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COSYSMO & COSYSMO-R
Parameter Estimation Biases

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LAI MIT
LEAN ADVANCEMENT INITIATIVE

- COnstructive SYStems Engineering COst Model [Valerdi, Boehm and Reifer, 2003]
  - Estimates the number of person-months necessary to complete systems engineering projects
  - COSYSMO uses project size and cost estimates which are entered into a parametric formula

COSYSMO Parametric Equation

$$PM_{NS} = A \cdot \left(\Sigma w_e \Phi_e + w_n \Phi_n + w_d \Phi_d\right)^E \cdot \prod_{j=1}^{14} EM_j$$

Size parameters

Cost ($) parameters

Error in the estimated inputs?

Assessment of parameters

- Size and Cost COSYSMO parameters assessment
  - Not by direct experience of a project's full details
  - Not determined from a thorough decomposition and integration of a projects many activities and aspects
  - Complete decomposition is impossible

- Biases & Heuristics investigation

Scales

- Scale of explorations of biases in COSYSMO
  - COSYSMO: Large size and complexity
  - Biases: Controlled experiments
- COSYSMO estimation concerns different aspects throughout the entirety of a complex systems project
  - Time
  - Management & engineering

Thesis

- Human influence on COSYSMO
- Human Biases responsible for (mostly) underestimation errors

- Survey to test

  Estimation biases

Optimism

- Optimism endemic

  [Valerdi and Blackburn, 2009]

- Underbidding
  - Underbidding the Contract archetype at http://www.sei.cmu.edu/acquisition/research/archetypes.cfm
  - manager who is selling a proposal and has a tendency to underestimate costs

- Complexity:

  Inadequate understanding

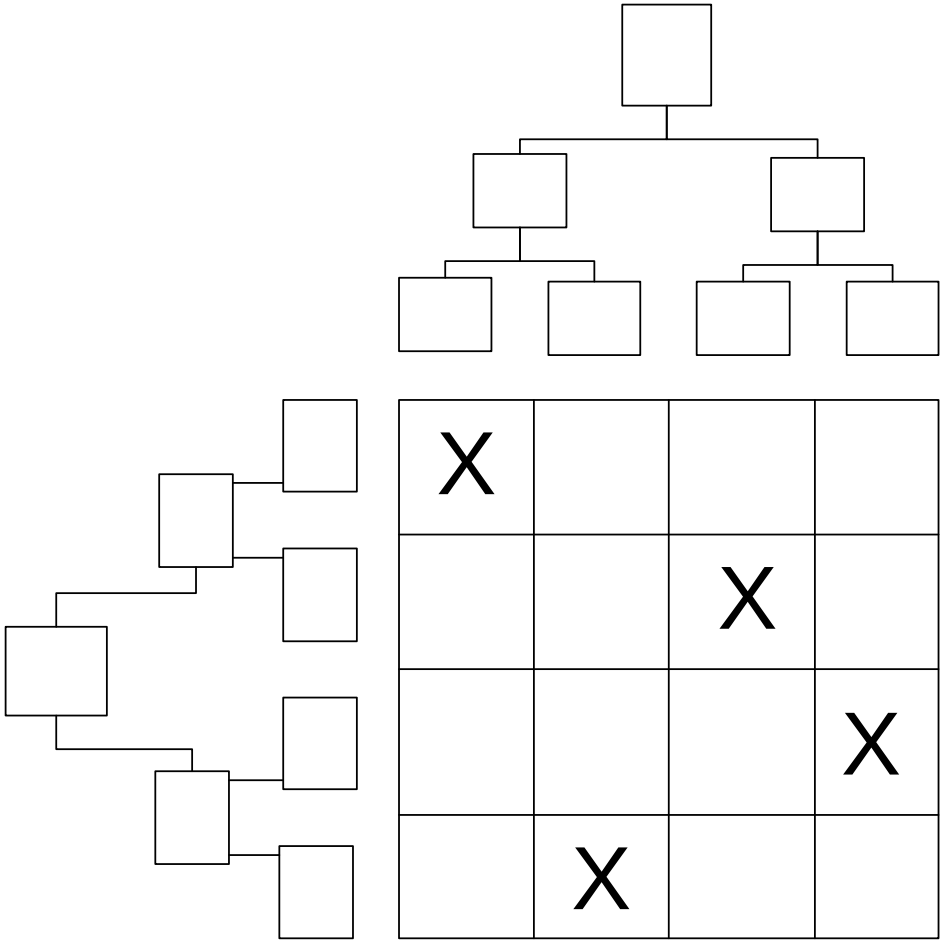
COSYSMO SIZE PARAMETERS

- # Requirements, # Interfaces, # Algorithms, # Operational Scenarios
- "Represent the functional size of a system which is believed to be a significant predictor of systems engineering effort" [Valerdi and Raj, 2005]
  - Counting requires access to project technical documentation
  - Engineering staff that can help interpret the content [Valerdi, Rieff and Wang, 2007]

Requirements: characteristics

- Level of design
- System interfaces, system specific algorithms, and operational scenarios
- Functional, performance, feature, or service-oriented
- Customer, Contractor & Integrator
  - Writing ability
- Verification & validation
- Dynamic nature
- Relations among requirements

Decompositions and a correlation matrix



Lump Judgments versus Arithmetic Counting

- Mental accessibility of a lump number over an arithmetically determined number [Meehl 1954]
  - averages rather than sums
  - differences rather than absolute values
  - similarity between two occurrences rather than the relevant probability calculation
- Intuitive judgments by expert clinicians often produce different results than computer-assisted statistical predictions [Lusted and Ledley, 1959]

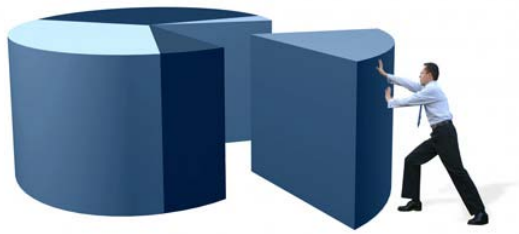
Interfaces

- Physical or functional junction between two or more systems elements
- Identification, specification, coordination, and control, test,
- Technical tradeoffs

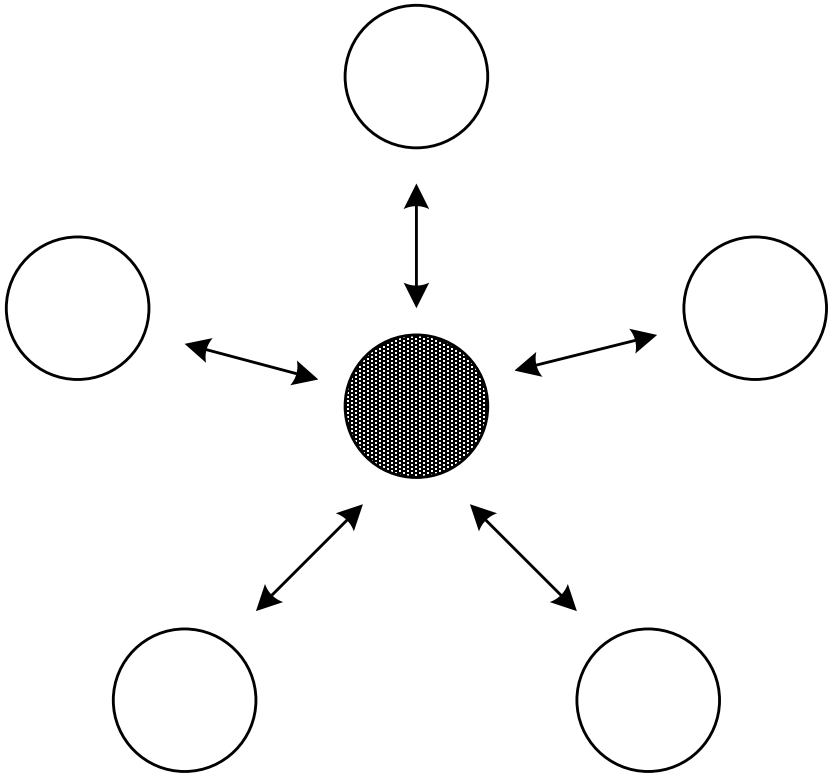
- Integration Bias or Interface Bias

Integration Bias

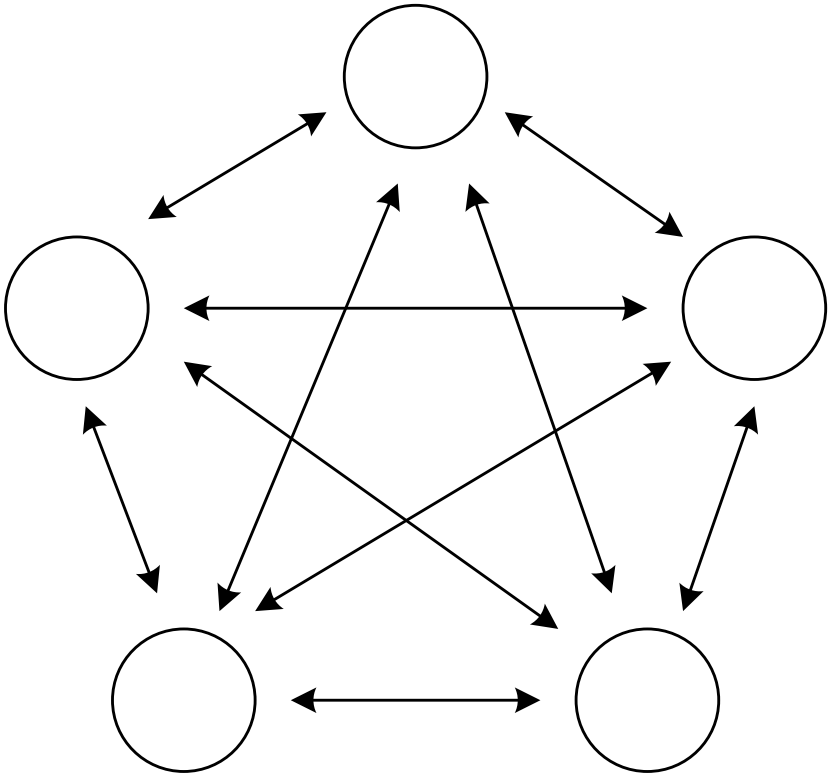
- Assuming common framework for subparts
- Human mind integrates disparate parts
  - N connections assumed among parts
  - $[N^2-N]/2$ actual connections
- Optimistic, confirmatory outlook by assuming a simplifying, integrative framework



[(N^2 –N)/2] interfaces for system understanding



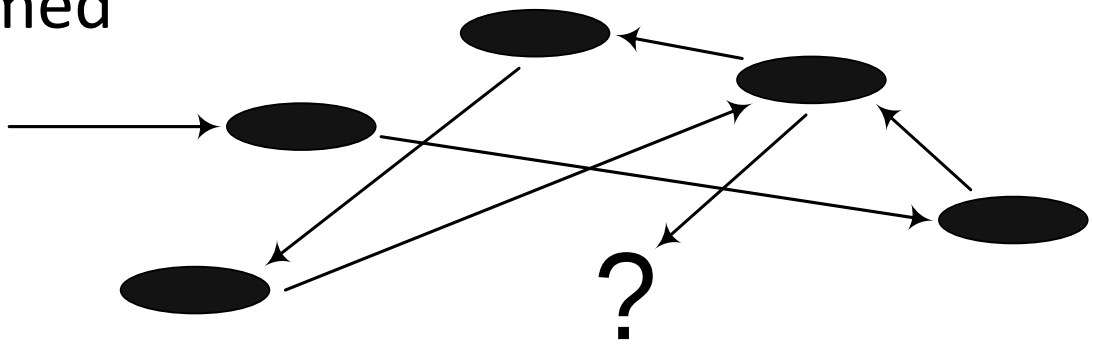
N interfaces
(often assumed)



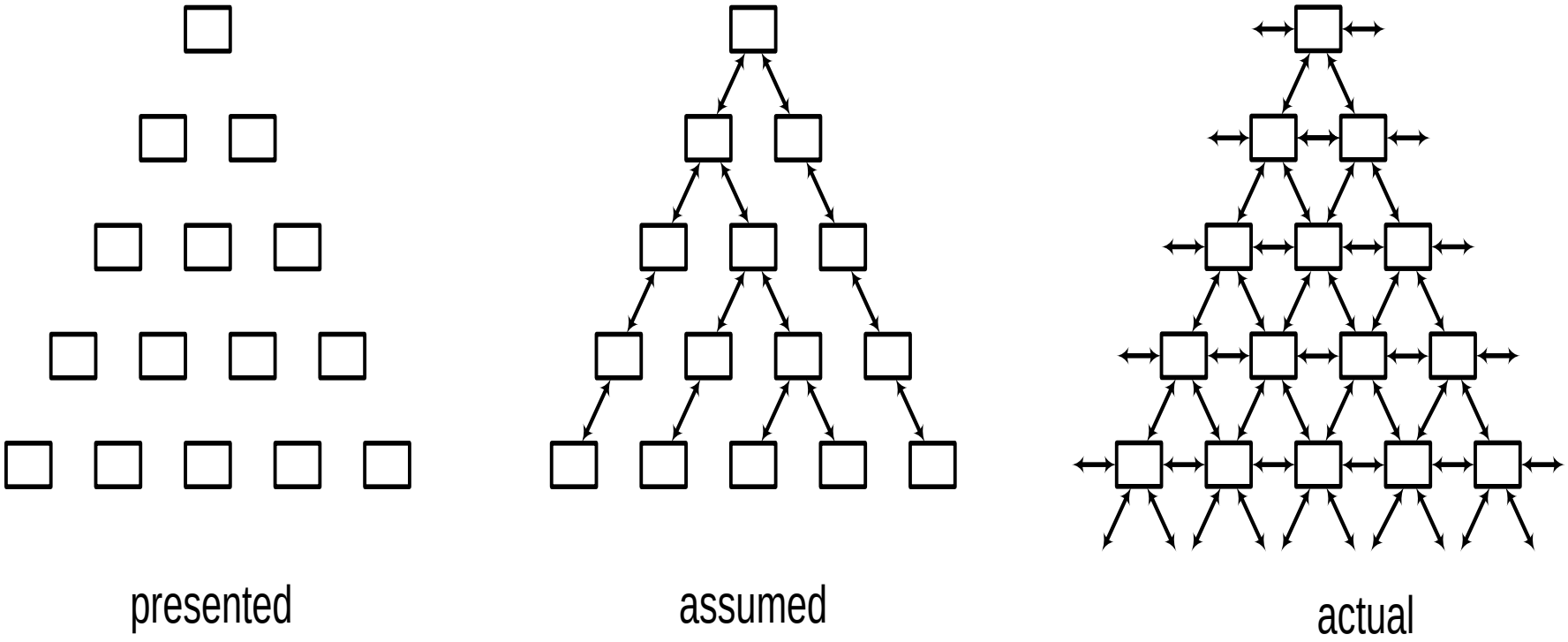
[N^2-N]/2 interfaces
(actual)

Interface Bias

- Under-estimation of needs, requirements, functions, or architectural components, and cross-correlations
- Schedules relations and dependencies across time and other dimensions
  - serial activities assumed



Assumptions in estimating



Algorithms

- "Unique mathematical algorithms to be derived in order to achieve the system performance requirements"

  [Valerdi, Boehm and Reifer, 2003, p. 77]

- 98% of all processors are now used in applications other than personal computers
- Algorithms are generally more numerous than assumed

Law of Small Numbers

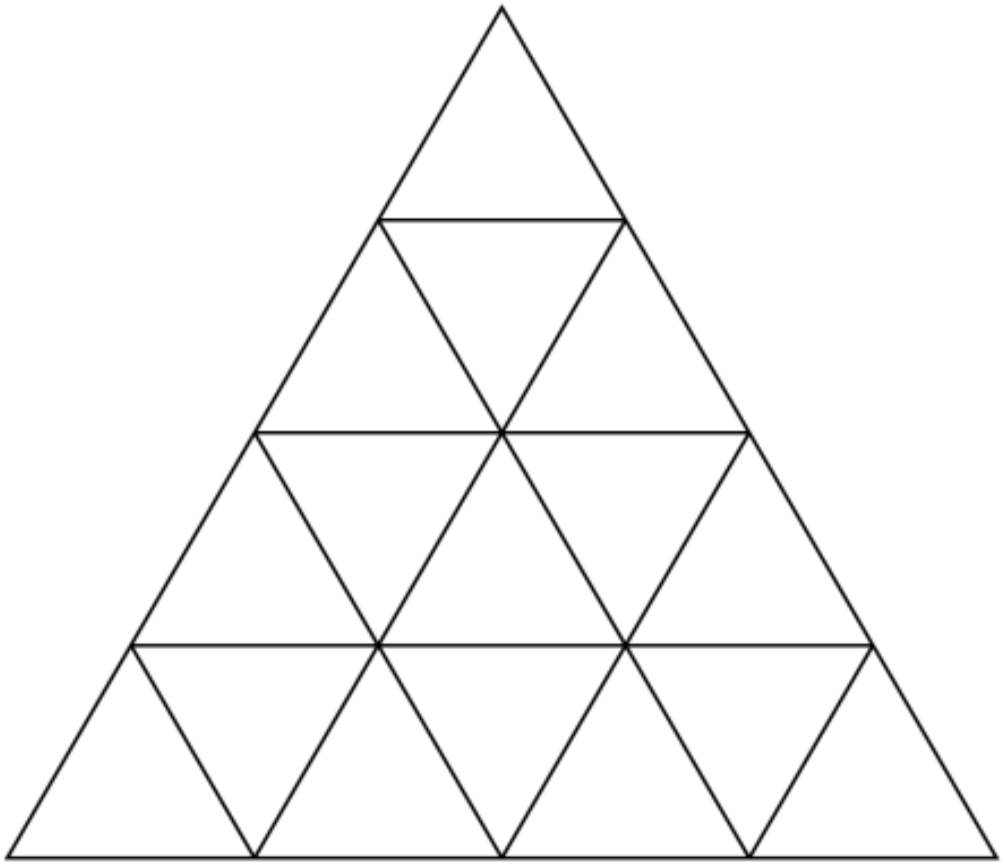
- "There aren't enough small numbers to meet the many demands made of them" [Weisstein, 2005]
- 1. small samples gambles (power overestimate)
- 2. undue confidence (significance overestimate)
- 3. high expectations about the replicability (precision overestimate)
- 4. causal 'explanation' for discrepancies

[Tversky and Kahneman,1971]

Operational Scenarios

- Multiple operational contexts for application of future
- “Such scenarios include both the nominal stimulus-response thread plus all of the off-nominal threads resulting from bad or missing data, unavailable processes, network connections, or other exception-handling cases” [Valerdi, 2005, p. 54].
- Overlap between and among scenarios

How many scenarios (triangles) are there?



COST PARAMETERS

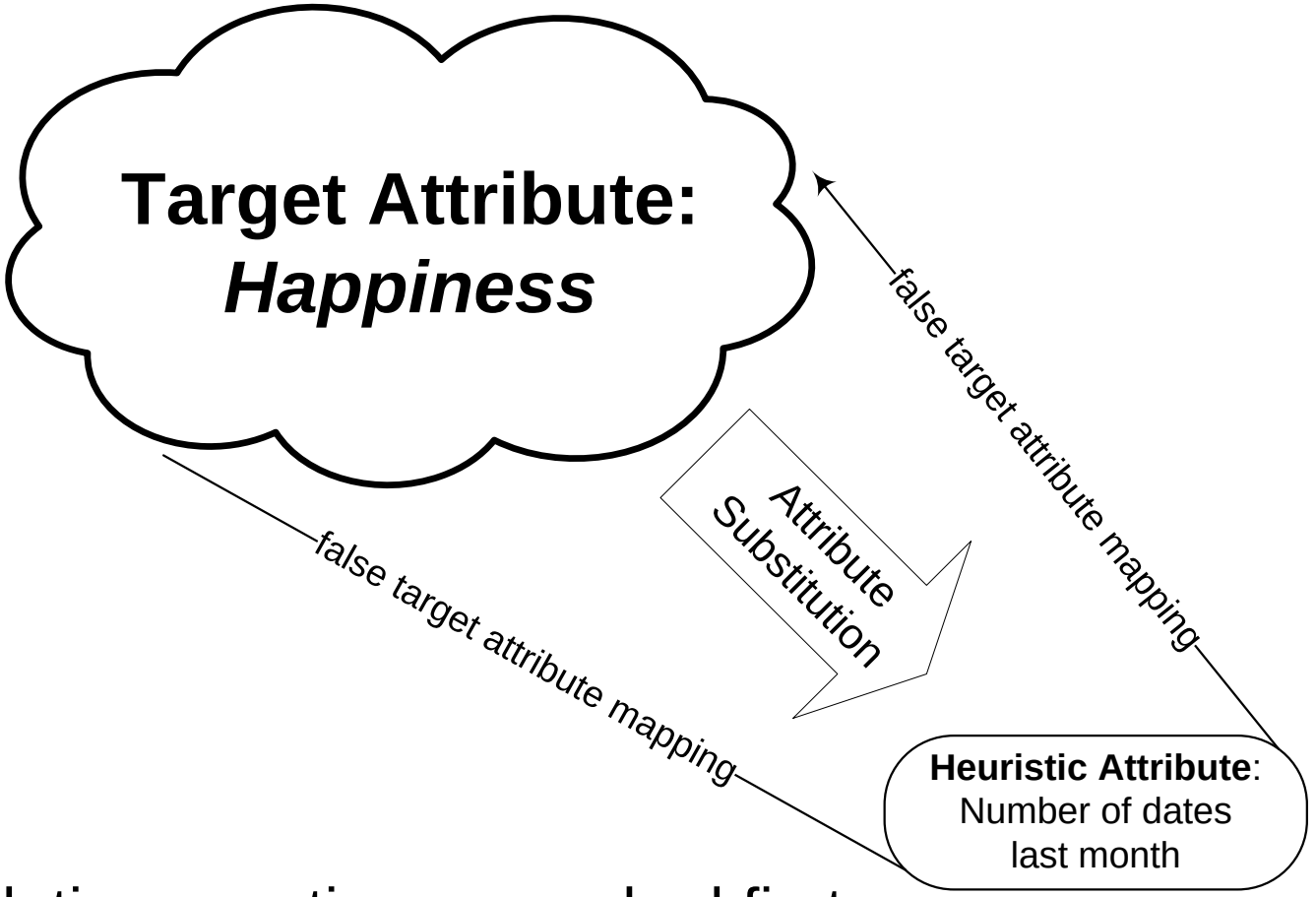
COSYSMO *TECHNICAL* COST PARAMETERS

- Requirements Understanding
- Architectural Understanding
- Level of Service Requirements
- Migration Complexity
- Technology Risk
- Documentation
- # and Diversity of Installations/Platforms
- # of Recursive Levels in the Design

Possible Biases

- Optimism
- Integration Bias
- Lump Judgment; Law of Small Numbers
- Attribute Substitution
- Prominence Hypothesis
- Limitations of Short-Term Memory
- Ambiguity Aversion
- Personal Experience

Attribute Substitution



Correlation:
A, Negligible, or
B, 0.66 when the dating question was asked first

Attribute Substitution

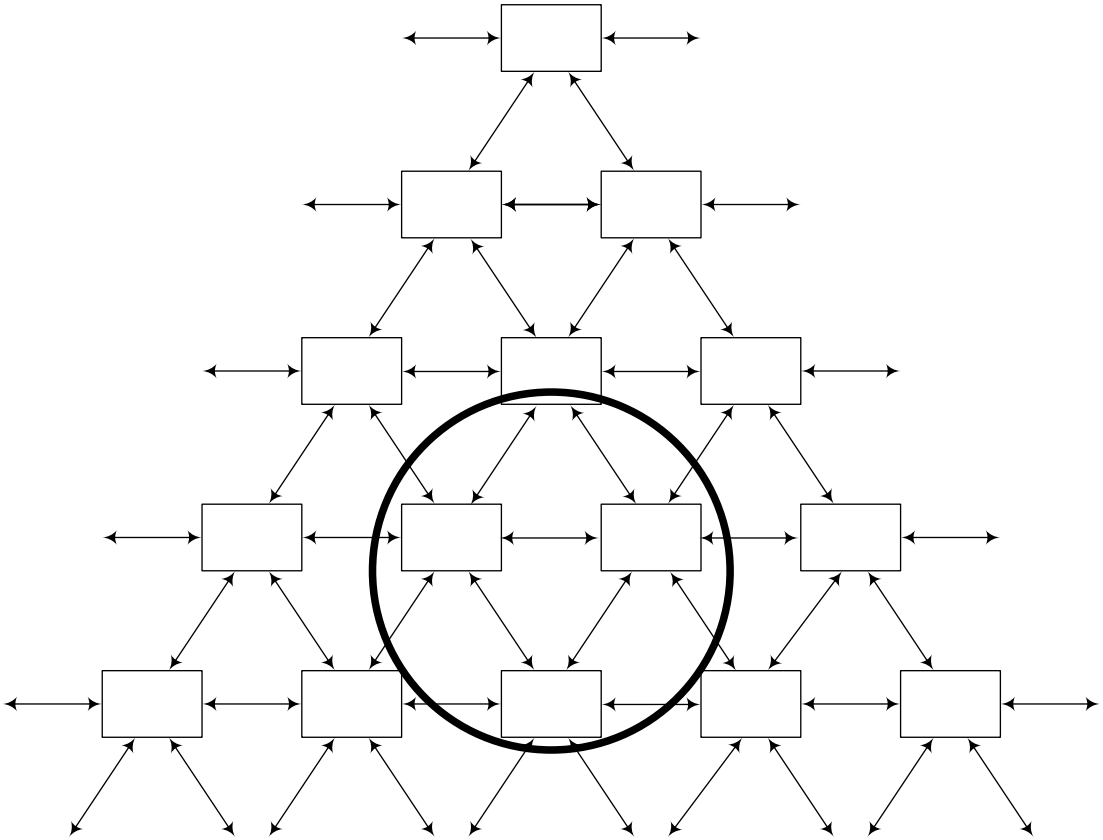
- Humans focus on a limited number of attributes of interest, when the complete list of attributes or items is much greater
  - Prioritization in project-solving tasks
  - **Optimism bias**

Short-Term Memory Limitation

7 ± 2 items

- Miller [1956]:
- Humans can only hold 7 ± 2 items in short-term memory
- Casts doubt on whether humans are capable of holistic understanding at all

Short-term memory limitation of 7 ± 2 items



3 elements and
5 interfaces

3 + 5 = 8 items
in short-term
memory

COSYSMO *TEAM* COST PARAMETERS

- Stakeholder Team Cohesion
- Heterogeneity (domains, cultures)
- Personnel/Team Capability
- Personnel Experience/Continuity
- Process Capability
- Multisite Coordination
- Tool Support

Ellsberg Paradox: Ambiguity Aversion

- Urn contains: 30 red balls, and

  60 other balls that are either **black** or yellow

Which gamble do you prefer?	
A	**B**
$100 if you draw a red ball	$100 if you draw a **black** ball

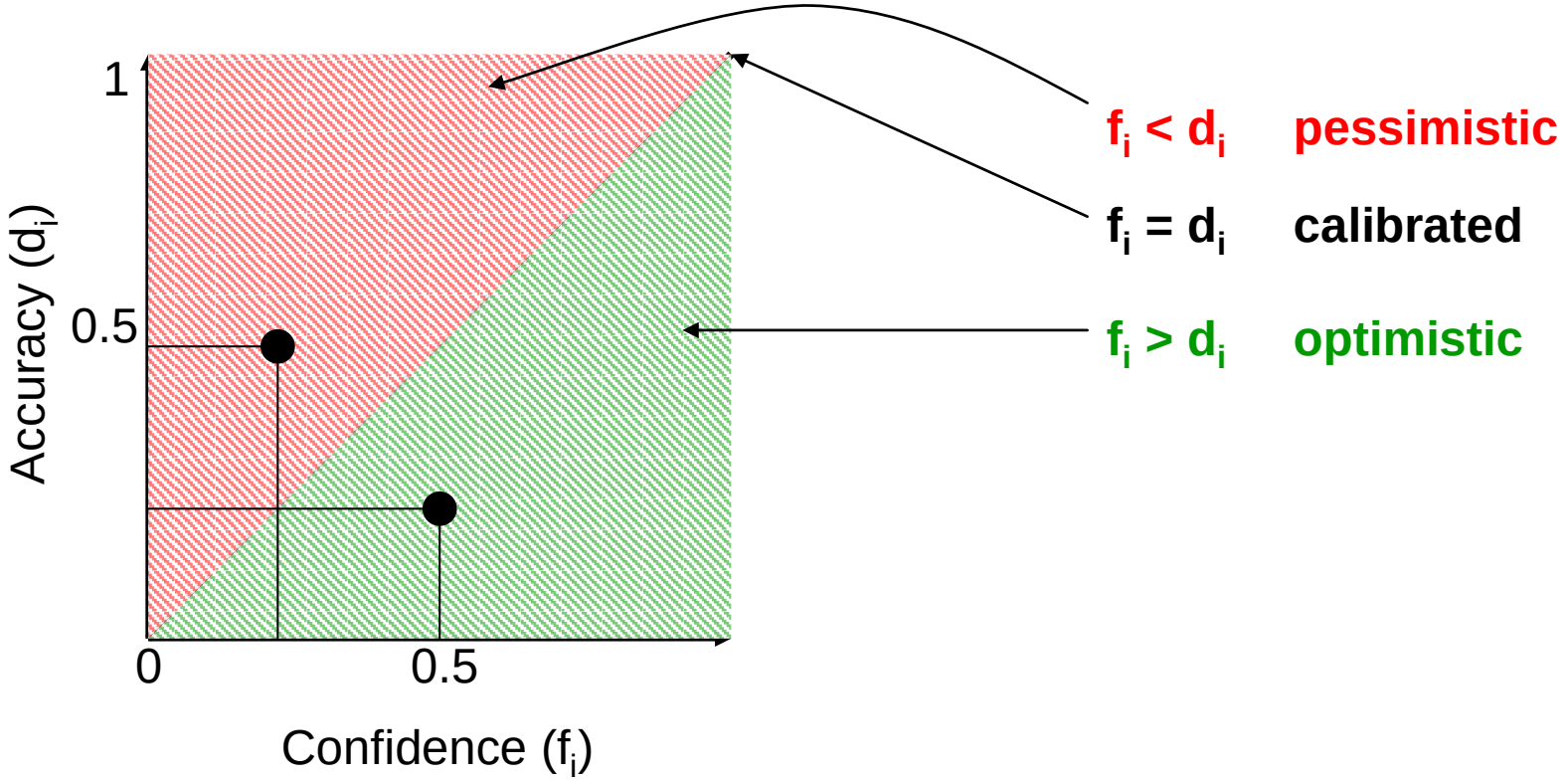
Which gamble do you prefer?	
C	**D**
$100 if you draw a red or yellow ball	$100 if you draw a **black** or yellow ball

Personal Experience

- personal experience is crucial to the estimation of COSYSMO human cost parameters
- specific industrial settings and cost impacts
- human costs involved in complex projects.

Calibrated Optimism

Confidence vs. Accuracy Dimensions



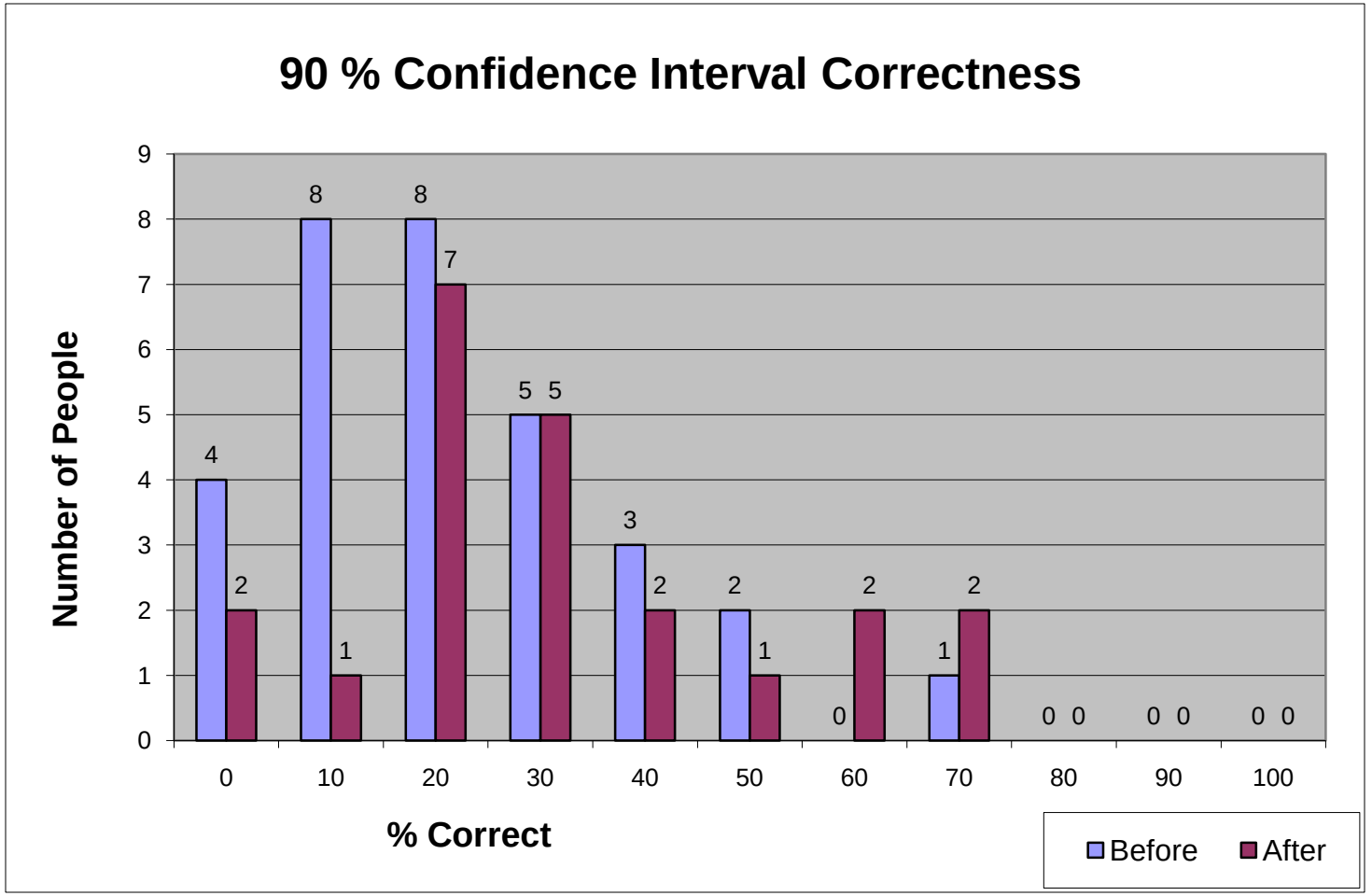
assessing the accuracy of weather reporters in the 1950's (Brier, 1950)

Optimism Calibration

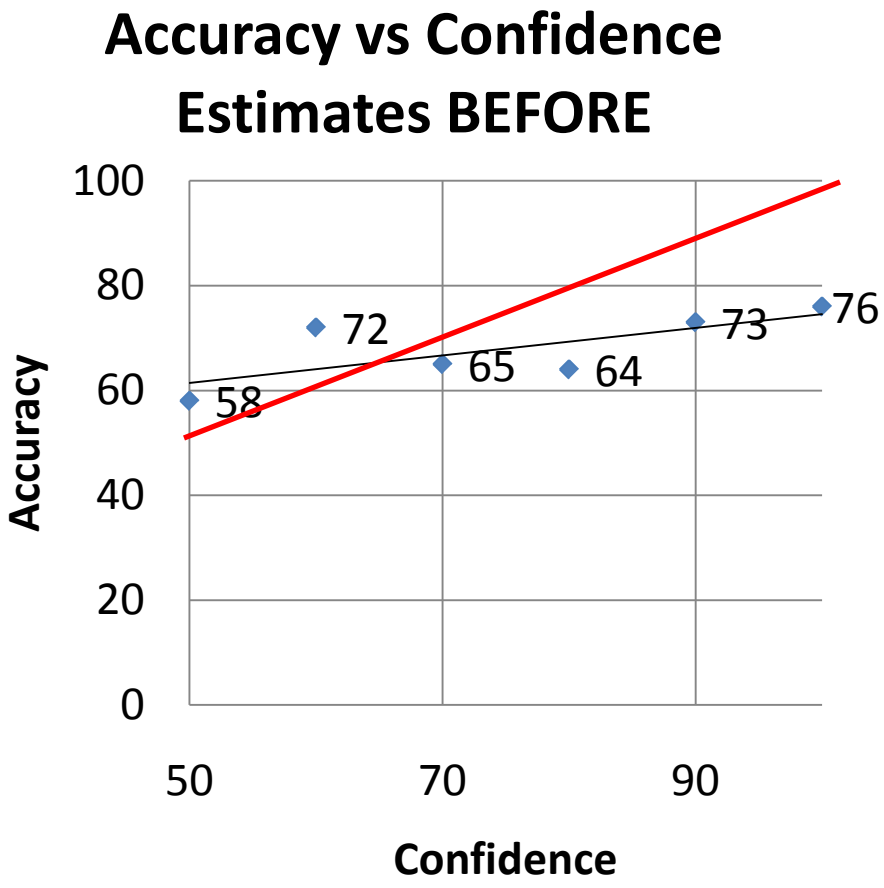
[Valerdi and Blackburn, 2009, p. 10]

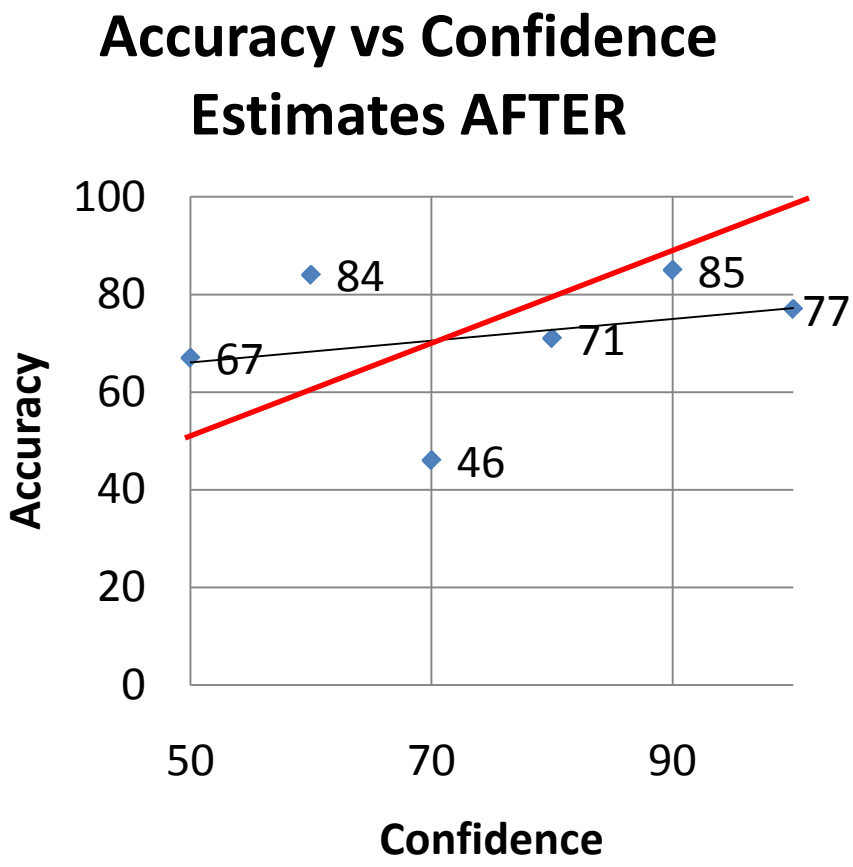
- Betting money or pretending to bet money
- separating “doing” from “observing”
  - Actually doing a task makes individuals more optimistic compared to those that simply observe it [Koehler and Harvey, 1997]
- personality
- professions
  - feedback about prior estimates
  - incentive structure that values accuracy in estimation
  - ensuring no over reaction to atypical even

Survey: Before & After Bias Training



Survey: Before & After Bias Training





COSYSMO-R (Risk)

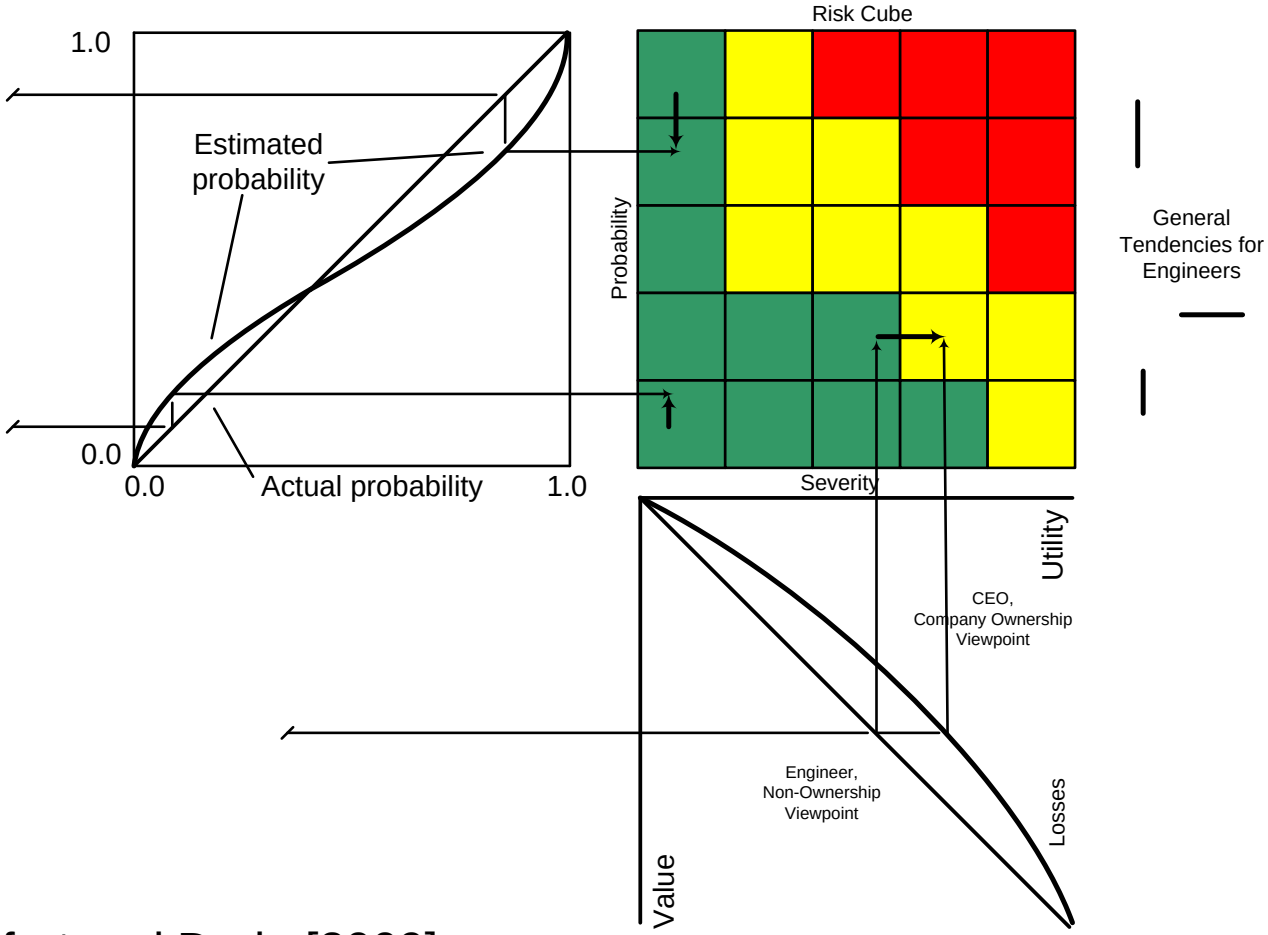
- **COSYSMO-R** goes beyond single point estimates of COSYSMO parameters
- Cost and Size parameters are entered
  - Low, Likely or High
- Outputs: Equivalent Size Risk, Cost Driver Product Risk, Person Hours Risk, Person Hours Overrun Risk, and Schedule Risk, as well as Effort and Person Hours by time, phase and activity [Gaffney, 2008]

Risk Biases in COSYSMO-R

- Risks = Probability x Consequence
- Subjectivity in risk parameters
- Expensive objectivity
- Biases associate with the parameters of risks have been explored by

  Smith, Siefert and Drain [2009].

Probability and Severity biases from Prospect Theory



Smith, Siefert and Drain [2009].

Correcting Biases

- Calibration training
- Analogous programs comparison
- Separate estimation tasks from program execution tasks [Koehler and Harvey, 1997]

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