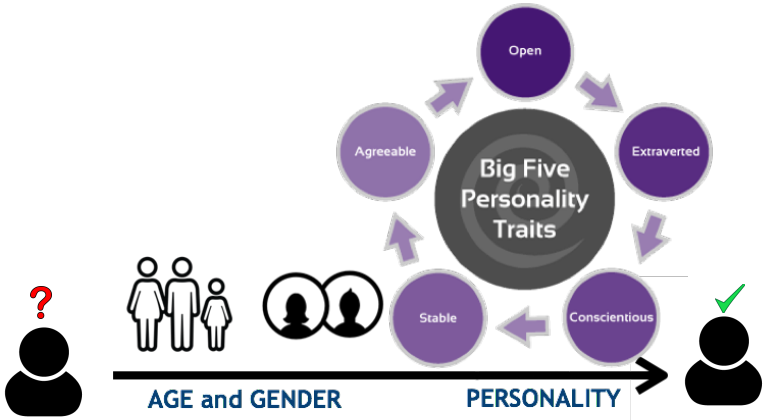
All	0.777315
All	0.913516



Other combinations?

Weight learning?

Knowledge Fusion Model for User Profiling Based on Multimedia and Multi-Relational User-Generated Content



- Personalised services
- Marketing and advertisement
- Law enforcement
- Employment selection

[Work in progress]

Predicting Users' Age, Gender and Big5 Personality traits

Task: Predicting Facebook Users':

Age, Gender and Big5 Personality traits (Extraversion (Ext), Agreeableness (Agr), Neuroticism (Neu), Openness (Opn), Conscientiousness (Con))

Using **Status updates**, **Profile Picture** and **Facebook Page Likes**

Data: ~6K Facebook users, ~49K Facebook pages and ~725K Page likes Relations

Results: Area under the curve (AUC), 10-fold CV

Model/Characteristic	Gender	Age	Opn	Con	Ext	Agr	Neu
Baseline	0.492	0.488	0.502	0.502	0.506	0.504	0.486
PSL-Textual	0.650	0.710	0.570	0.567	0.553	0.550	0.542
PSL-Visual	0.850	0.579	0.505	0.521	0.531	0.531	0.515
PSL-Relational	0.853	0.881	0.648	0.618	0.592	0.571	0.572
PSL-Fusion	**0.893**	**0.893**	**0.654**	**0.622**	**0.599**	**0.581**	**0.58**