

# The Jobs Puzzle: Taking on the Challenge via Controlled Natural Language Processing

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# Overview

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- The Jobs Puzzle (Wos et al. 1984)
- Shapiro's Challenge
- Shapiro's Lparse/Smodels Solution
- Simple Solution in Controlled Natural Language
- Compact Solution in Controlled Natural Language

# The Jobs Puzzle

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1. There are four people: Roberta, Thelma, Steve and Pete.
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.
5. The job of nurse is held by a male.
6. The husband of the chef is the telephone operator.
7. Roberta is not a boxer.
8. Pete has no education past the ninth grade.
9. Roberta, the chef, and the police officer went golfing together.
10. Question: Who holds which jobs?

# The Challenge

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- Shapiro's challenge is three-fold:
  - a) formalise the puzzle in a way that is neither difficult nor tedious,
  - b) formalise the puzzle so that it adheres closely to the English statements of the puzzle, and**
  - c) have an automated general-purpose commonsense reasoner that solves the puzzle efficiently.

# Solutions

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- TPTP participants (Larry Wos & friends)
  - 64 clauses
  - relies on equality predicates and special axioms for UNA
- SNePS (Stuart C. Shapiro)
  - uses SNePSLOG syntax
  - uses general quantifiers and set arguments
  - some statements need to be translated into contrapositives
- Lparse/Smodels (Stuart C. Shapiro)
  - answer set programming
- Controlled Natural Language (Schwitter)

# Lparse/Smodels Solution

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1. There are four people: Roberta, Thelma, Steve and Pete.
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4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Lparse/Smodels Solution

---

1. There are four people: Roberta, Thelma, Steve and Pete.  
**person(roberta ; thelma ; steve ; pete).**
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Lparse/Smodels Solution

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1. There are four people: Roberta, Thelma, Steve and Pete.  
**person(roberta ; thelma ; steve ; pete).**  
**female(roberta ; thelma).**
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.



# Lparse/Smodels Solution

---

1. There are four people: Roberta, Thelma, Steve and Pete.  
**person(roberta ; thelma ; steve ; pete).**  
**female(roberta ; thelma).**  
**male(steve ; pete).**
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Lparse/Smodels Solution

---

1. There are four people: Roberta, Thelma, Steve and Pete.  
**person(roberta ; thelma ; steve ; pete).**  
**female(roberta ; thelma).**  
**male(steve ; pete).**  
**:- person(X), male(X), female(X).**
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Lparse/Smodels Solution

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1. `person(roberta ; thelma ; steve ; pete).`  
`female(roberta ; thelma).`  
`male(steve ; pete).`  
`:- person(X), male(X), female(X).`
2. Among them, they hold eight different jobs.
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4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Lparse/Smodels Solution

---

1. **person(roberta ; thelma ; steve ; pete).**  
**female(roberta ; thelma).**  
**male(steve ; pete).**  
**:- person(X), male(X), female(X).**
2. Among them, they hold eight different jobs.  
**1 { hasJob(X, Y) : person(X) } 1 :- job(Y).**
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Lparse/Smodels Solution

---

1. `person(roberta ; thelma ; steve ; pete).`  
`female(roberta ; thelma).`  
`male(steve ; pete).`  
`:- person(X), male(X), female(X).`
2. `1 { hasJob(X, Y) : person(X) } 1 :- job(Y).`
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# Lparse/Smodels Solution

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- 1. person(roberta ; thelma ; steve ; pete).**  
**female(roberta ; thelma).**  
**male(steve ; pete).**  
**:- person(X), male(X), female(X).**
- 2. 1 { hasJob(X, Y) : person(X) } 1 :- job(Y).**
3. Each holds exactly two jobs.  
**2 { hasJob(X, Y) : job(Y) } 2 :- person(X).**
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Lparse/Smodels Solution

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1. **person(roberta ; thelma ; steve ; pete).**  
**female(roberta ; thelma).**  
**male(steve ; pete).**  
**:- person(X), male(X), female(X).**
2. **1 { hasJob(X, Y) : person(X) } 1 :- job(Y).**
3. **2 { hasJob(X, Y) : job(Y) } 2 :- person(X).**
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Lparse/Smodels Solution

---

1. **person(roberta ; thelma ; steve ; pete).**  
**female(roberta ; thelma).**  
**male(steve ; pete).**  
**:- person(X), male(X), female(X).**
2. **1 { hasJob(X, Y) : person(X) } 1 :- job(Y).**
3. **2 { hasJob(X, Y) : job(Y) } 2 :- person(X).**
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.  
**job(chef ; guard ; nurse ; operator ; police ; teacher ; actor ; boxer).**



# Lparse/Smodels Solution

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1. **person(roberta ; thelma ; steve ; pete).**  
**female(roberta ; thelma).**  
**male(steve ; pete).**  
**:- person(X), male(X), female(X).**
2. **1 { hasJob(X, Y) : person(X) } 1 :- job(Y).**
3. **2 { hasJob(X, Y) : job(Y) } 2 :- person(X).**
4. **job(chef ; guard ; nurse ; operator ; police ; teacher ; actor ;  
boxer).**

# Lparse/Smodels Solution

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5. The job of nurse is held by a male.
6. The husband of the chef is the telephone operator.
7. Roberta is not a boxer.
8. Pete has no education past the ninth grade.

# Lparse/Smodels Solution

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5. The job of nurse is held by a male.

**male(X) :- person(X), hasJob(X, nurse).**

6. The husband of the chef is the telephone operator.

7. Roberta is not a boxer.

8. Pete has no education past the ninth grade.

# Lparse/Smodels Solution

---

5. The job of nurse is held by a male.

**male(X) :- person(X), hasJob(X, nurse).**

**male(X) :- person(X), hasJob(X, actor).**

6. The husband of the chef is the telephone operator.

7. Roberta is not a boxer.

8. Pete has no education past the ninth grade.

# Lparse/Smodels Solution

---

5. **male(X) :- person(X), hasJob(X, nurse).**  
**male(X) :- person(X), hasJob(X, actor).**
6. The husband of the chef is the telephone operator.
7. Roberta is not a boxer.
8. Pete has no education past the ninth grade.

# Lparse/Smodels Solution

---

5. **male(X) :- person(X), hasJob(X, nurse).**  
**male(X) :- person(X), hasJob(X, actor).**
6. The husband of the chef is the telephone operator.  
**hasHusband(Y, X) :- person(X ; Y),**  
**hasJob(Y, chef), hasJob(X, operator).**
7. Roberta is not a boxer.
8. Pete has no education past the ninth grade.

# Lparse/Smodels Solution

---

5. **male(X) :- person(X), hasJob(X, nurse).**  
**male(X) :- person(X), hasJob(X, actor).**
6. The husband of the chef is the telephone operator.  
**hasHusband(Y, X) :- person(X ; Y),**  
**hasJob(Y, chef), hasJob(X, operator).**  
**2 { female(X), male(Y) } 2 :-**  
**person(X ; Y), hasHusband(X, Y).**
7. Roberta is not a boxer.
8. Pete has no education past the ninth grade.

# Lparse/Smodels Solution

---

5. `male(X) :- person(X), hasJob(X, nurse).`  
`male(X) :- person(X), hasJob(X, actor).`
6. `hasHusband(Y, X) :- person(X ; Y),`  
`hasJob(Y, chef), hasJob(X, operator).`  
`2 { female(X), male(Y) } 2 :-`  
`person(X ; Y), hasHusband(X, Y).`
7. Roberta is not a boxer.
8. Pete has no education past the ninth grade.



# Lparse/Smodels Solution

---

5. **male(X) :- person(X), hasJob(X, nurse).**  
**male(X) :- person(X), hasJob(X, actor).**
6. **hasHusband(Y, X) :- person(X ; Y),**  
**hasJob(Y, chef), hasJob(X, operator).**  
**2 { female(X), male(Y) } 2 :-**  
**person(X ; Y), hasHusband(X, Y).**
7. Roberta is not a boxer.  
**:- hasJob(roberta, boxer).**
8. Pete has no education past the ninth grade.

# Lparse/Smodels Solution

---

5. **male(X) :- person(X), hasJob(X, nurse).**  
**male(X) :- person(X), hasJob(X, actor).**
6. **hasHusband(Y, X) :- person(X ; Y),**  
**hasJob(Y, chef), hasJob(X, operator).**  
**2 { female(X), male(Y) } 2 :-**  
**person(X ; Y), hasHusband(X, Y).**
7. **:- hasJob(roberta, boxer).**
8. Pete has no education past the ninth grade.

# Lparse/Smodels Solution

---

5. **male(X) :- person(X), hasJob(X, nurse).**  
**male(X) :- person(X), hasJob(X, actor).**
6. **hasHusband(Y, X) :- person(X ; Y),**  
**hasJob(Y, chef), hasJob(X, operator).**  
**2 { female(X), male(Y) } 2 :-**  
**person(X ; Y), hasHusband(X, Y).**
7. **:- hasJob(roberta, boxer).**
8. Pete has no education past the ninth grade.  
**:- educated(pete).**

# Lparse/Smodels Solution

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5. **male(X) :- person(X), hasJob(X, nurse).**  
**male(X) :- person(X), hasJob(X, actor).**
6. **hasHusband(Y, X) :- person(X ; Y),**  
**hasJob(Y, chef), hasJob(X, operator).**  
**2 { female(X), male(Y) } 2 :-**  
**person(X ; Y), hasHusband(X, Y).**
7. **:- hasJob(roberta, boxer).**
8. Pete has no education past the ninth grade.  
**:- educated(pete).**  
**educated(X) :- 1 { hasJob(X, nurse), hasJob(X, police),**  
**hasJob(X, teacher) } 2, person(X).**

# Lparse/Smodels Solution

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5. `male(X) :- person(X), hasJob(X, nurse).`  
`male(X) :- person(X), hasJob(X, actor).`
6. `hasHusband(Y, X) :- person(X ; Y),`  
`hasJob(Y, chef), hasJob(X, operator).`  
`2 { female(X), male(Y) } 2 :-`  
`person(X ; Y), hasHusband(X, Y).`
7. `:- hasJob(roberta, boxer).`
8. `:- educated(pete).`  
`educated(X) :- 1 { hasJob(X, nurse), hasJob(X, police),`  
`hasJob(X, teacher) } 2, person(X).`

# Lparse/Smodels Solution

---

9. Roberta, [and] the chef, and the police officer went golfing together.
10. Question: Who holds which jobs?

# Lparse/Smodels Solution

---

9. Roberta, [and] the chef, and the police officer went golfing together.

**0 { hasJob(roberta, chef), hasJob(roberta, police) } 0.**

10. Question: Who holds which jobs?

# Lparse/Smodels Solution

---

9. Roberta, [and] the chef, and the police officer went golfing together.

**0 { hasJob(roberta, chef), hasJob(roberta, police) } 0.**

**0 { hasJob(X, chef), hasJob(X, police) } 1 :- person(X).**

10. Question: Who holds which jobs?



# Lparse/Smodels Solution

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9.  $0 \{ \text{hasJob}(\text{roberta}, \text{chef}), \text{hasJob}(\text{roberta}, \text{police}) \} 0.$   
 $0 \{ \text{hasJob}(X, \text{chef}), \text{hasJob}(X, \text{police}) \} 1 \text{ :- person}(X).$
10. Question: Who holds which job?

# Lparse/Smodels Solution

---

9. `0 { hasJob(roberta, chef), hasJob(roberta, police) } 0.`  
`0 { hasJob(X, chef), hasJob(X, police) } 1 :- person(X).`
10. Question: Who holds which job?  
`#hide.`  
`#show hasJob(X, Y).`

# Lparse/Smodels Solution

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9. `0 { hasJob(roberta, chef), hasJob(roberta, police) } 0.`  
`0 { hasJob(X, chef), hasJob(X, police) } 1 :- person(X).`
10. `#hide.`  
`#show hasJob(X, Y).`

# Output Smodels

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**hasJob(pete, operator)**

**hasJob(pete, actor)**

**hasJob(steve, nurse)**

**hasJob(steve, police)**

**hasJob(thelma, chef)**

**hasJob(thelma, boxer)**

**hasJob(roberta, guard)**

**hasJob(roberta, teacher)**

# Remember Shapiro's Challenge

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- Shapiro's challenge is three-fold:
  - a) formalise the puzzle in a way that is neither difficult nor tedious,
  - b) formalise the puzzle so that it adheres closely to the English statements of the puzzle, and**
  - c) have an automated general-purpose commonsense reasoner that solves the puzzle efficiently.

# Solution via Controlled Natural Language

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- A CNL consists of a well-defined subset of natural language.
- First, I will use the **simplest** possible subset of PENG Light to reconstruct the puzzle.
- Afterwards, I will introduce a **compact** solution.
- The reconstruction process is supported by a **predictive authoring tool** that guides the writing process.

# Simple Sentences

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Pattern	Example
PNoun is a CNoun.	Roberta is a person.
PNoun is Adjective.	Roberta is female.
There is a CNoun.	There is a job.
A CNoun is Adjective.	A person is female.
A OrdNumber CNoun is a CNoun of a OrdNumber CNoun.	A first person is a husband of a second person.
A CNoun Verb a CNoun as PNoun.	A person holds a job as nurse.
CardRest CNoun Verb a CNoun.	Exactly one person holds a job.
A CNoun Verb CardRest CNoun.	A person holds exactly two jobs.

# Complex Sentences

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- **If** Simple Sentence [**and** Simple Sentence]\* **then** Simple Sentence.
- **Exclude that** Simple Sentence [**and that** Simple Sentence]\*.



# Anaphora

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- Anaphoric references:  
a person ... the person  
a first person ... a second person ... the first person  
Roberta ... Roberta ...

# Reconstruction in CNL (simple version)

---

1. There are four people: Roberta, Thelma, Steve and Pete.
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

1. There are four people: Roberta, Thelma, Steve and Pete.  
**Roberta is a person. Thelma is a person. Steve is a person. Pete is a person.**  
Among them, they hold eight different jobs.
2. Each holds exactly two jobs.
3. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

1. There are four people: Roberta, Thelma, Steve and Pete.  
**Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.**  
**Roberta is female. Thelma is female.**
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

1. There are four people: Roberta, Thelma, Steve and Pete.  
**Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.**  
**Roberta is female. Thelma is female.**  
**Steve is male. Pete is male.**
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

1. There are four people: Roberta, Thelma, Steve and Pete.  
**Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.**  
**Roberta is female. Thelma is female.**  
**Steve is male. Pete is male.**  
**Exclude that a person is male and that the person is female.**
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

- 1. Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.  
Roberta is female. Thelma is female.  
Steve is male. Pete is male.  
Exclude that a person is male and that the person is female.**
2. Among them, they hold eight different jobs.
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

- 1. Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.  
Roberta is female. Thelma is female.  
Steve is male. Pete is male.  
Exclude that a person is male and that the person is female.**
2. Among them, they hold eight different jobs.  
**If there is a job then exactly one person holds the job.**
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.



# Reconstruction in CNL (**simple version**)

---

- 1. Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.  
Roberta is female. Thelma is female.  
Steve is male. Pete is male.  
Exclude that a person is male and that the person is female.**
- 2. If there is a job then exactly one person holds the job.**
3. Each holds exactly two jobs.
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

- 1. Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.  
Roberta is female. Thelma is female.  
Steve is male. Pete is male.  
Exclude that a person is male and that the person is female.**
- 2. If there is a job then exactly one person holds the job.**
3. Each holds exactly two jobs.  
**If there is a person then the person holds exactly two jobs.**
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

- 1. Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.  
Roberta is female. Thelma is female.  
Steve is male. Pete is male.  
Exclude that a person is male and that the person is female.**
- 2. If there is a job then exactly one person holds the job.**
- 3. If there is a person then the person holds exactly two jobs.**
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.

# Reconstruction in CNL (**simple version**)

---

- 1. Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.  
Roberta is female. Thelma is female.  
Steve is male. Pete is male.  
Exclude that a person is male and that the person is female.**
- 2. If there is a job then exactly one person holds the job.**
- 3. If there is a person then the person holds exactly two jobs.**
4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.  
**Chef is a job. Guard is a job. Nurse is a job. Telephone operator is a job. Police officer is a job. Teacher is a job. Actor is a job. Boxer is a job.**

# Reconstruction in CNL (**simple version**)

---

- 1. Roberta is a person. Thelma is a person. Steve is a person.  
Pete is a person.  
Roberta is female. Thelma is female.  
Steve is male. Pete is male.  
Exclude that a person is male and that the person is female.**
- 2. If there is a job then exactly one person holds the job.**
- 3. If there is a person then the person holds exactly two jobs.**
- 4. Chef is a job. Guard is a job. Nurse is a job. Telephone operator is a job. Police officer is a job. Teacher is a job.  
Actor is a job. Boxer is a job.**

# Reconstruction in CNL (simple version)

---

5. The job of nurse is held by a male.
6. The husband of the chef is the telephone operator.
7. Roberta is not a boxer.

## Reconstruction in CNL (**simple version**)

---

5. The job of nurse is held by a male.

**If a person holds a job as nurse then the person is male.**

6. The husband of the chef is the telephone operator.

7. Roberta is not a boxer.

# Reconstruction in CNL (**simple version**)

---

5. The job of nurse is held by a male.

**If a person holds a job as nurse then the person is male.**

**If a person holds a job as actor then the person is male.**

6. The husband of the chef is the telephone operator.

7. Roberta is not a boxer.



# Reconstruction in CNL (**simple version**)

---

- 5. If a person holds a job as nurse then the person is male.  
If a person holds a job as actor then the person is male.**
6. The husband of the chef is the telephone operator.
7. Roberta is not a boxer.

## Reconstruction in CNL (**simple version**)

---

5. **If a person holds a job as nurse then the person is male.**  
**If a person holds a job as actor then the person is male.**
6. The husband of the chef is the telephone operator.  
**If a first person holds a job as chef and a second person holds a job as telephone operator then the second person is a husband of the first person.**
7. Roberta is not a boxer.

## Reconstruction in CNL (**simple version**)

---

5. **If a person holds a job as nurse then the person is male.**  
**If a person holds a job as actor then the person is male.**
6. The husband of the chef is the telephone operator.  
**If a first person holds a job as chef and a second person holds a job as telephone operator then the second person is a husband of the first person.**  
**If a first person is a husband of a second person then the first person is male.**
7. Roberta is not a boxer.

## Reconstruction in CNL (**simple version**)

---

5. **If a person holds a job as nurse then the person is male.**  
**If a person holds a job as actor then the person is male.**
6. The husband of the chef is the telephone operator.  
**If a first person holds a job as chef and a second person holds a job as telephone operator then the second person is a husband of the first person.**  
**If a first person is a husband of a second person then the first person is male.**  
**If a first person is a husband of a second person then the second person is female.**
7. Roberta is not a boxer.

# Reconstruction in CNL (**simple version**)

---

5. **If a person holds a job as nurse then the person is male.**  
**If a person holds a job as actor then the person is male.**
6. **If a first person holds a job as chef and a second person holds a job as telephone operator then the second person is a husband of the first person.**  
**If a first person is a husband of a second person then the first person is male.**  
**If a first person is a husband of a second person then the second person is female.**
7. Roberta is not a boxer.

## Reconstruction in CNL (**simple version**)

---

5. **If a person holds a job as nurse then the person is male.**  
**If a person holds a job as actor then the person is male.**
6. **If a first person holds a job as chef and a second person holds a job as telephone operator then the second person is a husband of the first person.**  
**If a first person is a husband of a second person then the first person is male.**  
**If a first person is a husband of a second person then the second person is female.**
7. **Roberta is not a boxer.**  
**Exclude that Robert holds a job as boxer.**

# Reconstruction in CNL (**simple version**)

---

5. **If a person holds a job as nurse then the person is male.**  
**If a person holds a job as actor then the person is male.**
6. **If a first person holds a job as chef and a second person holds a job as telephone operator then the second person is a husband of the first person.**  
**If a first person is a husband of a second person then the first person is male.**  
**If a first person is a husband of a second person then the second person is female.**
7. **Exclude that Robert holds a job as boxer.**

# Reconstruction in CNL (simple version)

---

8. Pete has no education past the ninth grade.
9. Roberta, the chef, and the police officer went golfing together.
10. Question: Who holds which jobs?



# Reconstruction in CNL (**simple version**)

---

8. Pete has no education past the ninth grade.

**Exclude that Pete is educated.**

9. Roberta, the chef, and the police officer went golfing together.

10. Question: Who holds which jobs?

## Reconstruction in CNL (**simple version**)

---

8. Pete has no education past the ninth grade.

**Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

9. Roberta, the chef, and the police officer went golfing together.

10. Question: Who holds which jobs?

## Reconstruction in CNL (**simple version**)

---

8. Pete has no education past the ninth grade.

**Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

9. Roberta, the chef, and the police officer went golfing together.

10. Question: Who holds which jobs?

## Reconstruction in CNL (**simple version**)

---

8. Pete has no education past the ninth grade.

**Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

**If a person holds a job as teacher then the person is educated.**

9. Roberta, the chef, and the police officer went golfing together.

10. Question: Who holds which jobs?

# Reconstruction in CNL (**simple version**)

---

## 8. **Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

**If a person holds a job as teacher then the person is educated.**

9. Roberta, the chef, and the police officer went golfing together.

10. Question: Who holds which jobs?

# Reconstruction in CNL (**simple version**)

---

## 8. **Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

**If a person holds a job as teacher then the person is educated.**

## 9. Roberta, the chef, and the police officer went golfing together.

**Exclude that Roberta holds a job as chef.**

## 10. Question: Who holds which jobs?

# Reconstruction in CNL (**simple version**)

---

## 8. **Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

**If a person holds a job as teacher then the person is educated.**

## 9. Roberta, the chef, and the police officer went golfing together.

**Exclude that Roberta holds a job as chef.**

**Exclude that Roberta holds a job as police officer.**

## 10. Question: Who holds which jobs?

## Reconstruction in CNL (**simple version**)

---

### 8. **Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

**If a person holds a job as teacher then the person is educated.**

### 9. Roberta, the chef, and the police officer went golfing together.

**Exclude that Roberta holds a job as chef.**

**Exclude that Roberta holds a job as police officer.**

**Exclude that a person holds a job as chef and that the person holds a job as police officer.**

### 10. Question: Who holds which jobs?



# Reconstruction in CNL (**simple version**)

---

## 8. **Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

**If a person holds a job as teacher then the person is educated.**

## 9. **Exclude that Roberta holds a job as chef.**

**Exclude that Roberta holds a job as police officer.**

**Exclude that a person holds a job as chef and that the person holds a job as police officer.**

## 10. Question: Who holds which jobs?

# Reconstruction in CNL (**simple version**)

---

## 8. **Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

**If a person holds a job as teacher then the person is educated.**

## 9. **Exclude that Roberta holds a job as chef.**

**Exclude that Roberta holds a job as police officer.**

**Exclude that a person holds a job as chef and that the person holds a job as police officer.**

## 10. Question: Who holds which jobs?

**Who holds which jobs?**

# Reconstruction in CNL (**simple version**)

---

## 8. **Exclude that Pete is educated.**

**If a person holds a job as nurse then the person is educated.**

**If a person holds a job as police officer then the person is educated.**

**If a person holds a job as teacher then the person is educated.**

## 9. **Exclude that Roberta holds a job as chef.**

**Exclude that Roberta holds a job as police officer.**

**Exclude that a person holds a job as chef and that the person holds a job as police officer.**

## 10. **Who holds which jobs?**

# A more Compact CNL Specification

---

- We can make the CNL specification more compact.
- We add the following constructions to the initial CNL:
  - Universal quantifier: every, for every
  - Existential there: there is
  - Relative clauses
  - Additional forms of coordination

# Reconstruction in CNL (**compact version**)

---

- 0. Every person who holds a job as chef is a chef.  
Every person who holds a job as guard is a guard.  
...**

# Reconstruction in CNL (**compact version**)

---

- 1. Roberta, Thelma, Steve, and Pete are persons.  
Roberta and Thelma are female.  
Steve and Pete are male.  
Exclude that a person is male and is female.**
- 2. For every job there is exactly one person who holds the job.**
- 3. Every person holds exactly two jobs.**
- 4. Chef, guard, nurse, telephone operator, police officer, teacher actor, and boxer are jobs.**

# Reconstruction in CNL (**compact version**)

---

5. **Every person who is a nurse or who is an actor is male.**
6. **If there is a telephone operator and there is a chef then the telephone operator is the husband of the chef.**  
**Every person who is a chef is female.**  
**Every person who is a telephone operator is male.**
7. **Exclude that Roberta is a boxer.**
8. **Exclude that Pete is educated.**  
**Every person who is a nurse or who is a police officer or who is a teacher is educated.**

# Reconstruction in CNL (**compact version**)

---

**9. Exclude that Roberta is a chef and exclude that Roberta is a police officer.**

**Exclude that a person is a chef and is a police officer.**

**10. Who holds which jobs?**



# CNL Processing

---

- The CNL specification is translated into an extended discourse representation structure during the parsing process.
- The discourse representation structure is then further translated into an answer set program.
- The answer set program is processed with *clingo*, a state-of-the-art answer set solver.

# Discourse Representation Structure

---

```
[A,B,C,D,E,F]
  [G,H,I]
  object(G,person)
  object(H,job)
  named(H,chef)
  predicate(I,hold,G,H)
  ==>
    [J,K]
    object(J,chef)
    predicate(K,isa,G,J)
named(A,roberta)
named(B,thelma)
named(C,steve)
named(D,pete)
object(E,person)
predicate(F,isa,(A;B;C;D),E)
```

# Discourse Representation Structure

---

[M2]

object(M2, person)

==>

[N2, O2]

cardinal(N2, eq, 2)

object(N2, job)

predicate(O2, hold, M2, N2)

# Discourse Representation Structure

---

CSTR

[T3,U3]

object(T3,chef)

predicate(U3,isa,A,T3)

CSTR

[V3,W3]

object(V3,police)

predicate(W3,isa,A,V3)

# Answer Set Program

---

```
chef(A) :- person(A), job(chef), hold(A,chef).
guard(B) :- person(B), job(guard), hold(B,guard).
nurse(C) :- person(C), job(nurse), hold(C,nurse).
operator(D) :- person(D), job(operator), hold(D,operator).
police(E) :- person(E), job(police), hold(E,police).
teacher(F) :- person(F), job(teacher), hold(F,teacher).
actor(G) :- person(G), job(actor), hold(G,actor).
boxer(H) :- person(H), job(boxer), hold(H,boxer).
person(roberta;thelma;steve;pete).
female(roberta;thelma).
male(steve;pete).
:- person(I), male(I), female(I).
1 { hold(J,K) : person(J) } 1 :- job(K).
2 { hold(L,M) : job(M) } 2 :- person(L).
job(chef;guard;nurse;operator;police;teacher;actor;boxer).
male(N) :- person(N), nurse(N).
male(N) :- person(N), actor(N).
husband(O,P) :- operator(O), chef(P).
female(Q) :- person(Q), chef(Q).
male(R) :- person(R), operator(R).
:- boxer(roberta).
:- educated(pete).
educated(S) :- person(S), nurse(S).
educated(S) :- person(S), police(S).
educated(S) :- person(S), teacher(S).
:- chef(roberta).
:- police(roberta).
:- person(T), chef(T), police(T).
answer(hold(U,V)) :- job(V), hold(U,V).
```

# Clingo Statistics

---

Shapiro

```
Models      : 1
Time        : 0.000
  Prepare   : 0.000
  Prepro.   : 0.000
  Solving   : 0.000
Choices     : 6
Conflicts   : 3
Restarts    : 0

Atoms       : 135
Rules       : 170
Bodies      : 138
Equivalences : 282
Tight       : Yes

Variables   : 101
Constraints : 63
Lemmas      : 3
  Conflicts : 3
  Loops     : 0
  Other     : 0
  Deleted   : 0
```

CNL (**simple**)

```
Models      : 1
Time        : 0.000
  Prepare   : 0.000
  Prepro.   : 0.000
  Solving   : 0.000
Choices     : 3
Conflicts   : 2
Restarts    : 0

Atoms       : 141
Rules       : 180
Bodies      : 130
Equivalences : 311
Tight       : Yes

Variables   : 84
Constraints : 45
Lemmas      : 2
  Conflicts : 2
  Loops     : 0
  Other     : 0
  Deleted   : 0
```

CNL (**compact**)

```
Models      : 1
Time        : 0.000
  Prepare   : 0.000
  Prepro.   : 0.000
  Solving   : 0.000
Choices     : 0
Conflicts   : 0
Restarts    : 0

Atoms       : 157
Rules       : 184
Bodies      : 122
Equivalences : 351
Tight       : Yes

Variables   : 66
Constraints : 0
Lemmas      : 0
  Conflicts : 0
  Loops     : 0
  Other     : 0
  Deleted   : 0
```

# Conclusion

---

- We took on Shapiro's challenge to formalise the Jobs Puzzle:
  - a) formalise the puzzle in a way that is neither difficult nor tedious,
  - b) formalise the puzzle so that it adheres closely to the English statements of the puzzle, and
  - c) have an automated general-purpose common-sense reasoner that solves the puzzle efficiently.

# Conclusion



---

- We took on Shapiro's challenge to formalise the Jobs Puzzle:
  - ✓ formalise the puzzle in a way that is neither difficult nor tedious,
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# Conclusion

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  - ✓ formalise the puzzle so that it adheres closely to the English statements of the puzzle, and
  - ✓ have an automated general-purpose common-sense reasoner that solves the puzzle efficiently.