Conducting and Visualizing Set-Theoretic Social Research with Python

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Overview

- Introduction to QCA
- History of QCA software
- First (mis-)steps in developing Kirq: the fsQCA package for R
- Use cases and design goals for acq and Kirq
- Python's role in meeting these design goals
- Developing visualizations for QCA
- Lessons learned: Using Python for academic software projects

What is Qualitative Comparative Analysis?

- A method of conducting social research by analyzing subset relationships, using Boolean algebra

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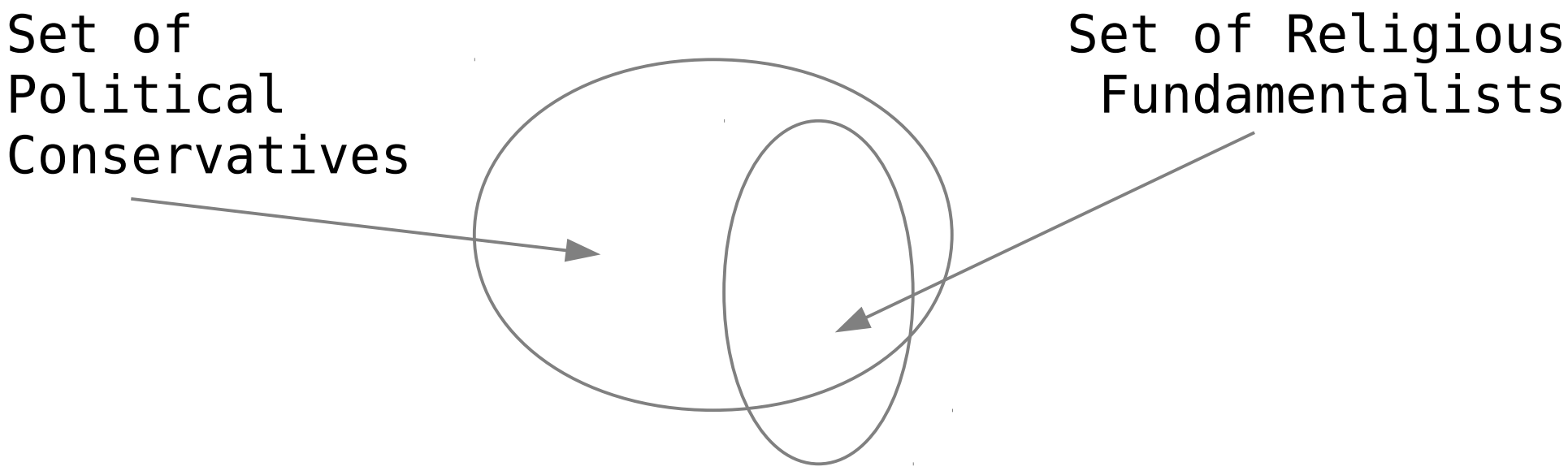
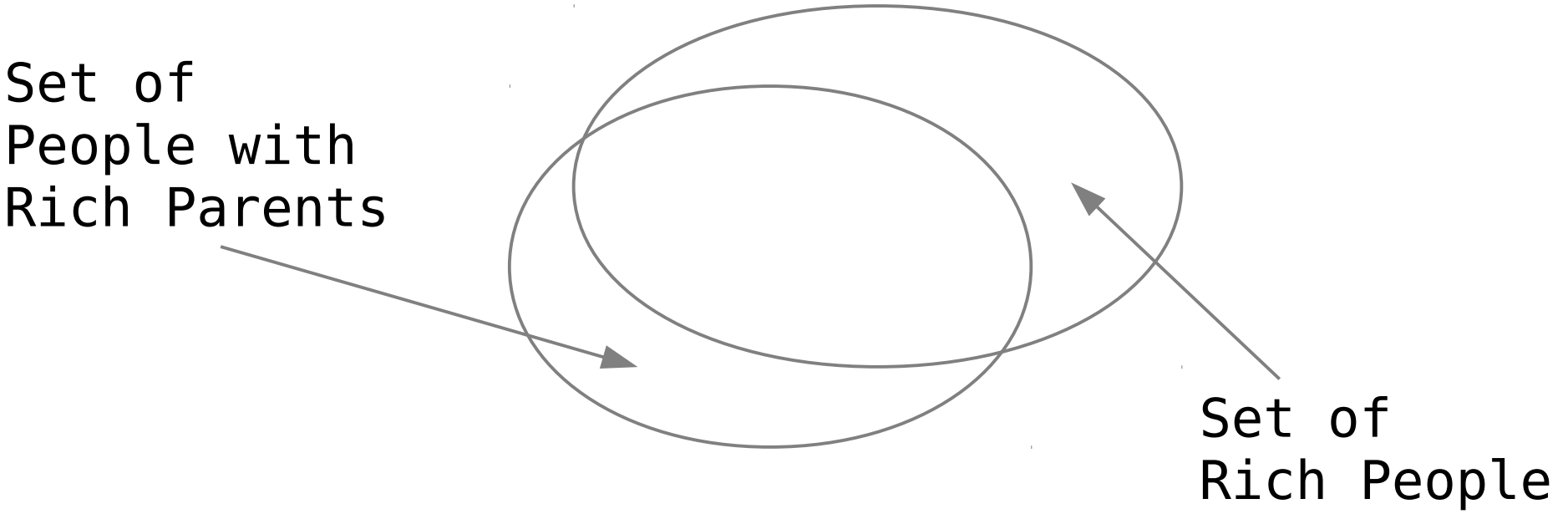
- Example: Religious fundamentalists tend to be politically conservative.



What is Qualitative Comparative Analysis?

- A method of conducting social research by analyzing subset relationships, using Boolean algebra
- Example: Wealthy individuals tend to come from privileged families.

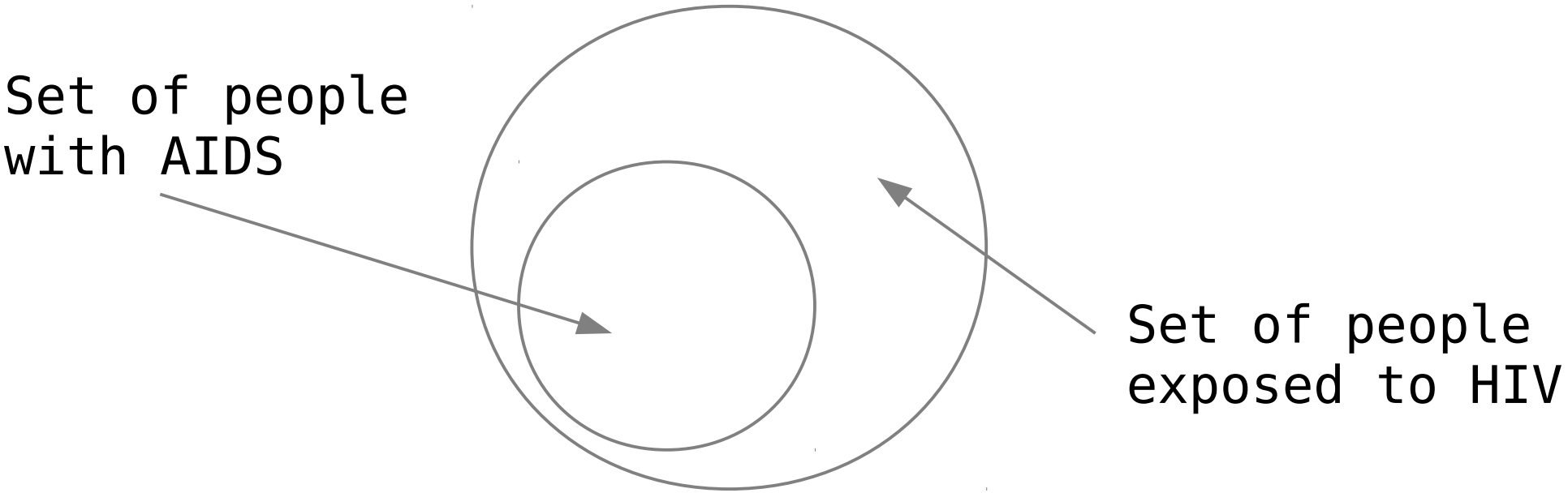


What is Qualitative Comparative Analysis?

- Particularly concerned with two types of causal relationships: necessary conditions and sufficient conditions

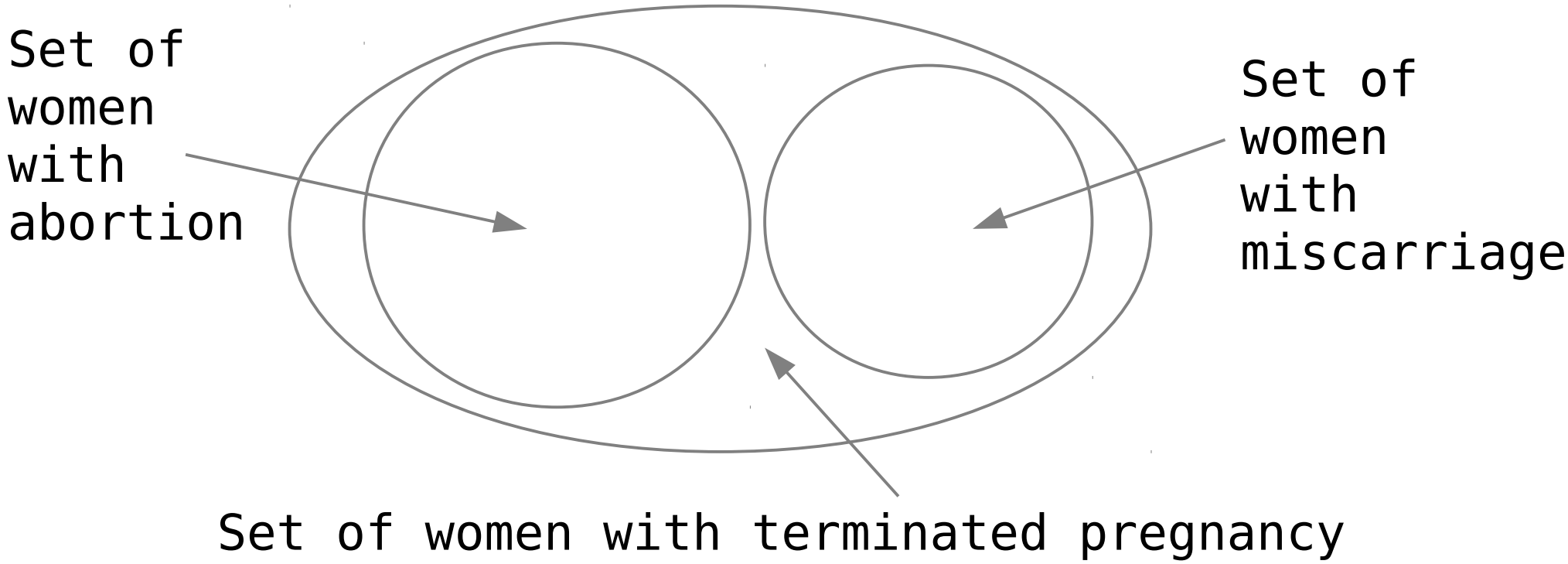
What is Qualitative Comparative Analysis?

- Necessary condition: cause must be present for outcome to occur
- Example: Must be exposed to HIV to contract AIDS



What is Qualitative Comparative Analysis?

- Sufficient condition: if cause occurs, outcome will occur
- Example: Abortion *or* miscarriage will terminate pregnancy



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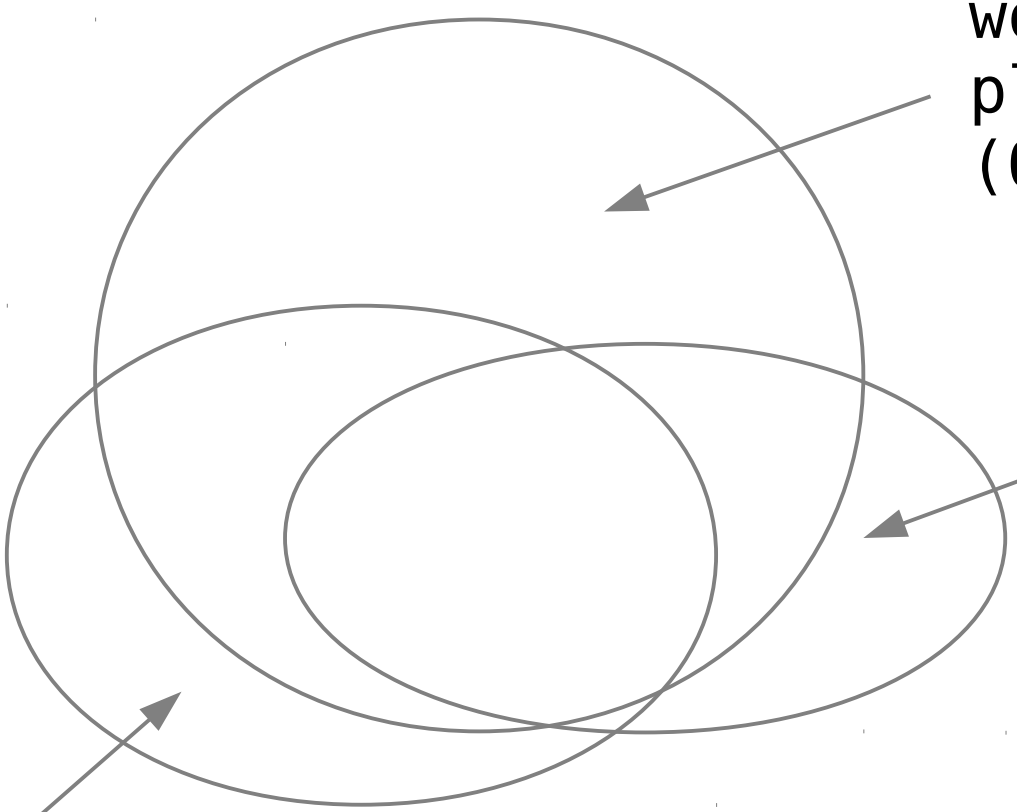

Recently deported women who do not plan to cross again (Outcome)

High SES women who haven't lived in the U.S. and aren't traveling with family (X_1)

High SES women who haven't lived in the U.S., have only attempted cross a few times and felt that their last crossing experience was very dangerous (X_2)

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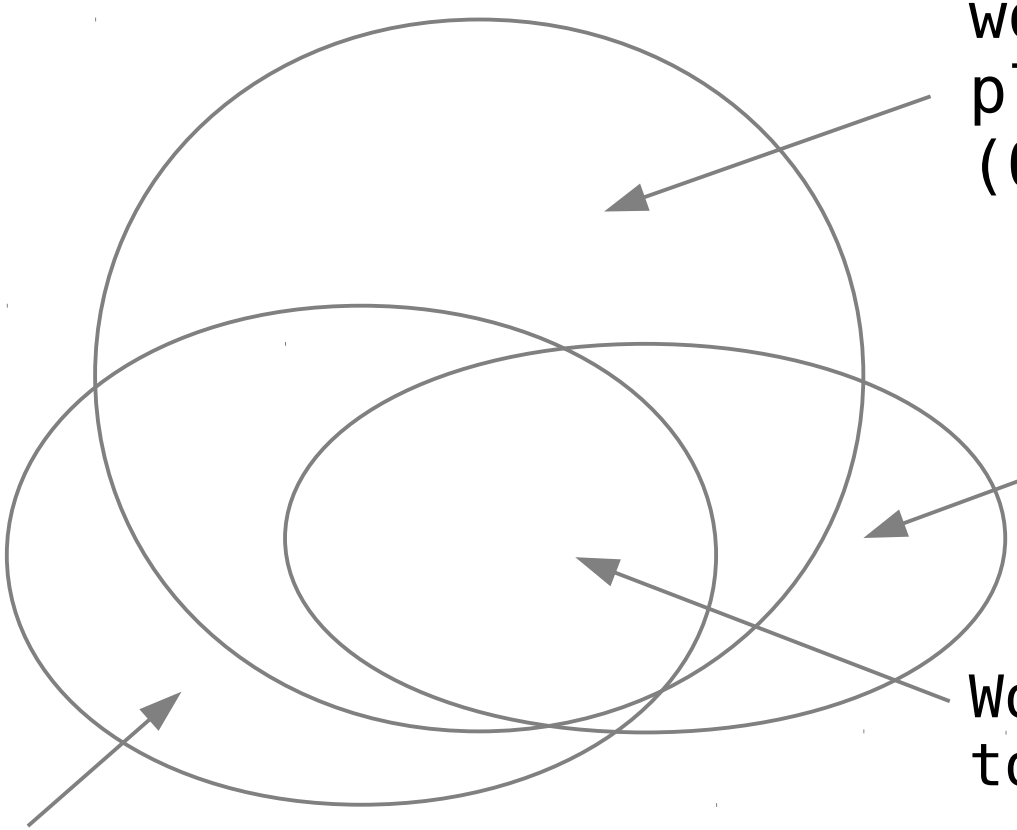

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Women belonging to sets X_1 and X_2

High SES women who haven't lived in the U.S., have only attempted cross a few times and felt that their last crossing experience was very dangerous (X_2)

What is Qualitative Comparative Analysis?

- Challenges conventional statistical analysis, which is based upon a linear-additive model
- Complements other set-theoretic research methods (e.g., SNA and QNA)
- Does not depend upon degrees of freedom, so is useful for small-, medium-, and large-N studies
- Encourages a research process that is “retroductive” and “case-oriented”

What is Qualitative Comparative Analysis?

Example: Brown and Boswell (1995)

Truth Table with Contradiction (from Table 4 of Brown and Boswell 1995)

Recent Black Migrants	Weak Union	Black Strikebreaking	Observations
T	T	T	East Chicago, Pittsburgh, Youngstown
T	F	Con	Buffalo, Chicago, Gary, Johnstown, [Cleveland]
F	T	F	Bethlehem, Joliet, McKeesport, Milwaukee, New Castle, Reading
F	F	F	Decatur, Wheeling

What is Qualitative Comparative Analysis?

Example: Brown and Boswell (1995)

Revised Truth Table without Contradiction (from Table 5 of Brown and Boswell 1995)

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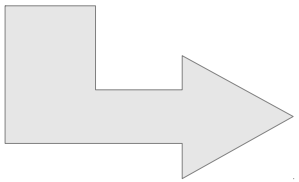

```
RBM * WU * LGR +
RBM * ~WU * LGR
        = Black Strikebreaking
```

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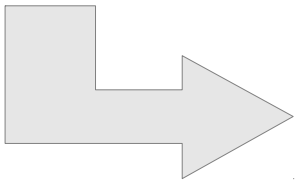

```
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RBM * ~WU * LGR
                = Black Strikebreaking

RBM * LGR       = Black Strikebreaking
```
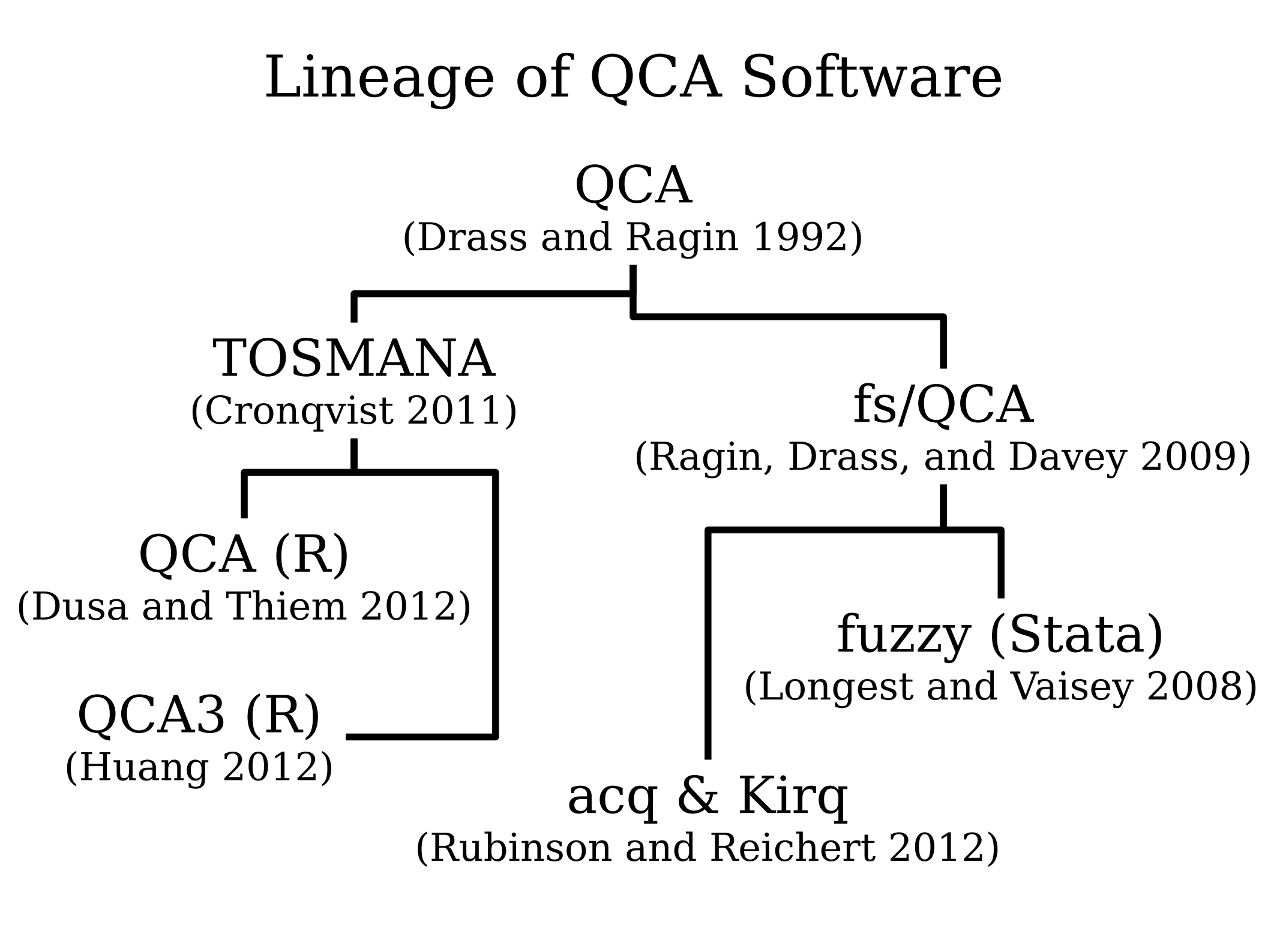

Technical and Usability Challenges

- QCA algorithms are:
  - NP-hard (no exact algebraic solution)
  - $O(2^N)$ complexity, where N indicates the number of variables (not observations) in the data set
- Because data sets tend to be small and matrix algebra isn't used, no need for NumPy
- How to maintain and encourage retroductive, case-oriented research process?
- How to make software that's efficient, useful, and usable?


Lineage of QCA Software
QCA
(Drass and Ragin 1992)
TOSMANA
(Cronqvist 2011)
fs/QCA
(Ragin, Drass, and Davey 2009)
QCA (R)
(Dusa and Thiem 2012)
QCA3 (R)
(Huang 2012)
fuzzy (Stata)
(Longest and Vaisey 2008)
acq & Kirq
(Rubinson and Reichert 2012)

“Plan to throw one away; you will, anyhow”

- fsQCA module for R
  - Cross-platform, but requires R
  - Not user-friendly
  - Too slow
  - R programming “considered harmful”
  - But: allowed me to realize that the user interface should be task-oriented

Use Cases for acq and Kirq

- acq: QCA at the Unix commandline
  - a “scratch my own itch” project
- Kirq: QCA for everybody else
  - a user-friendly, crossplatform GUI program

Design Goals for acq and Kirq

- Software that is efficient, useful, and usable:
  - Follow the Unix philosophy
  - Good “out of the box” performance, plus ability to optimize performance
  - Support and encourage good QCA research practices
  - Kirq should be crossplatform and user-friendly
- Also important: Avoid sucking up all of my time

Why Python?

- The surrounding ecosystem
  - Ability to hire others
  - Confidence that the supporting environments is stable and will continue to be maintained
  - Python is *lingua franca* in academia
  - Rich environment for GUI toolkits, installers, etc.
  - Chose Qt for GUI toolkit and PyInstaller for installer

Design Goal: Avoiding a time sink

- Relatively easy to recruit and hire good programmers
- Easy to mix procedural and OOP programming
- Official online documentation remains top notch
- The core Python language remains relatively compact
  - but not the standard library, and certainly not the surrounding environment (PyPI, etc)

Design Goal: Follow the Unix Philosophy

- Build a prototype as soon as possible
- Small is beautiful/do one thing well
  - acq's GUI scripts: gtt and concov
  - have resisted adding a data editor to Kirq; now writing a Google Sheets add-on
  - still working out how to implement visualizations
- Make every program a filter
  - Because Kirq can read data from the commandline, it's easy for other programs to call out to it

Design Goal: Good “out of the box” performance and ability to optimize

- acq had fewer lines of code than my fsQCA module for R, and was faster
  - compare to QCA module for R
- Good tools for profiling
- Some standard, well documented practices for improving performance, although Python optimization often requires expertise
- Potential of projects such as Cython and PyPy

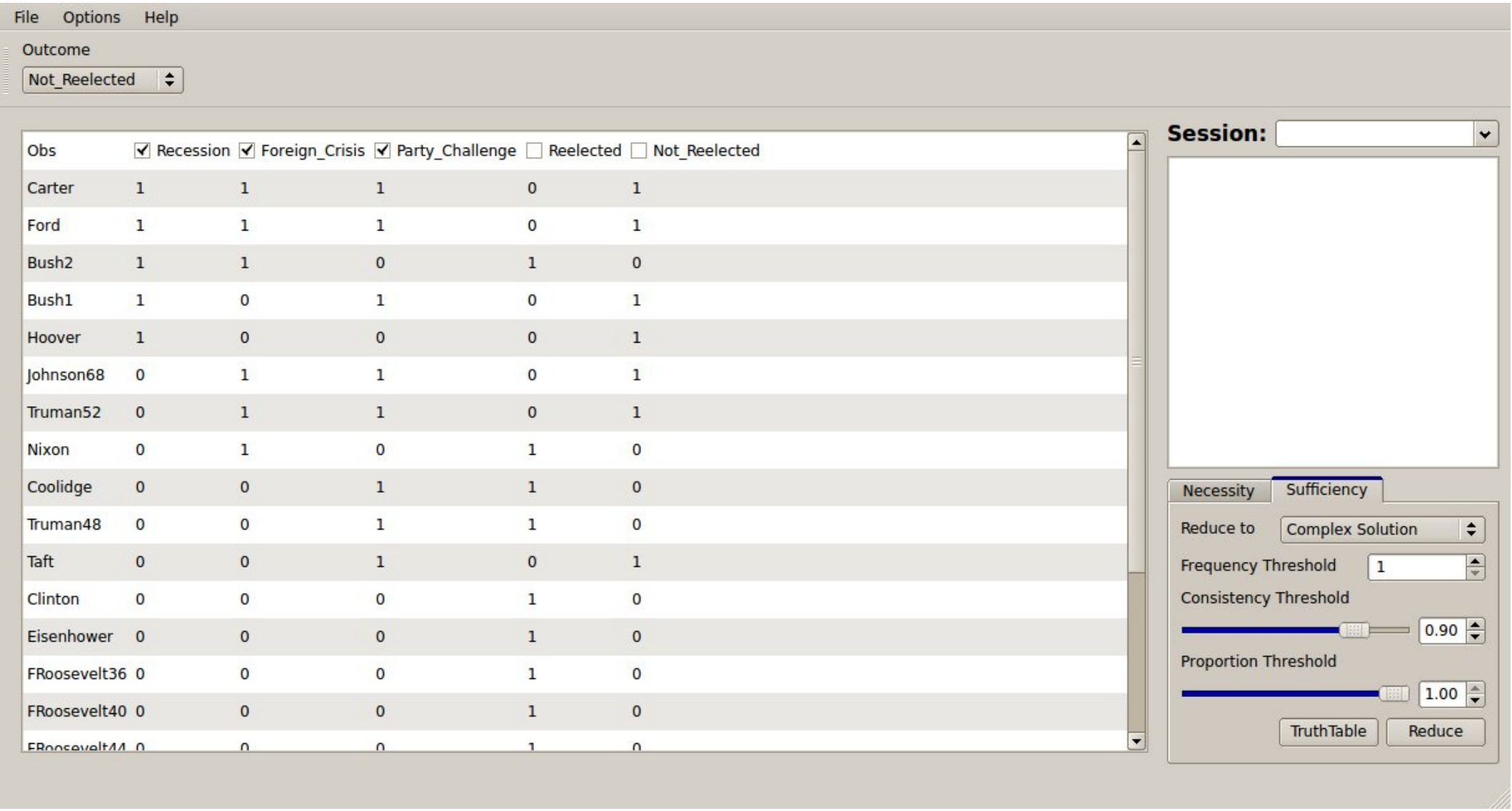
Design Goal: Support and encourage good QCA research practices

- Less concern for performance means more attention to user-interface issues
- Writing acq as Unix shell scripts helped me streamline the QCA analysis; both acq and Kirq make it easy to modify and rerun analyses
- Have designed Kirq to facilitate interrogation and comparisons of solutions
- Lots of GUI niceties, such as tooltips and pop-out windows
- Importance of “eating your own dogfood”

Design Goal: Kirq should be cross-platform and user-friendly

- Standardized on Python 2.7, for PyQt
- Only minor compatibility issues with PyQt bindings and OSX, and none with Windows – Kirq always feels native
- Could never build Qt for OSX; used MacPorts instead (slow, but works well)
- PyInstaller works well, but originally had to use development branch for OSX (dev branch is now stable)
- Session history is Kirq's killer feature

Example: Defeats of Incumbent U.S. Presidents (Winders 2008)



Example: Defeats of Incumbent U.S. Presidents (Winders 2008)

File Options Help

Row	Recession	Foreign_Crisis	Party_Challenge	N	Consist	Outcome	ObsConsist	ObsInconsist
1	True	True	True	2	1.00	True	Carter;Ford	-
2	True	True	False	1	0.00	False	-	Bush2
3	True	False	True	1	1.00	True	Bush1	-
4	True	False	False	1	1.00	True	Hoover	-
5	False	True	True	2	1.00	True	Johnson68;Tr...	-
6	False	True	False	1	0.00	False	-	Nixon
7	False	False	True	3	0.33	Con	Taft	Coolidge;Truman48
8	False	False	False	10	0.00	False	-	Clinton;Eisenhower...

Session:

winders/Not_Reelected
gtt_suf_1

Necessity | Sufficiency

Reduce to: Complex Solution

Frequency Threshold: 1

Consistency Threshold: 0.90

Proportion Threshold: 1.00

TruthTable | Reduce

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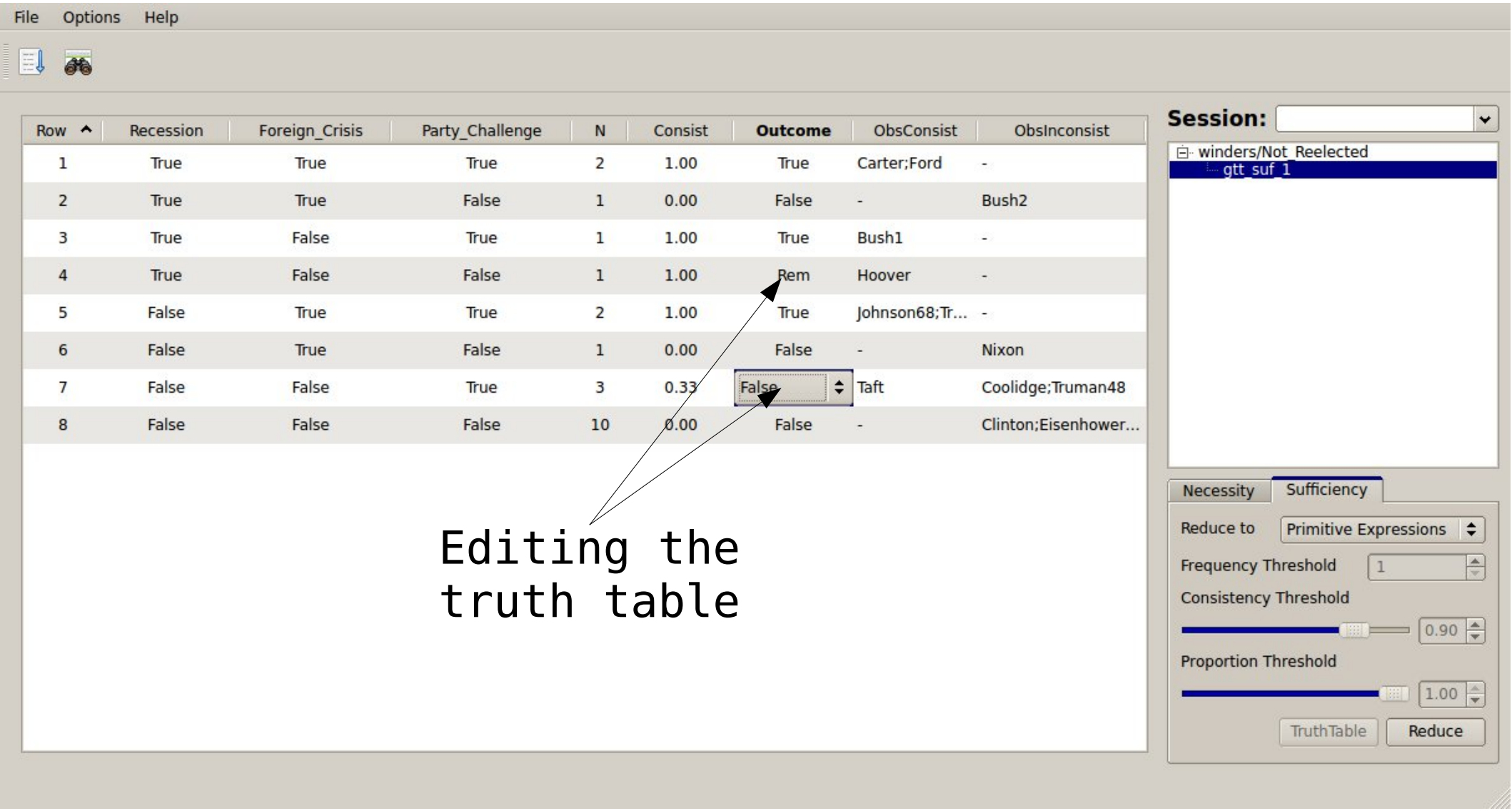

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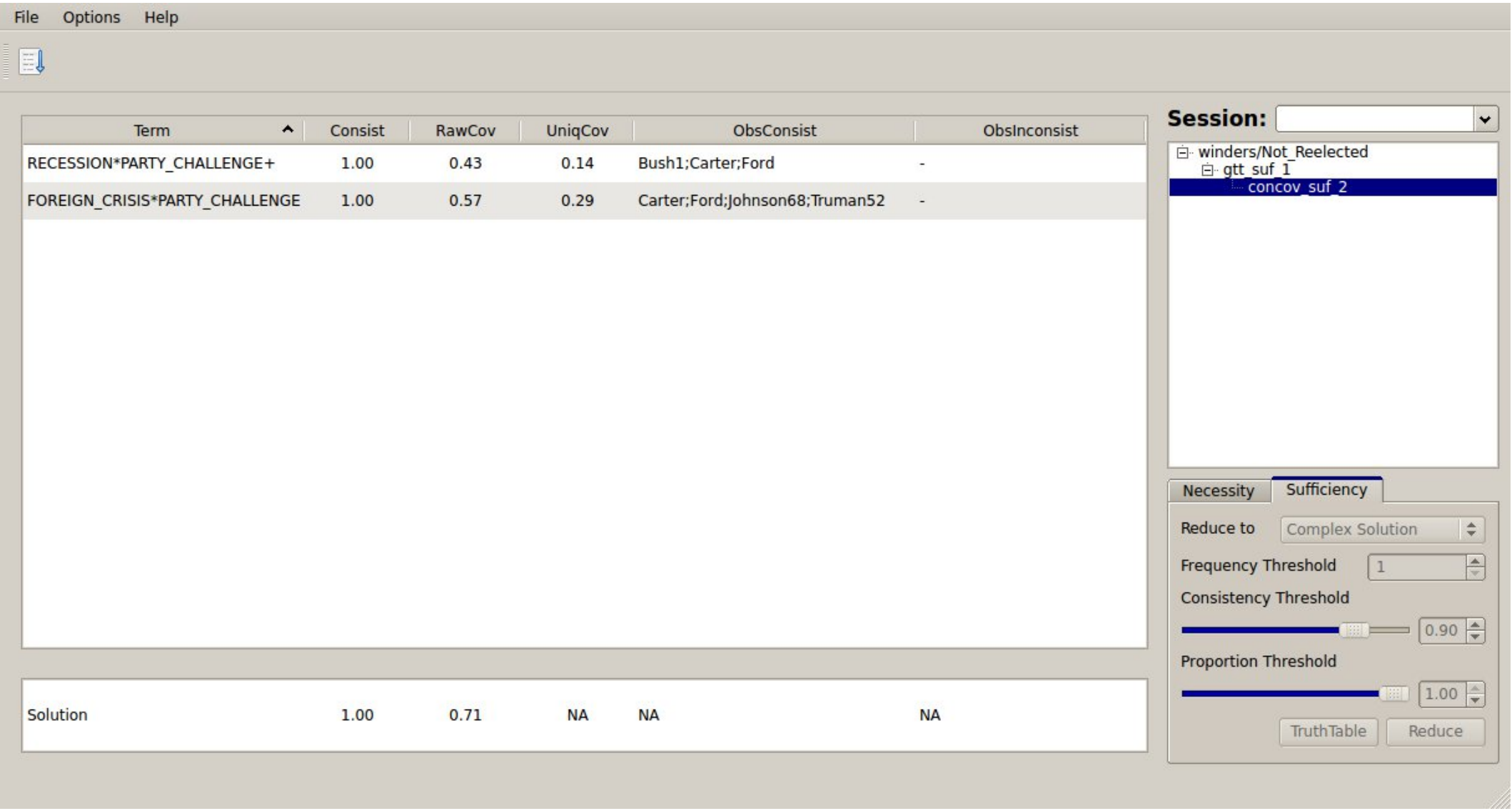

Visualizing Set-Theoretic Relationships

- Venn and Euler diagrams are familiar and relatively easy to interpret, but limited
  - Low information density
  - Interpretability declines as intersections increase
  - Difficult to convey proportionality
  - Programmatically generating area-proportional Euler diagrams with more than 3 sets is an unsolved problem

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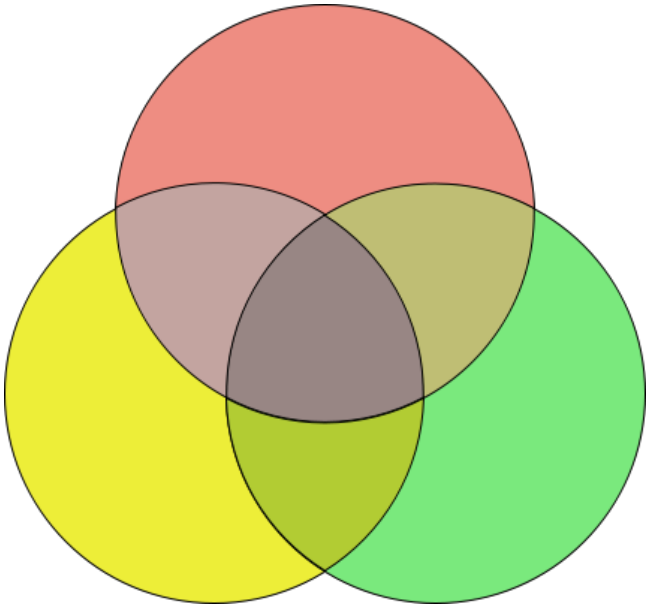
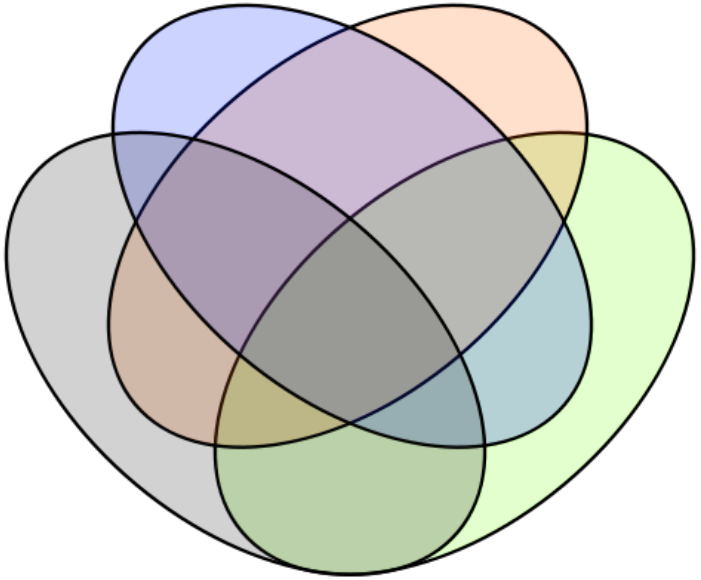
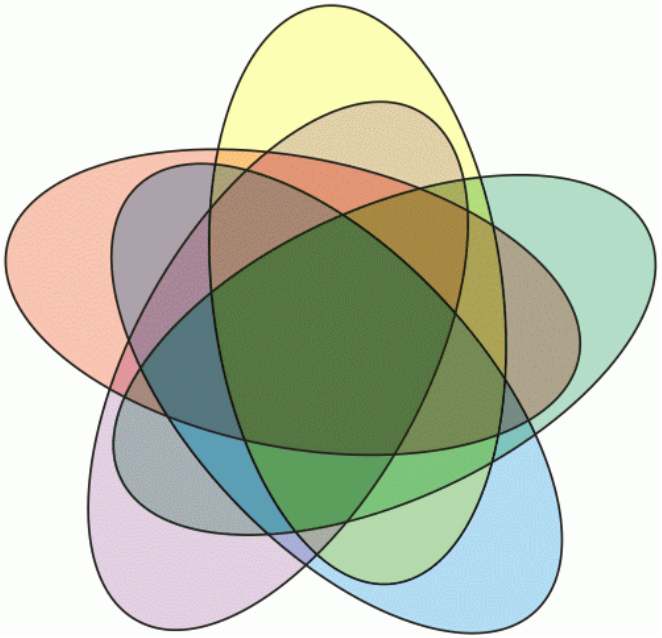


3 set Venn



4 set Venn



5 set Venn

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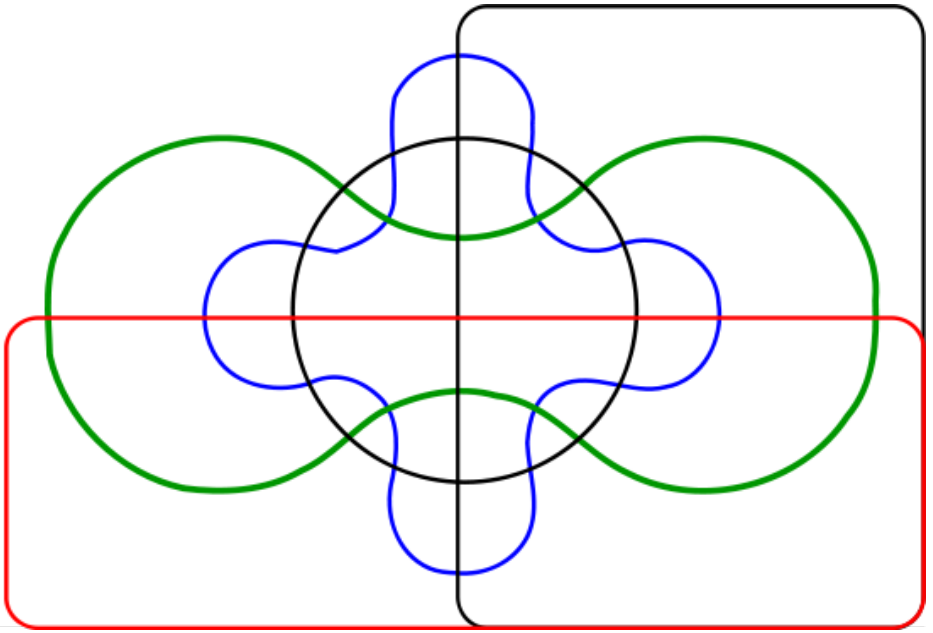
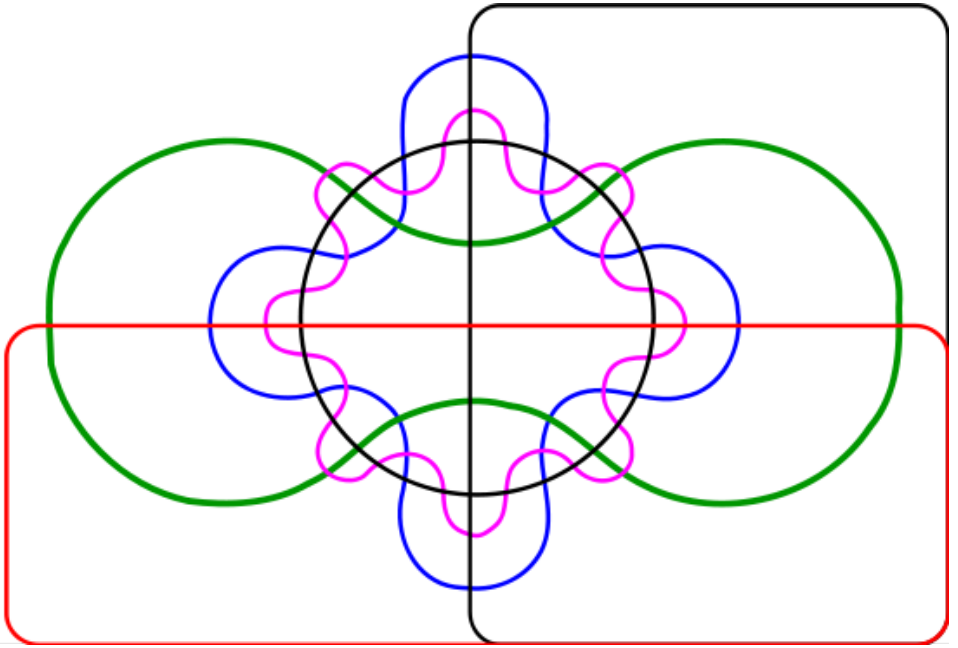


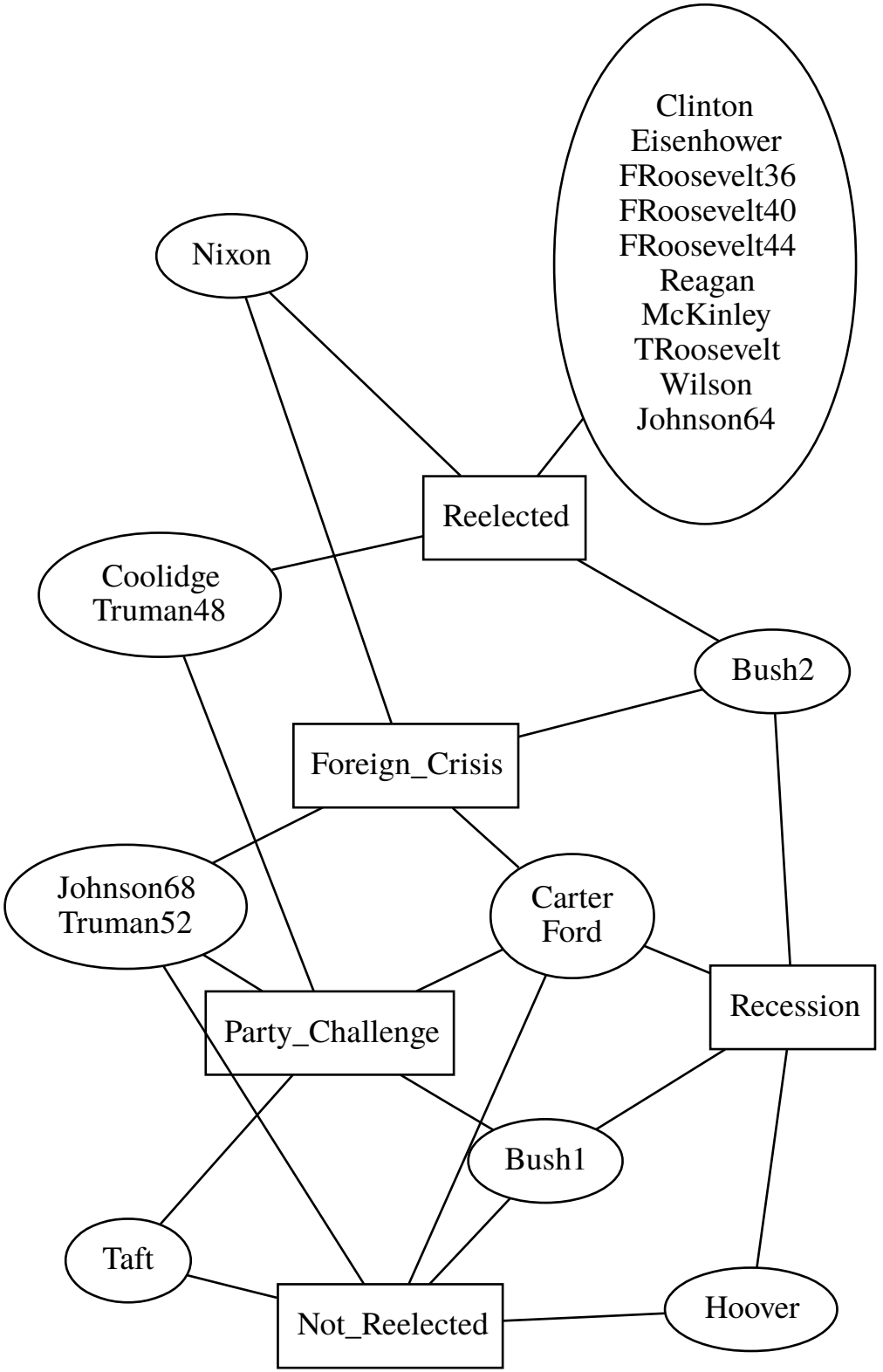
5 set Edwards-Venn



6 set Edwards-Venn

Visualizing Set-Theoretic Relationships

- Goals
  - Area-proportional sets and intersections
  - Identification of subset relationships
  - Help users to understand their data and the set-theoretic relationships embedded in their data set
- Implementation
  - QCA data sets may be represented as forest/trees, bipartite graphs, and lattices
  - Bash/Python scripts that generate gnuplot, GraphViz DOT, and/or Ti*k*Z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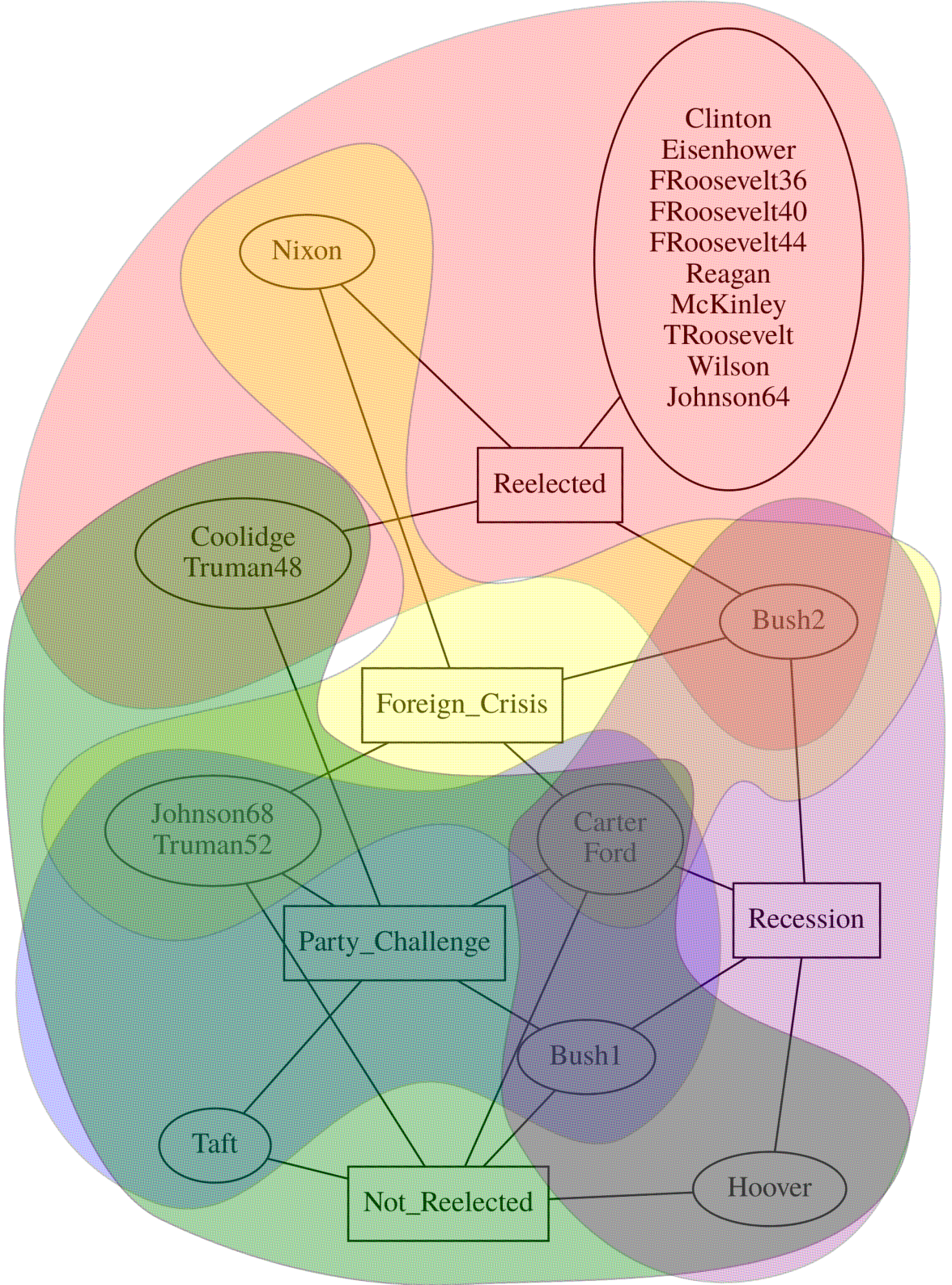
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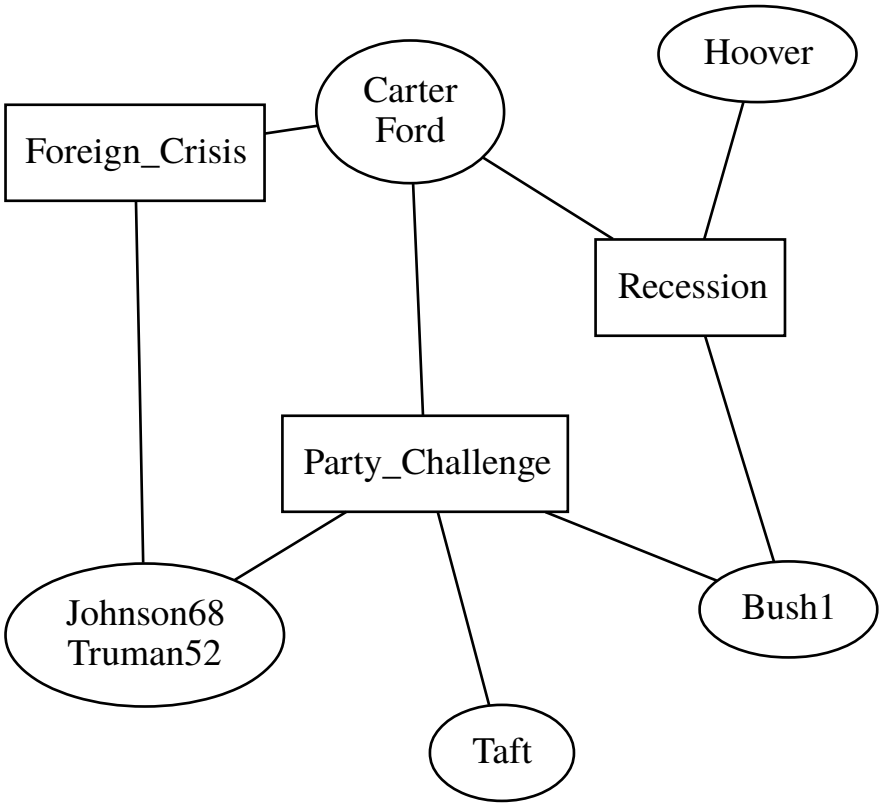
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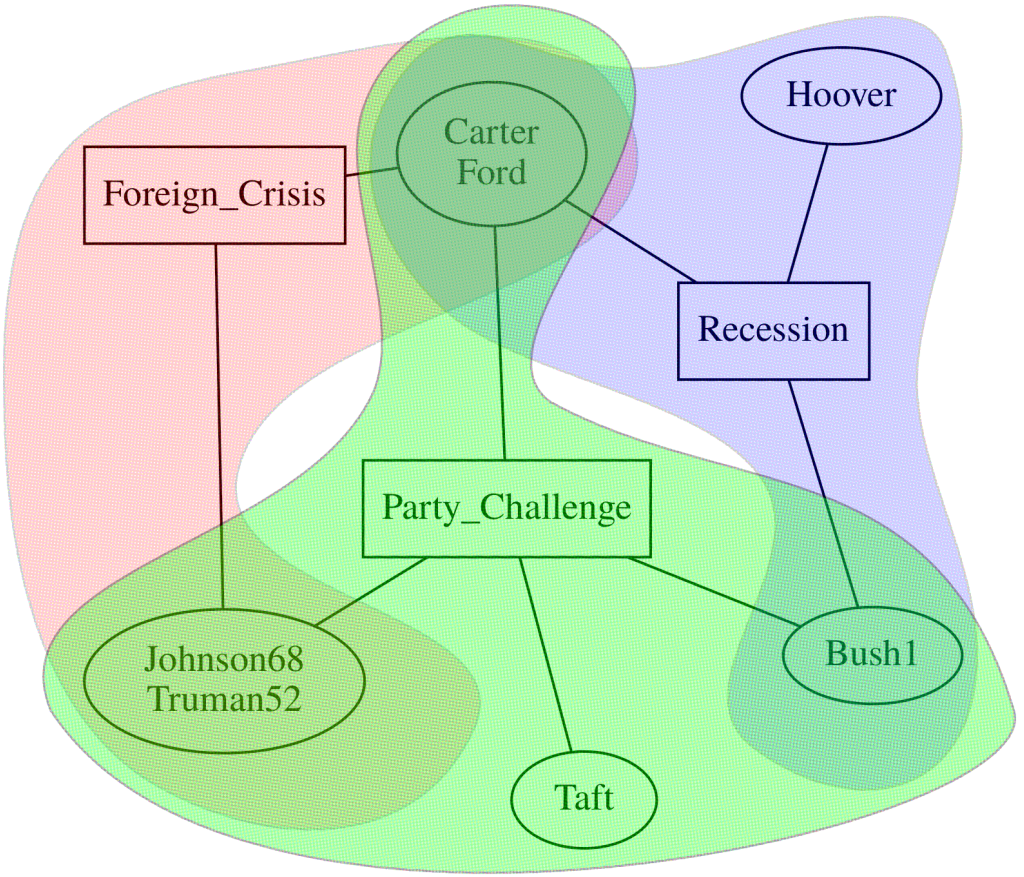
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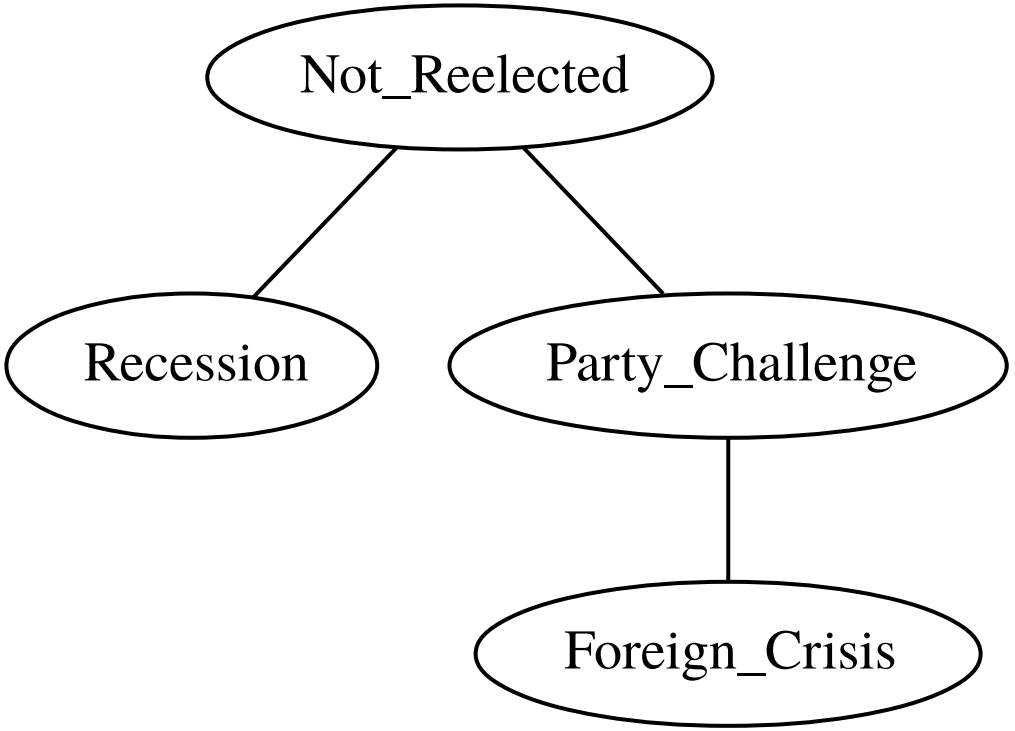
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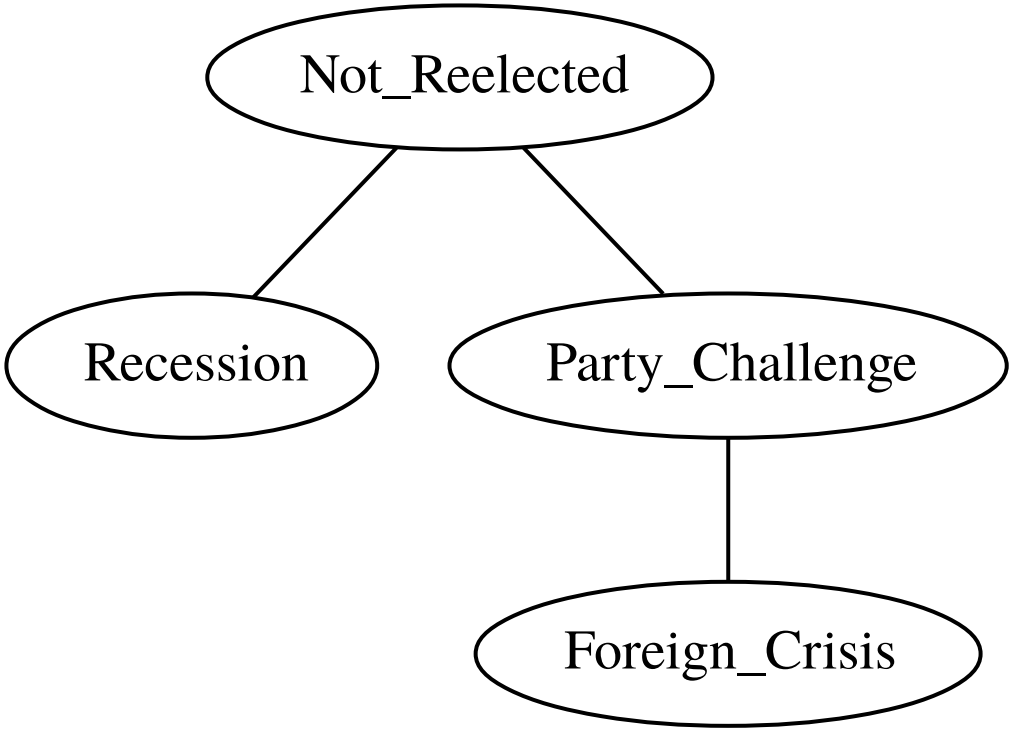
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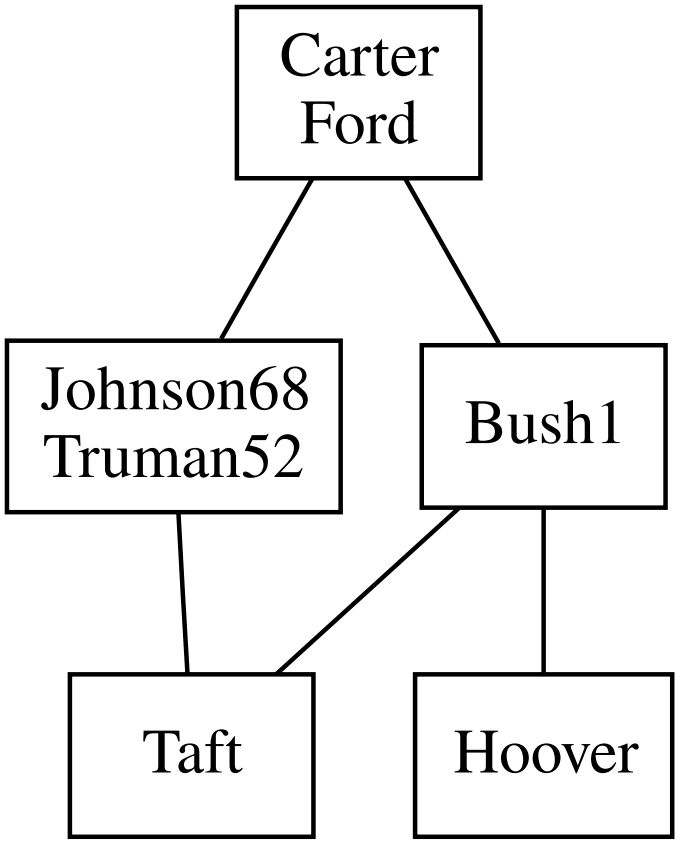
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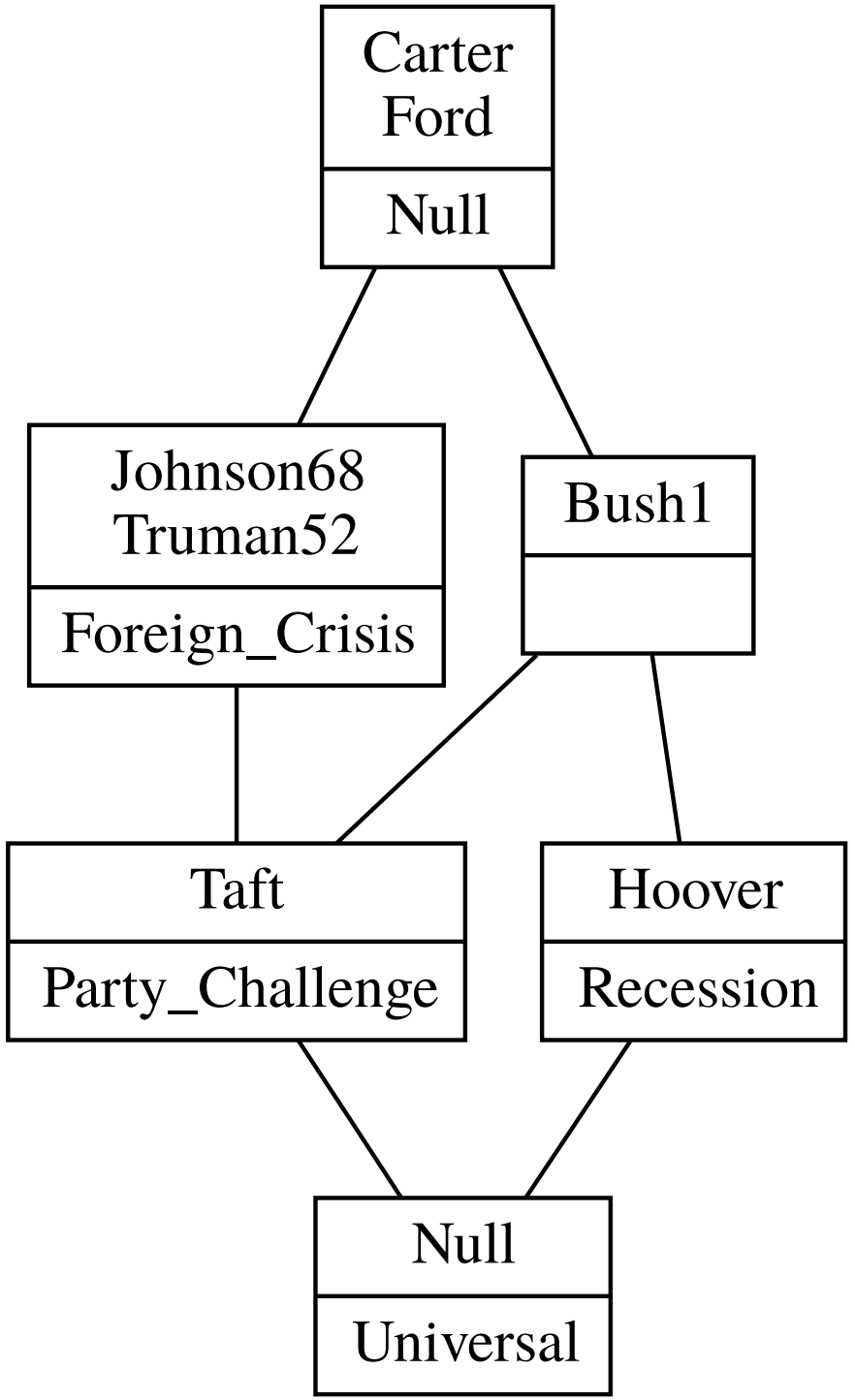
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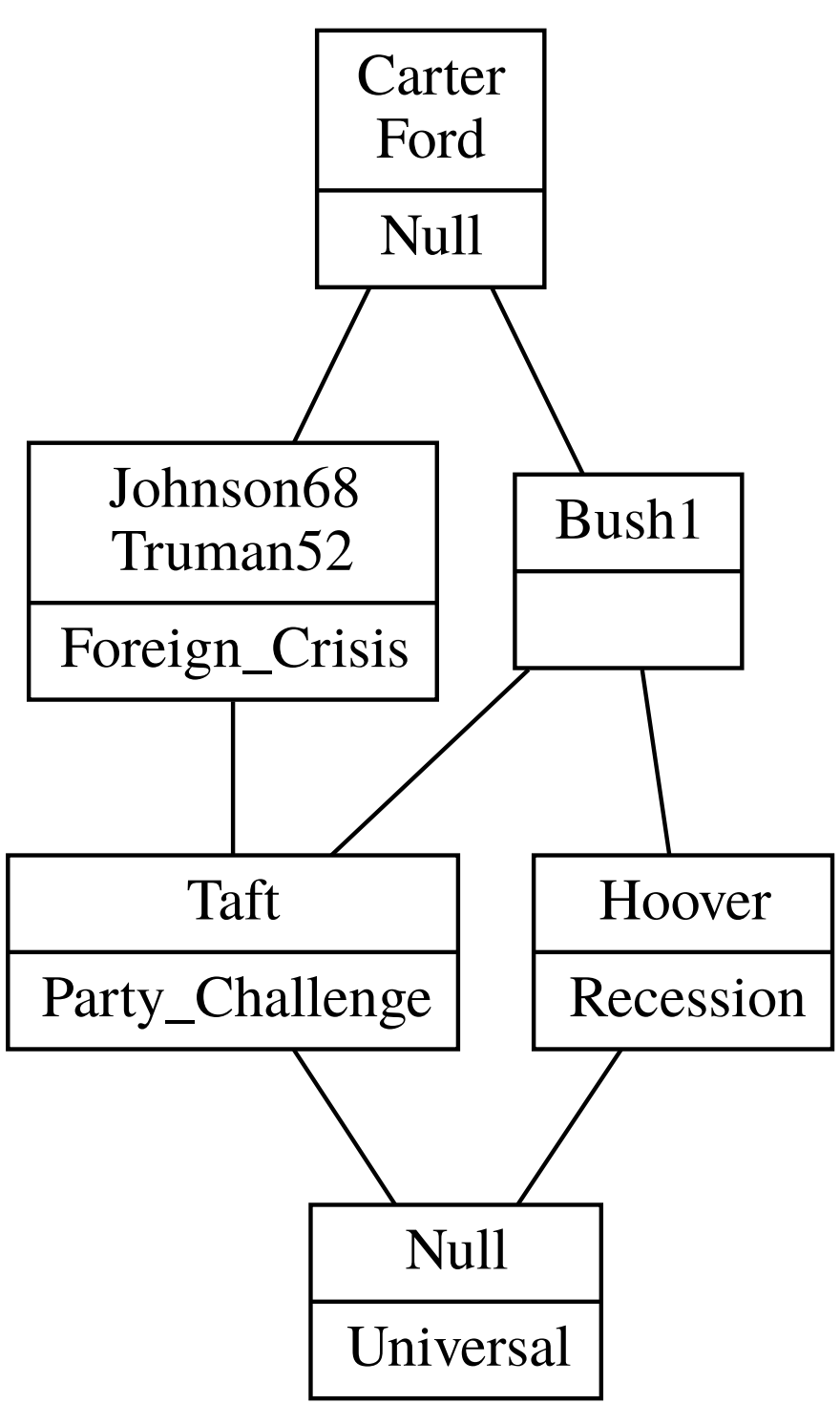
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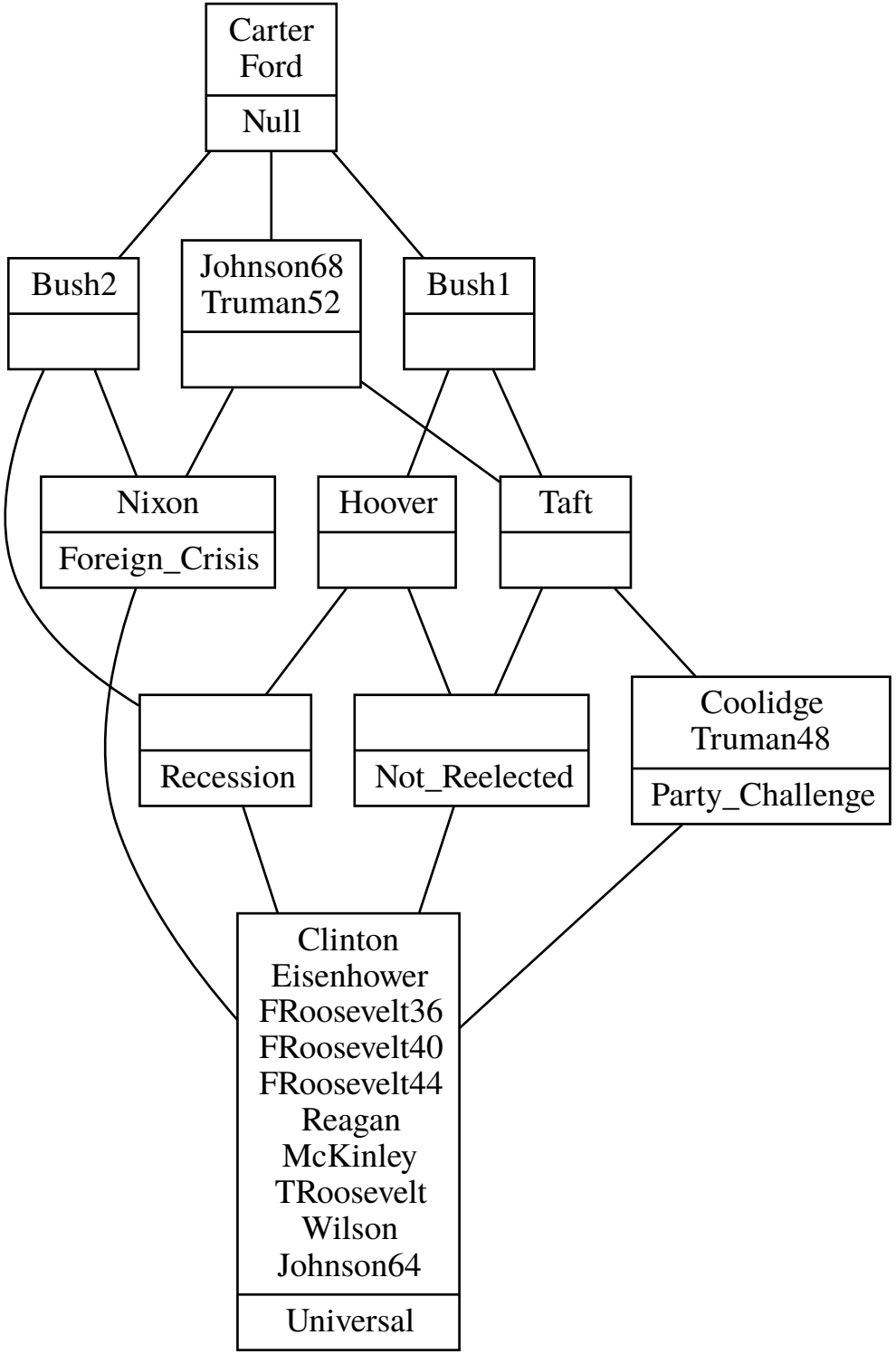
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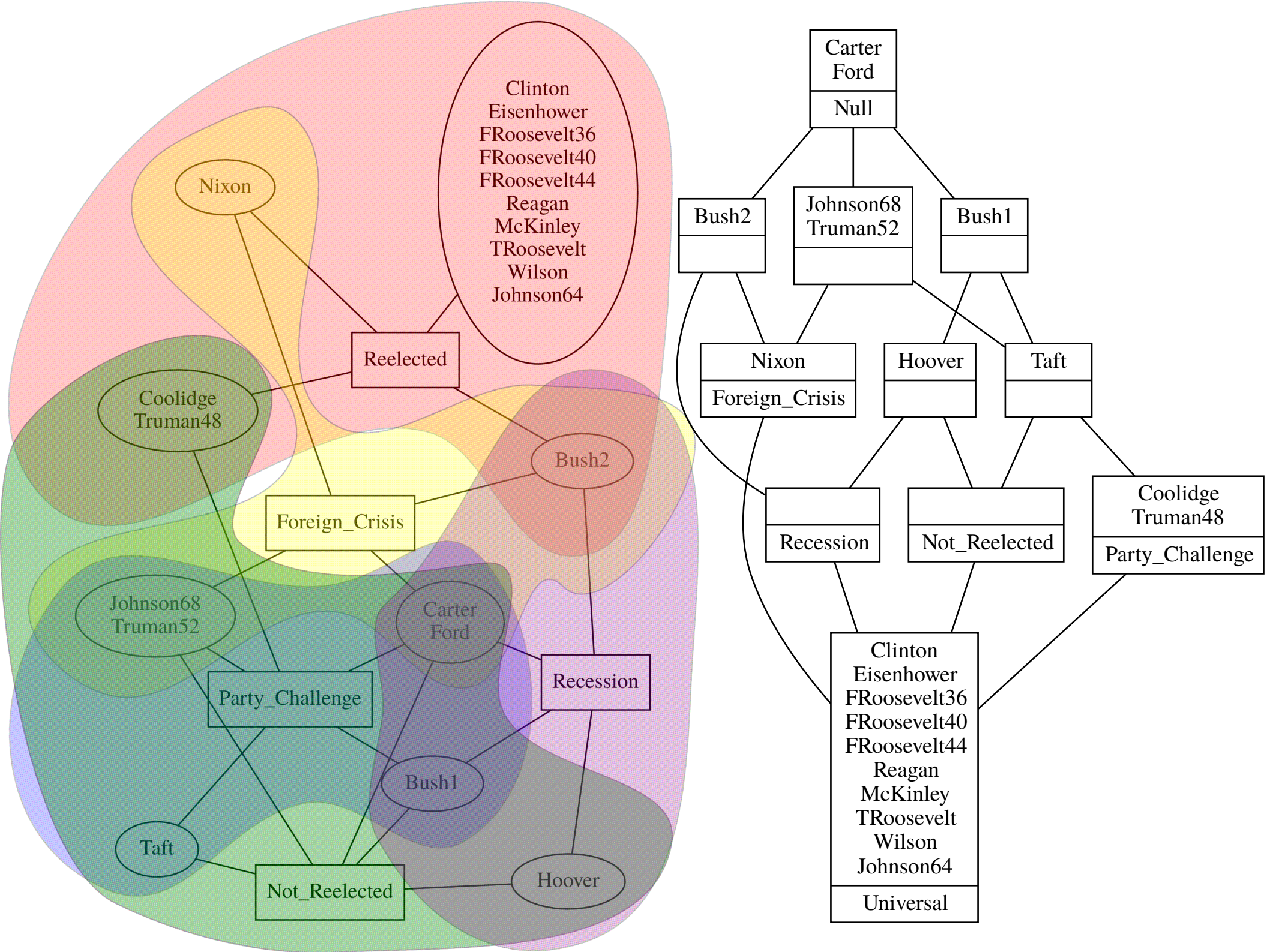
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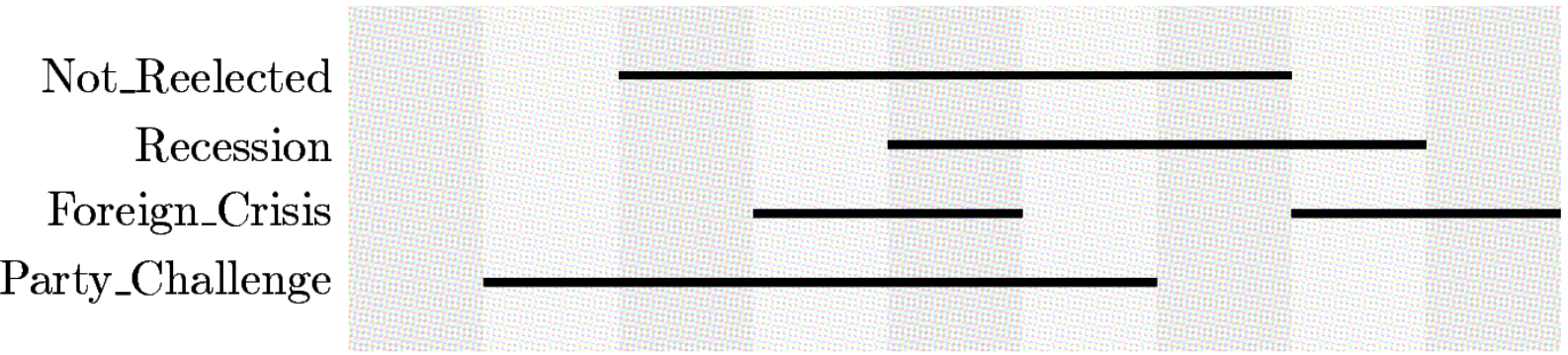
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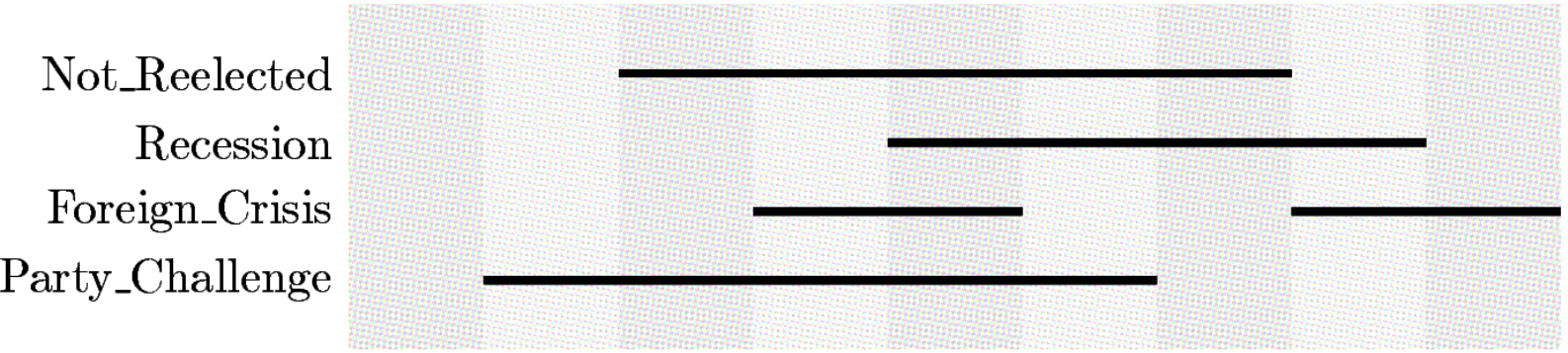
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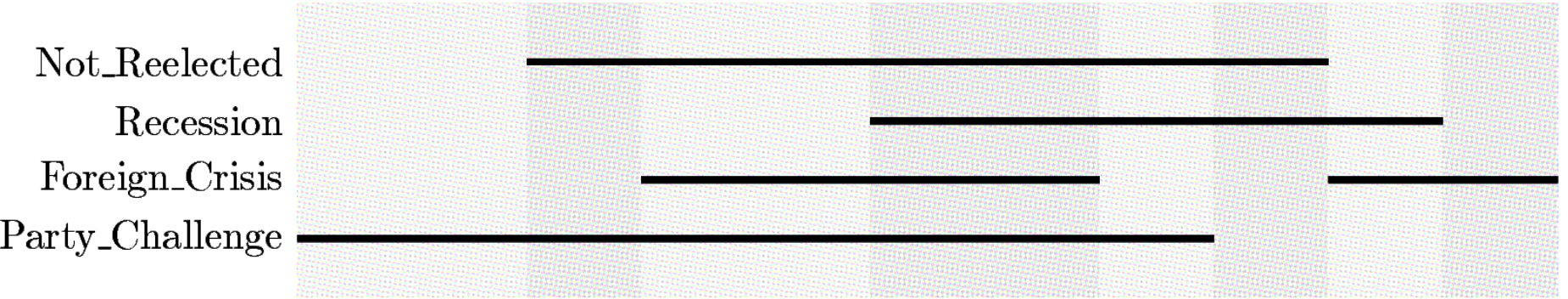
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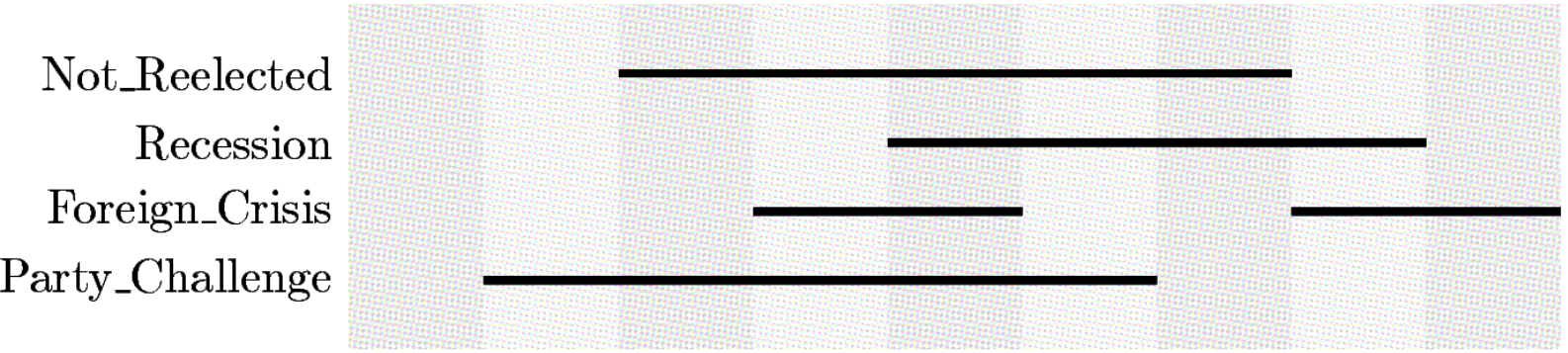
Not_Reelected
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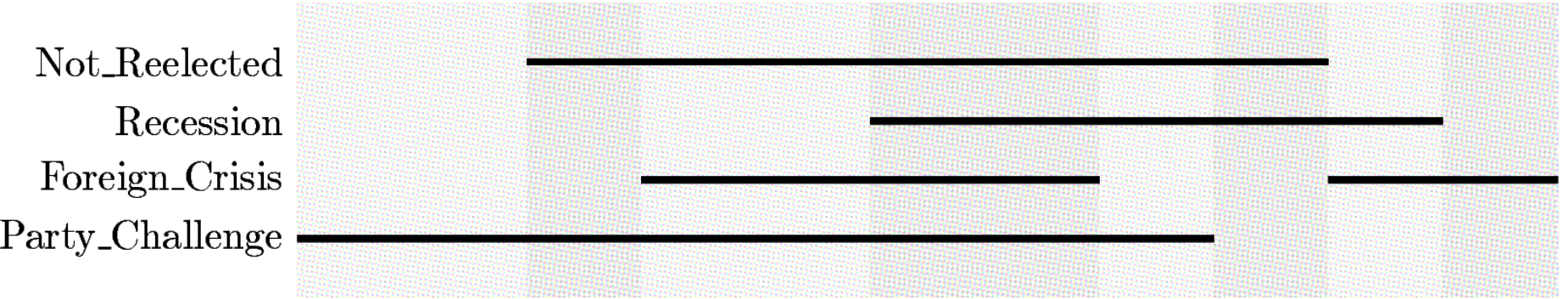
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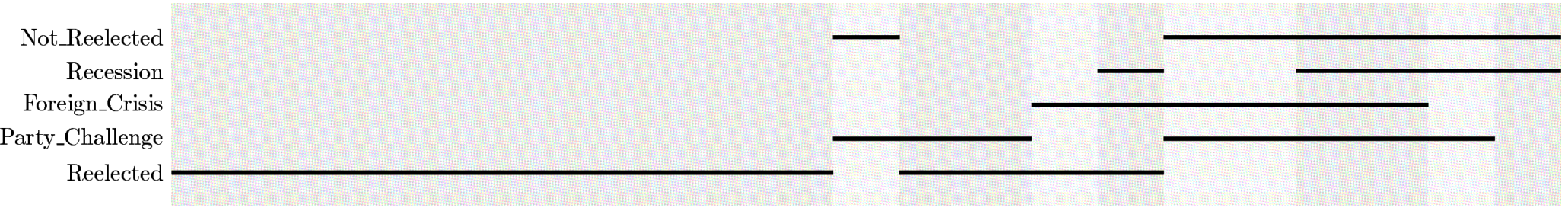
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Lessons Learned – Python's Advantages (for Academic Projects)

- Core language is relatively compact, with excellent documentation
- Relatively easy to find developers
- Strong, well-developed environment of GUI toolkits, installers, etc.
- Good performance out of the box, with ability to optimize when necessary

Lessons Learned – Python's Disadvantages (for Academic Projects)

- Package distribution is a mess, as is associated documentation
- Churn in the standard library is too rapid to keep up with for a part-time developer
- Introductory and intermediate dead-tree documentation is lousy
- Online signal-to-noise ratio is low
- Python community online is too insular; overly concerned with “idiomatic Python”