Software Cost Estimation
Issues for Future Ground Systems

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Outline

1. Background
2. Software Cost Estimation Research
   - OO Software Development
   - Developing with Reuse
   - Developing with COTS
3. Conclusions
Multiple large efforts to replace and upgrade current ground systems

Initial emphasis on modernizing systems using OO technology for better maintainability, flexibility, and extensibility

Current focus on fielding systems with maximum re-utilization of legacy systems and COTS
Application of Software Cost Knowledge

- Need to have a good understanding of cost implications in order to
  - Develop independent cost estimates at conceptual design phases
  - Evaluate the reasonableness of contractor estimates (cost and schedule) at contract award
  - Identify and manage the risks involved in the development approaches selected

- Cost    Schedule    Technical
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Cost Estimation Research
OO Software Development

- Research recently conducted on current practice and new methods for Object-Oriented (OO) SW cost estimation
  - Professional Organizations and Universities
  - DoD Support Organizations
  - Commercial Organizations

- Collection and analysis of data from large-scale OO Software developments planned
Most difficult task is estimating the size of the software system

Many approaches to measuring software

- Function Points and variations
- Object Points and variations
- Object Artifacts (e.g., Use Cases)
- Source Lines of Code (SLOC)

SLOC continues to be most widely used
Anecdotal evidence indicates productivity rates for OO languages similar to that for other 3GLs.

Productivity increases claimed in contractor historical data may be the result of over-counting for generated code (4GLs) and reused code.

Future Aerospace research into OO Cost Estimating Relationships (CERs):
- Collection and analysis of OO project data (TBD)
- Delphi Study of OO Cost Drivers (TBD)
- OO Metrics Study (Ongoing)
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Developing with Reuse

- High expectations for cost and schedule savings by maximizing legacy reuse.
- Over-optimism regarding the amount, quality, and availability of “reusable” code.
- Creates a significant risk area that must be mitigated and managed through the entire life-cycle.
- Challenge in estimating amount of code that can be reused and the effort required to reuse it.
White Box vs. Black Box Reuse

- **Black Box - Reuse with no modifications**
  - Known inputs and outputs
  - Unknown/irrelevant contents
  - Cost of reuse is > 0

- **White Box - Reuse with modifications**
  - Requires knowledge of the contents to be used
  - Cost of reuse is >> 0
  - Cost of reuse vs % modification is non-linear
Reuse with Modifications

Source: NASA Selby Study, 1988
Reuse with No Modifications

- Numerous published studies estimate the effort required to reuse software unmodified.
- Study results (as a percent of effort required for new development) range from 4.6% to 40%.
- Results of Preferred Studies:
  - Jeff Poulin: 20%
  - USC/CSE: 18-30%
  - Aerospace Corporation: 25-30%
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Developing with COTS

- High expectations for cost/schedule savings by emphasizing COTS.
- Expected extent of benefits is rarely being met.
- Amounts of effort for integrating COTS packages are significantly under-estimated (or ignored).
- Expect additional cost and schedule to be required to complete developments involving COTS
COTS Implementation Costs

- COTS product assessments
- COTS tailoring (e.g., customization via installation parameters)
- COTS Glue Code
- Increased application effort due to COTS volatility

Source: Chris Abts (USC-CSE / COCOTS POC)
COTS Integration Cost Exercise

What is the average cost related to integration for a typical COTS product?

- A. Insufficient data
- B. $0
- C. Cost of 1000 Glue SLOC
- D. Cost of 1000 Glue SLOC + X ESLOC
A. Insufficient Data

- Obviously the correct answer
- Unfortunately an unacceptable answer

B. $0

- Historically, the contractor’s answer of choice
- Wrong!
USC Glue Code Data

Total SLOC

Glue SLOC

Source: Chris Abts (USC-CSE)
C. Cost of 1000 SLOC of Glue Code

- 1000 + 300 Glue SLOC on average per COTS product *
- Based on USC-CSE data collected for COCOTS
- In line with 1200 SLOC observed in recent ICEs
- Partial Credit
  - This answer represents a ROM estimation of a portion of the glue-related development costs

* A very rough rule of thumb!
COTS Implementation Costs - Expanded

- COTS product assessments
- COTS tailoring (e.g., customization via installation parameters)
- COTS Glue Code
  - Cost of Glue Code development
  - Cost of additional system design, integration, and test efforts related to the COTS
- Increased application effort due to COTS volatility
D. Cost of (1000 Glue SLOC + X ESLOC)

- **ESLOC**
  - Equivalent (or Effective) SLOC
  - Adjusts the SLOC estimate to account for additional non-coding effort that will decrease productivity

- **Value of X depends on**
  - System (or subsystem) size
  - Ease of integrating the COTS product into the system
    - Represented as $F_{res}$ factor in 1997 publication by R. Jensen
    - Factor typically ranges from .05 (easy) to .25 (difficult)
    - Recent estimates using PRICE range from 0.09 to .15
Calculation of COTS Integration Effort

- $S_e = S_{en} \times (1 + F_{res})$
  - $S_e =$ Effective size of system including component integration
  - $S_{en} =$ Effective size of system ignoring COTS effort
  - $F_{res} =$ Ratio of the effort to integrate the component into the product to the development effort ignoring component integration effort

- $X = S_e + \text{Glue SLOC}$

- $X$ increases quickly as either $S_{en}$ or $F_{res}$ increases
COTS Integration Effort Range Estimates
Impact of Multiple COTS Products on Cost

- As the number of COTS products to be integrated into a system increases, the effort involved is probably not linear.
  - is likely to grow at least geometrically.
  - may grow exponentially.

- If the average cost of integrating 1 COTS product into a system is 5,000 ESLOC:
  - Integrating 10 products costs >>50,000 ESLOC.
  - Integrating 100 products costs >>>>> 500,000 ESLOC.
Estimation of Additional Effort to Integrate Multiple COTS Products

- Need to re-adjust the effective size (ESLOC) for additional effort due to COTS interactions.

- For a very conservative estimate:
  - Use total glue code SLOC instead of system size for $S_{en}$ to calculate $X$
  - Use a low $F_{res}$ value of 0.05

- Example: To integrate 10 COTS products
  - $S_{en} = \text{Total Glue SLOC} = 10 \times 1000 = 10000$ SLOC
  - Each COTS: $S_{e} = 10000 \times 1.05 = 10500$ ESLOC
  - Additional effort per COTS = 10500 - 10000 = 500 ESLOC
  - Total additional effort = 10*500 ESLOC = 5000 ESLOC
Effort (due to COTS interactions) to integrate multiple COTS products

![Graph showing the relationship between the number of COTS products and the additional integration effort in ESLOC (K).]
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Conclusions

- Use of OO, Legacy Reuse, and COTS in large Ground System developments have not met expectations for cost/schedule reductions
- Further studies needed to develop good OO Cost Estimating Relationships (CERs)
- Good tools and methods are available for estimating costs associated with Legacy Reuse
- Hidden costs of COTS development are significant
  - Need to closely scrutinize COTS-related estimates
  - USC working to address these issues with COCOTS
- Recommend Cost-Risk analyses to develop distributions for Low, High, and Most Likely estimates
Bibliography

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