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

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Overview

• The Jobs Puzzle (Wos et al. 1984)
• Shapiro’s Challenge
• Shapiro’s Lparse/Smmodels Solution
• Simple Solution in Controlled Natural Language
• Compact Solution in Controlled Natural Language
The Jobs Puzzle

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

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

- **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/Smmodels Solution

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.
Lparse/Smmodels Solution

1. There are four people: Roberta, Thelma, Steve and Pete.
   \texttt{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/Smmodels Solution

1. There are four people: Roberta, Thelma, Steve and Pete.
   \[
   \text{person(roberta; thelma; steve; pete).}
   \]
   \[
   \text{female(roberta; thelma).}
   \]
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/Smmodels Solution

1. There are four people: Roberta, Thelma, Steve and Pete.
   \[\text{person(roberta ; thelma ; steve ; pete).}\\
   \text{female(roberta ; thelma).}\\
   \text{male(steve ; pete).}\]

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/Smmodels Solution

1. There are four people: Roberta, Thelma, Steve and Pete.
   \[\text{person(roberta ; thelma ; steve ; pete)}.\]
   \[\text{female(roberta ; thelma)}.\]
   \[\text{male(steve ; pete)}.\]
   \[\text{:- person(X), male(X), female(X)}.\]

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/Smmodels 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.

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/Smmodels Solution

1. `person(roberta; thelma; steve; pete).
female(roberta; thelma).
males(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/Smmodels 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. Each holds exactly two jobs.

4. The jobs are: chef, guard, nurse, telephone operator, police officer (gender not implied), teacher, actor, and boxer.
Lparse/Smmodels Solution

1. \texttt{person(roberta ; thelma ; steve ; pete).
   female(roberta ; thelma).
   male(steve ; pete).
   :- person(X), male(X), female(X).}

2. \texttt{1 \{ hasJob(X, Y) : person(X) \} 1 :- job(Y).}

3. Each holds exactly two jobs.
   \texttt{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/Smmodels 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.
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/Smmodels 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.  job(chef ; guard ; nurse ; operator ; police ; teacher ; actor ; boxer).
Lparse/Smmodels Solution

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/Smmodels Solution

5. The job of nurse is held by a male.
   \[ \text{male}(X) :- \text{person}(X), \text{hasJob}(X, \text{nurse}). \]

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.
   \[
   \text{male}(X) :- \text{person}(X), \text{hasJob}(X, \text{nurse}).
   \]

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/Smmodels Solution

5. \texttt{male(X) :- person(X), hasJob(X, nurse).}
   \texttt{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.
5. \texttt{male(X) :- person(X), hasJob(X, nurse).}
   \texttt{male(X) :- person(X), hasJob(X, actor).}

6. The husband of the chef is the telephone operator.
   \texttt{hasHusband(Y, X) :- person(X ; Y),}
   \texttt{hasJob(Y, chef), hasJob(X, operator).}

7. Roberta is not a boxer.

8. Pete has no education past the ninth grade.
Lparse/Smmodels 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/Smmodels 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.
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/Smmodels 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/Smmodels Solution

5. \[ \text{male}(X) : \neg \text{person}(X), \text{hasJob}(X, \text{nurse}). \]
   \[ \text{male}(X) : \neg \text{person}(X), \text{hasJob}(X, \text{actor}). \]

6. \[ \text{hasHusband}(Y, X) : \neg \text{person}(X ; Y), \]
   \[ \quad \text{hasJob}(Y, \text{chef}), \text{hasJob}(X, \text{operator}). \]
   \[ 2 \{ \text{female}(X), \text{male}(Y) \} 2 : \neg \]
   \[ \quad \text{person}(X ; Y), \text{hasHusband}(X, Y). \]

7. \[ : \neg \text{hasJob}(\text{roberta}, \text{boxer}). \]

8. Pete has no education past the ninth grade.
   \[ : \neg \text{educated}(\text{pete}). \]
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/Smmodels 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. :- educated(pete).
   educated(X) :- 1 { hasJob(X, nurse), hasJob(X, police),
   hasJob(X, teacher) } 2, person(X).

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Lparse/Smmodels Solution

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

10. Question: Who holds which jobs?
Lparse/Smmodels 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/Smmodels Solution

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

$$0 \{ \text{hasJob(roberva, chef), hasJob(roberva, police) } \} 0.$$  
$$0 \{ \text{hasJob(X, chef), hasJob(X, police) } \} 1 :- \text{person(X).}$$

10. Question: Who holds which jobs?
Lparse/Smmodels Solution

9. \[ 0 \{ \text{hasJob(roberta, chef), hasJob(roberta, police) } \} 0. \]
   \[ 0 \{ \text{hasJob(X, chef), hasJob(X, police) } \} 1 : \text{person(X).} \]

10. Question: Who holds which job?
Lparse/Smmodels Solution

9. \( 0 \{ \text{hasJob(roberta, chef), hasJob(roberta, police)} \} 0. \)
   \( 0 \{ \text{hasJob(X, chef), hasJob(X, police)} \} 1 :- \text{person(X)}. \)

10. Question: Who holds which job?
    
    #hide.
    #show hasJob(X, Y).
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 Smoodels

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

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

• 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

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNoun is a CNoun.</td>
<td>Roberta is a person.</td>
</tr>
<tr>
<td>PNoun is Adjective.</td>
<td>Roberta is female.</td>
</tr>
<tr>
<td>There is a CNoun.</td>
<td>There is a job.</td>
</tr>
<tr>
<td>A CNoun is Adjective.</td>
<td>A person is female.</td>
</tr>
<tr>
<td>A OrdNumber CNoun is a CNoun of</td>
<td>A first person is a husband of</td>
</tr>
<tr>
<td>a OrdNumber CNoun.</td>
<td>a second person.</td>
</tr>
<tr>
<td>A CNoun Verb a CNoun as PNoun.</td>
<td>A person holds a job as nurse.</td>
</tr>
<tr>
<td>CardRest CNoun Verb a CNoun.</td>
<td>Exactly one person holds a job.</td>
</tr>
<tr>
<td>A CNoun Verb CardRest CNoun.</td>
<td>A person holds exactly two jobs.</td>
</tr>
</tbody>
</table>
Complex Sentences

• **If** Simple Sentence [*and Simple Sentence]* then Simple Sentence.

• **Exclude that** Simple Sentence [*and that Simple Sentence]*.
Anaphora

• 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.
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.
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?
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?
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

\[
[A,B,C,D,E,F]
\]
\[
[G,H,I]
object(G,person)
object(H,job)
named(H,chef)
predicate(I,hold,G,H)
\]
\[
==>
[J,K]
object(J,chef)
predicate(K,isa,G,J)
\]
\[
\text{named}(A,roberta)
\text{named}(B,thelma)
\text{named}(C,steve)
\text{named}(D,pete)
object(E,person)
predicate(F,isa,(A;B;C;D),E)
\]
Discourse Representation Structure

[M2]
object(M2, person)

==> 
[N2, 02]
cardinal(N2, eq, 2)
object(N2, job)
predicate(02, 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

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