USC Viterbi School of Engineering

Software Engineering Institute

Comparing Causal Search Analyses with Traditional Statistical Methods

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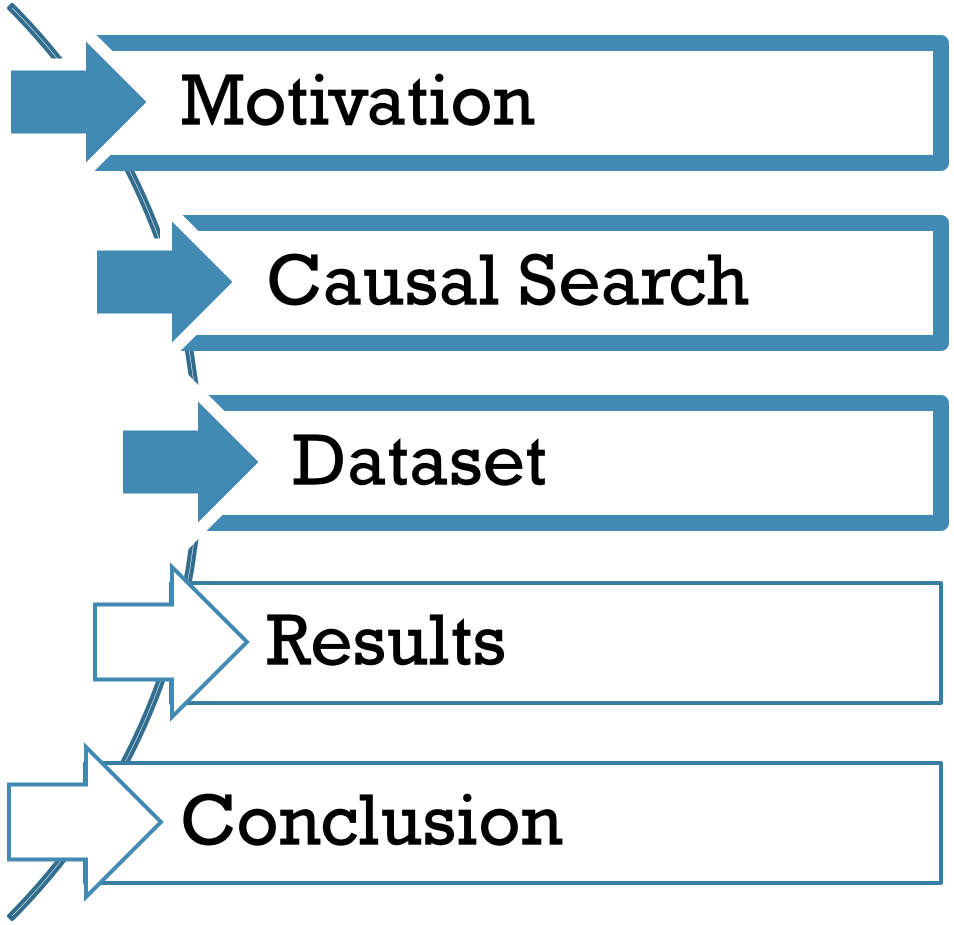
* This presentation and paper is a follow-up to the paper "Preliminary Causal Discovery Results with Software Effort Estimation Data" presented at Innovations in Software Engineering Conference (ISEC) 2018

Outline

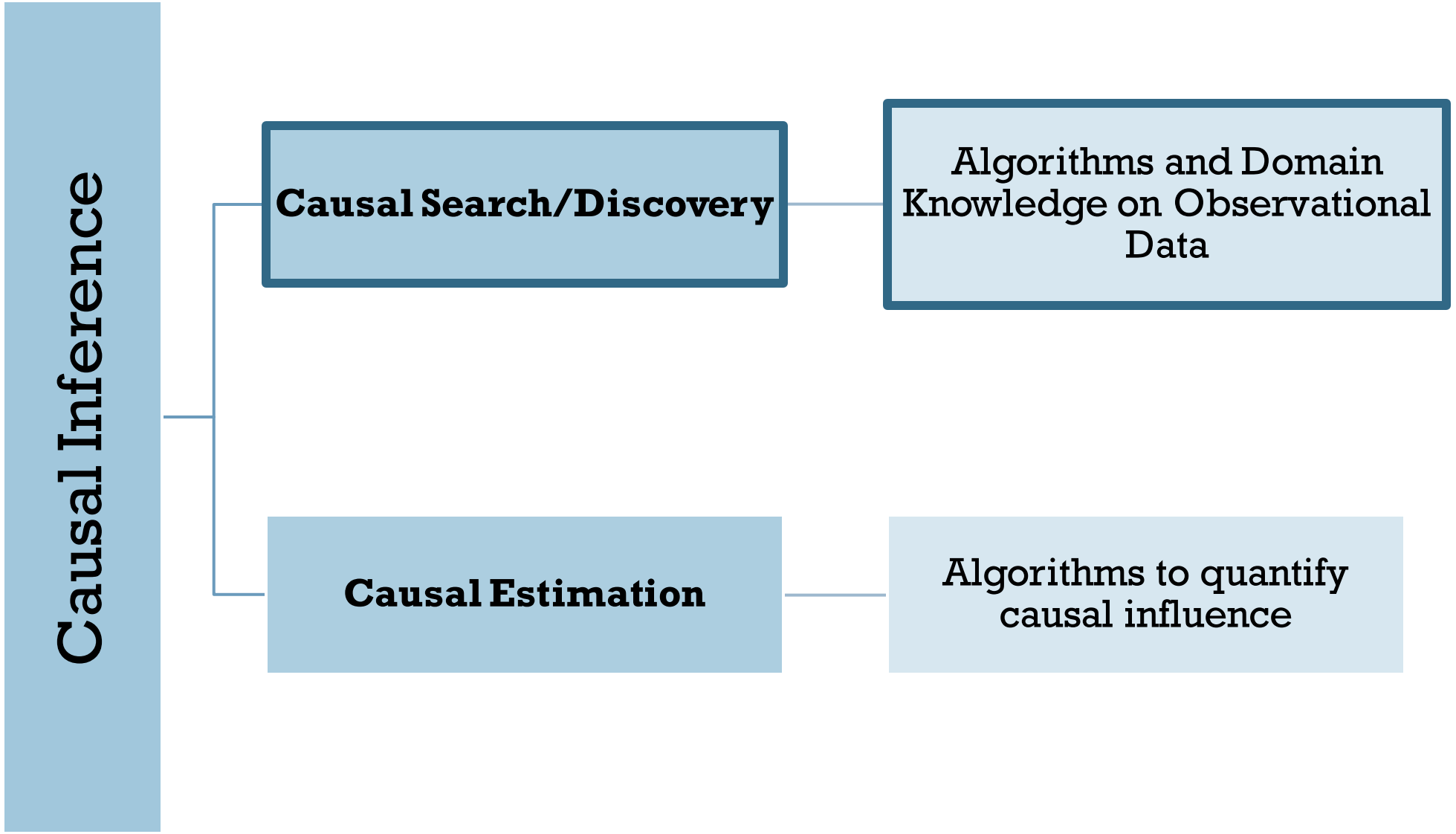


Parametric Cost Models

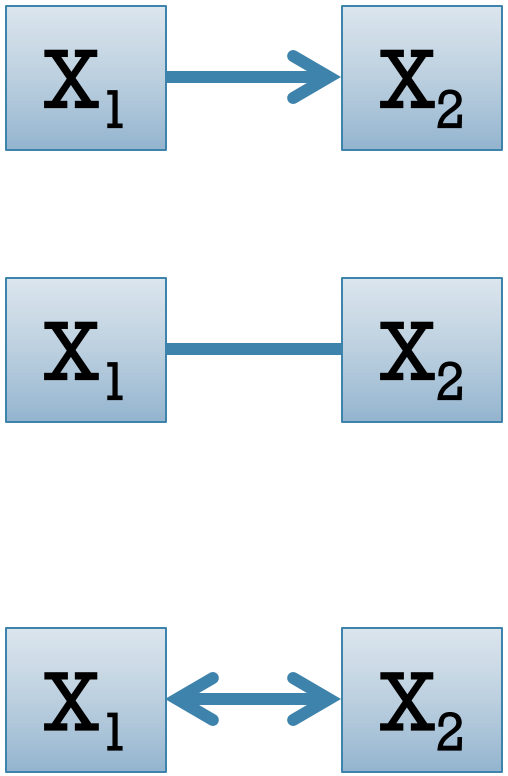
COCOMO® II

$$Effort = 2.94 \times Size^{E} \times \prod_{i=1}^{17} EM_i$$

- Input: size, product and personnel attributes
- Effort in Person-Months (PM)
- Size in KSLOC (1000 SLOC)
- Domain Experts
- Data calibration
- No causal analysis


Causal Inference
Causal Search/Discovery
Algorithms and Domain Knowledge on Observational Data
Causal Estimation
Algorithms to quantify causal influence

Causal Search Algorithm Results



Change in X_1 causes change in X_2

Insufficient information to select orientation

May be common confounder of both variables, missing from dataset

Causal Search Algorithms

PC SEARCH

- **Constraint-based algorithm**
- First developed by Peter Spirtes and Clark Glymour
- Highly accurate and scalable

PC STABLE

- **Constraint-based algorithm**
- Variant of PC, addressing problem that output depends on order of variables in dataset

FGES (FAST GREEDY EQUIVALENT SEARCH)

- **Score-based algorithm**
- Reduces bi-directed edges in output

FASK (FAST ADJACENCY SKEWNESS)

- **Score-based algorithm**
- Makes use of asymmetry in univariate distributions to determine edge orientations

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Dataset: Unified Code Count (UCC)

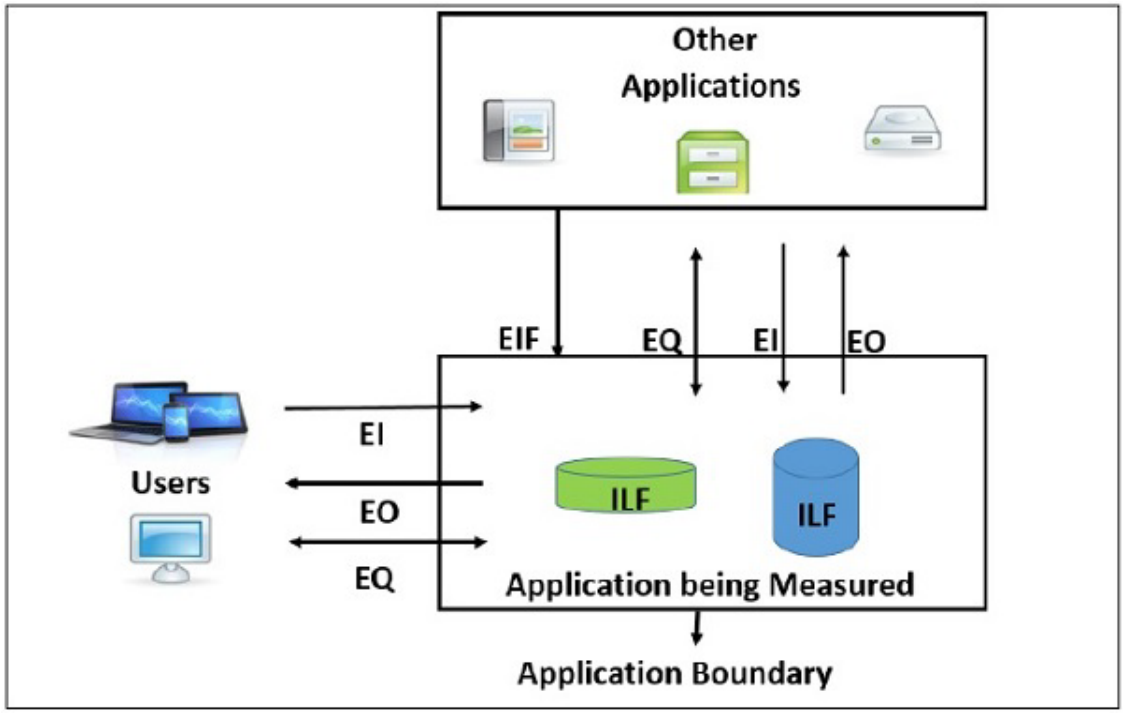
PROJECT DESCRIPTION

- Code metrics tool (logical SLOC, cyclomatic complexity)
- Maintained at USC
- UCC is released to users across world, primarily used in U.S. Aerospace industry
- Recommended for SLOC-based size input to Software Resources Data Report (SRDR)
- Implemented in C++
- Modularized architecture
- Tasks started and finished between 2010 to 2014

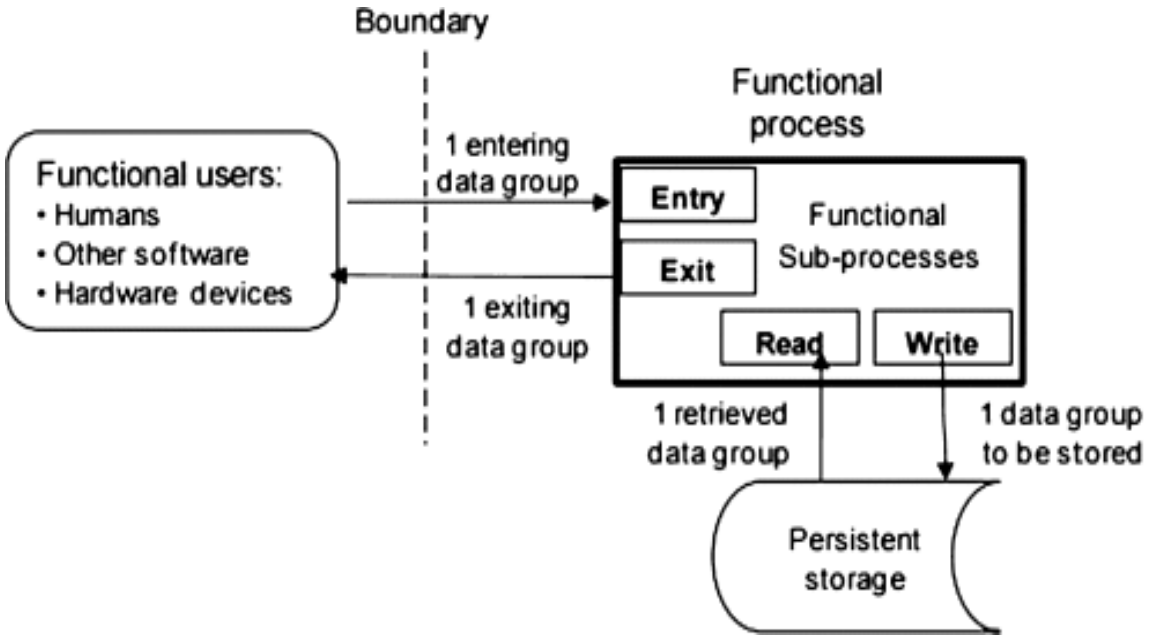
Dataset Attributes

1. Equivalent SLOC (ESLOC)
2. IFPUG Function Points (FPs)
3. IFPUG Software Non-functional Assessment Process (SNAP)
4. COSMIC Function Points (CFPs)
5. Total Effort
6. Applications Experience (APEX)
7. Platform Experience (PLEX)
8. Use of Software Tools (TOOL)
9. Personnel Continuity (PCON)
10. Product Complexity (CPLX)
11. Analyst Capability (ACAP)
12. Programmer Capability (PCAP)
13. Documentation Match to Lifecycle Needs (DOCU)

IFPUG



COSMIC



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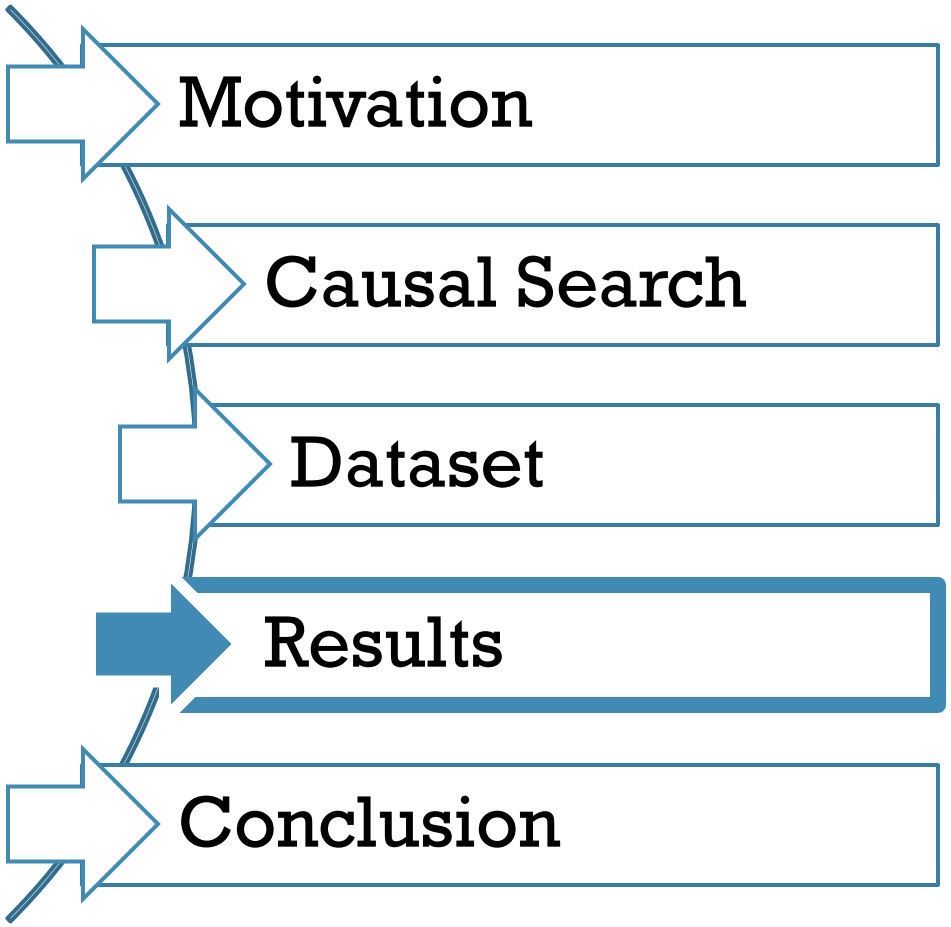

Algorithm	Direct Cause of Total Effort: ESLOC	FP	SNAP	CFP	CPLX	ACAP	PCAP	DOCU
PC All Size Metrics				YES			YES	
PC ESLOC							YES	
PC FP							YES	
PC SNAP			YES				YES	
PC CFP				YES			YES	
PC-Stable All Size Metrics				YES				
PC-Stable ESLOC					YES			
PC-Stable FP					YES			
PC-Stable SNAP					YES			
PC-Stable CFP				YES				
FGES All Size Metrics				YES			YES	
FGES ESLOC							YES	
FGES FP							YES	
FGES SNAP							YES	
FGES CFP				YES			YES	
FASK All Size Metrics		YES	YES	YES				YES
FASK ESLOC								YES
FASK FP		YES						YES
FASK SNAP			YES					YES
FASK CFP				YES				YES

Note: Black cells are Not Applicable as factor not present in model

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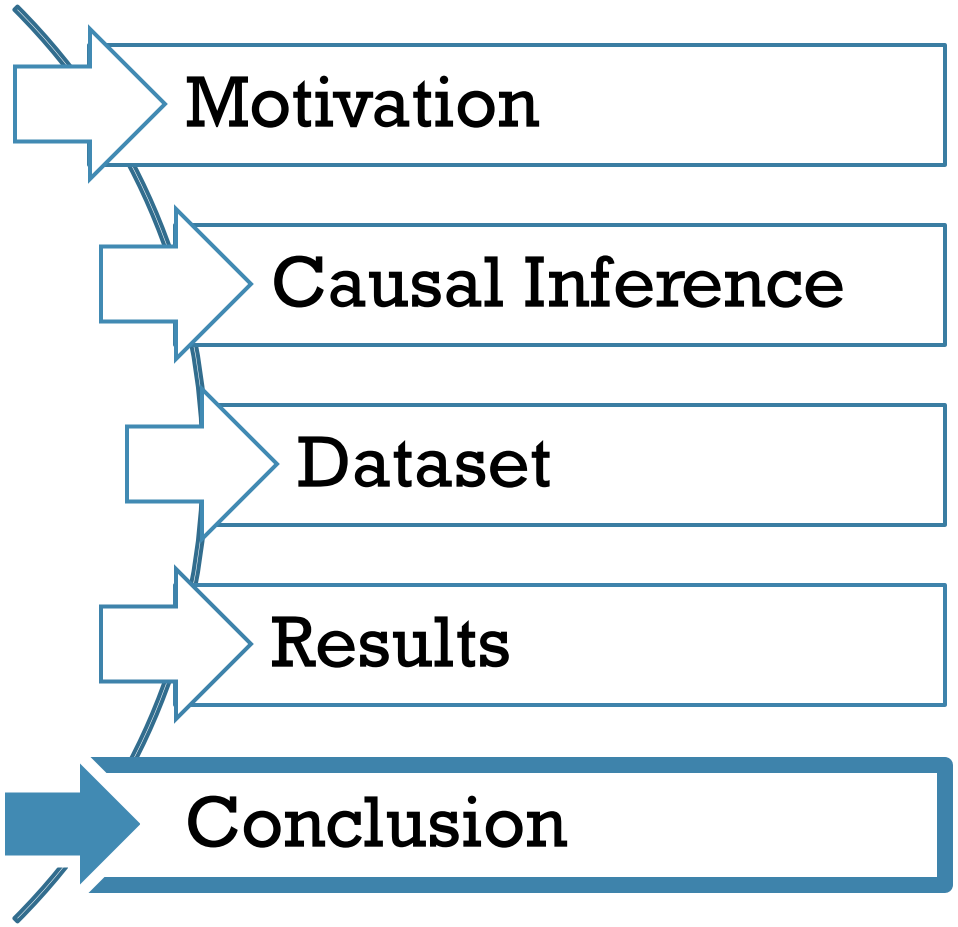
Multiple Regression

Vars	R-Sq	R-Sq (adj)	R-Sq (pred)	CFPs	ESLOC	FPs	SNAP	ACAP	PCAP	DOCU	CPLX
1	57.6	56.1	51.0						X		
1	54.6	53.0	47.9	X							
2	84.9	83.8	78.3	X					X		
2	78.5	76.9	67.4				X		X		
3	85.3	83.6	76.1	X					X		X
3	85.1	83.4	77.2	X		X			X		
4	85.4	83.0	73.0	X			X		X		X
4	85.3	83.0	68.6	X				X	X		X
5	85.4	82.3	61.9	X			X	X	X		X
5	85.4	82.3	67.0	X	X		X		X		X
6	85.4	81.6	55.2	X	X		X	X	X		X
6	85.4	81.6	59.9	X			X	X	X	X	X
7	85.4	80.8	53.0	X	X		X	X	X	X	X
7	85.4	80.8	52.0	X	X	X	X	X	X		X
8	85.4	79.8	49.5	X	X	X	X	X	X	X	X

Outline



Threats to Validity

- Small Sample Size
  - Conditional independence testing can only detect strong correlational effects
  - Resulting in sparsely-connected graphs
- Dataset of convenience – UCC
  - Maintained by Masters students
  - UCC is released to users across world, primarily used in U.S. Aerospace industry
  - Continuing study with various datasets

Conclusions

SUMMARY OF RESULTS

- Consistent Results
  - CFP – Total Effort
  - SNAP – Total Effort
  - PCAP – Total Effort

FUTURE WORK

- Run similar analyses on larger and varied cost estimation datasets
- Especially focus on impacts to acquisition cost and schedule
- Datasets including various source code metrics

Acquisition Research Implications

- Expensive, prohibitive experiments of acquisition factors could be obviated by use of causal methods
- Revisit effort factors, potentially reducing number of required dataset characteristics
- Acquisition researchers could integrate causal conclusions for holistic model
- Identify and prioritize research funding towards causal research outcomes worthy of investment in repeatability and reproducibility studies
- Causal research findings more confidently tested by acquisition program interventions with less risk of waste

Thank you for your time!