The Evolution from Software Components to Domain Analysis

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Goals

- Produce large, quality software systems.
- Build systems from reusable software components.
- Create systems that may be extended and maintained over a lifetime of many years.

Software Components

- McIlroy at NATO68
- craftsman vs. mass-production
- system size forces reusable components

Areas of Investigation and Experience

- software components
- program transformations
- system architecture
- large systems
- automatic programming and program generation

Software Part Libraries

- reuse without modification ("what" information)
  - classification problem
  - search problem
- reuse with modification ("how" information)
  - structural specification problem
  - flexibility problem
- overall *library problem*
  - many small parts for flexibility increases search
  - few large parts decreases search and decreases flexibility

Lessons from Software Component Libraries

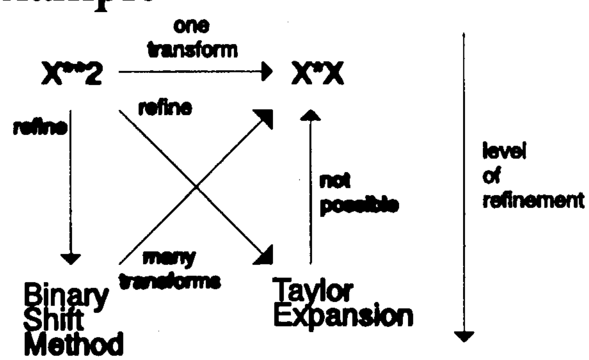
- libraries are an immediate success
- libraries have been a success for years
- simple flat libraries do not scale up (sorts, lists, etc. are not the problem)
- domain-specific parts from domain analysts are powerful

Program Transformations

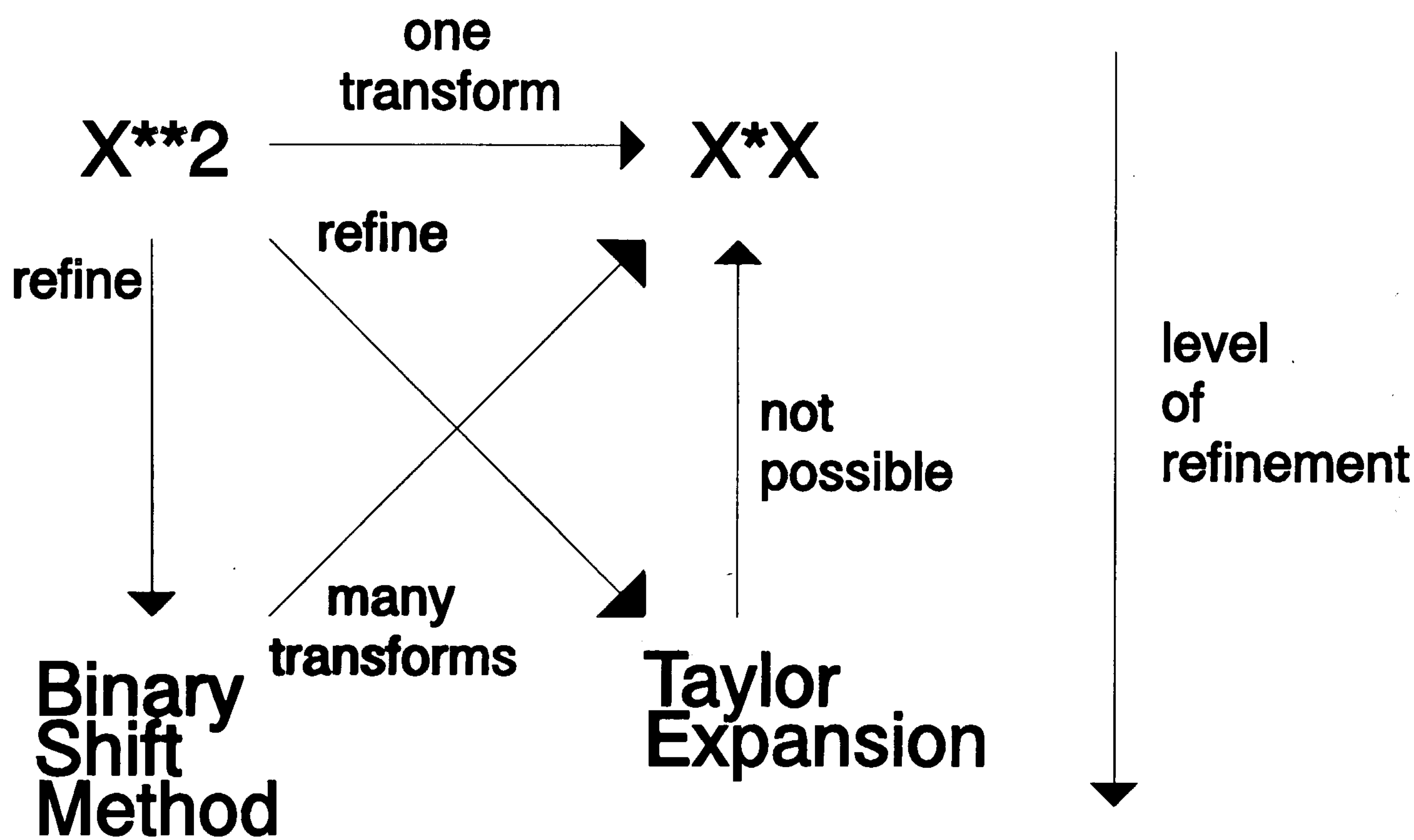
- motivation: store fewer source programs and specialize
- example transformation

  LHS: `X*(IF P THEN A ELSE B)` <=>
  RHS: `(IF P THEN X*A ELSE X*B)`
  EC: X and P are execution order independent

- matrix multiply example in paper
- refinement example



- formal algebra theory

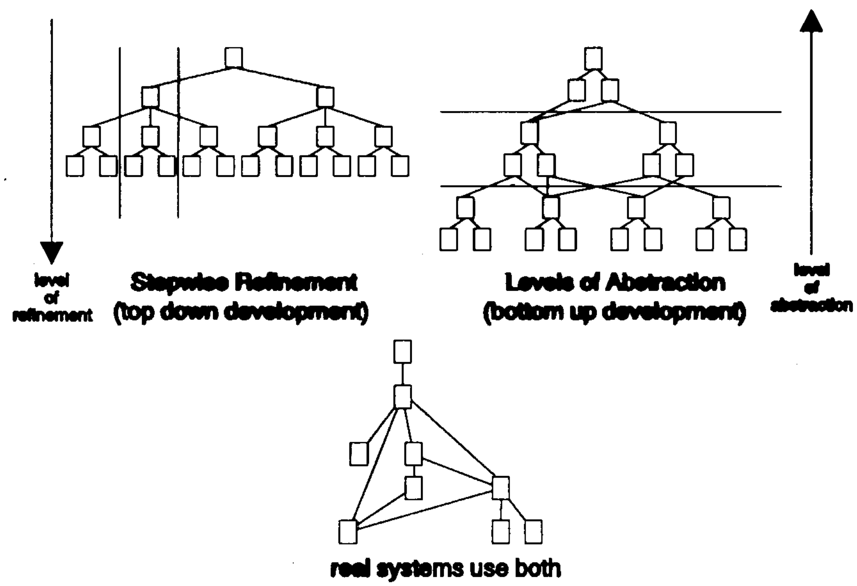

one
transform
X**2
X*X
refine
refine
not
possible
level
of
refinement
many
transforms
Binary
Shift
Method
Taylor
Expansion

Lessons from Program Transformations

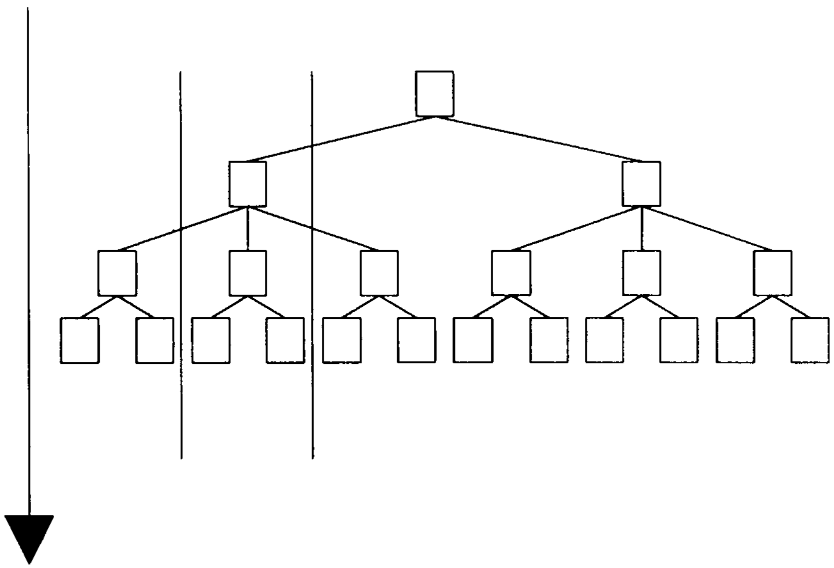
- few equivalence preserving transformations
- optimization at appropriate level of abstraction
- idea of a domain to encapsulate level of abstraction
  - semantics independent of implementations
  - optimizations independent of implementations

System Architecture

- motivation: how to encapsulate system and domain information
- architecture is distinct from function
- stepwise refinement vs. levels of abstraction

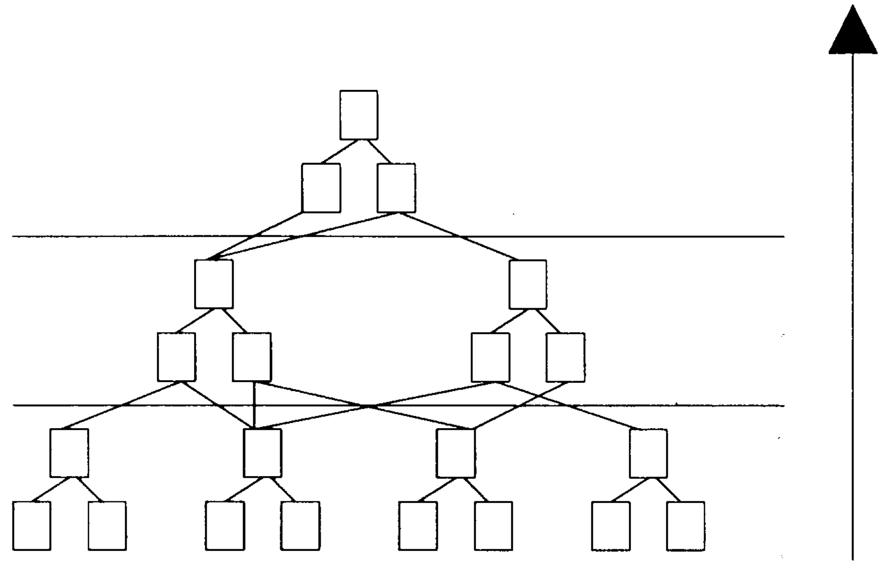


- vertical partitioning vs. horizontal partitioning
- dynamic creates cells of encapsulation



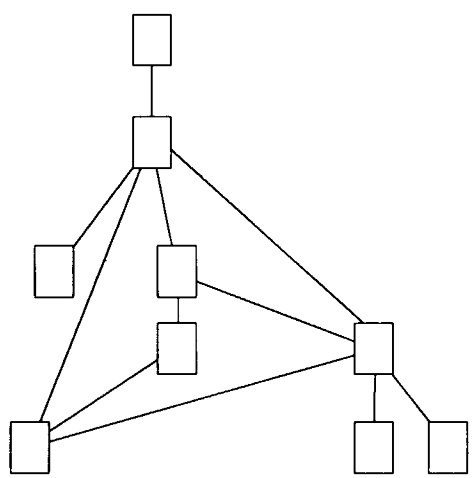
level
of
refinement

Stepwise Refinement
(top down development)



Levels of Abstraction
(bottom up development)

level
of
abstraction



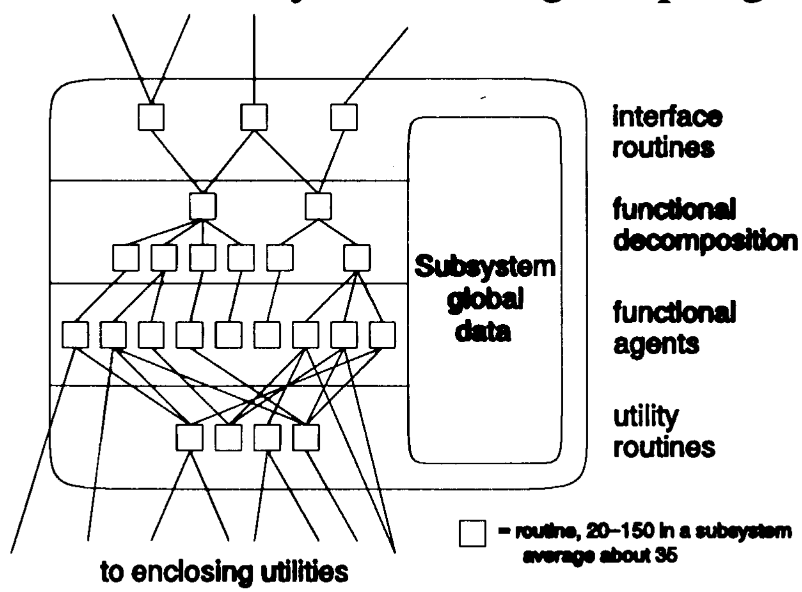
real systems use both

Lessons from System Architecture

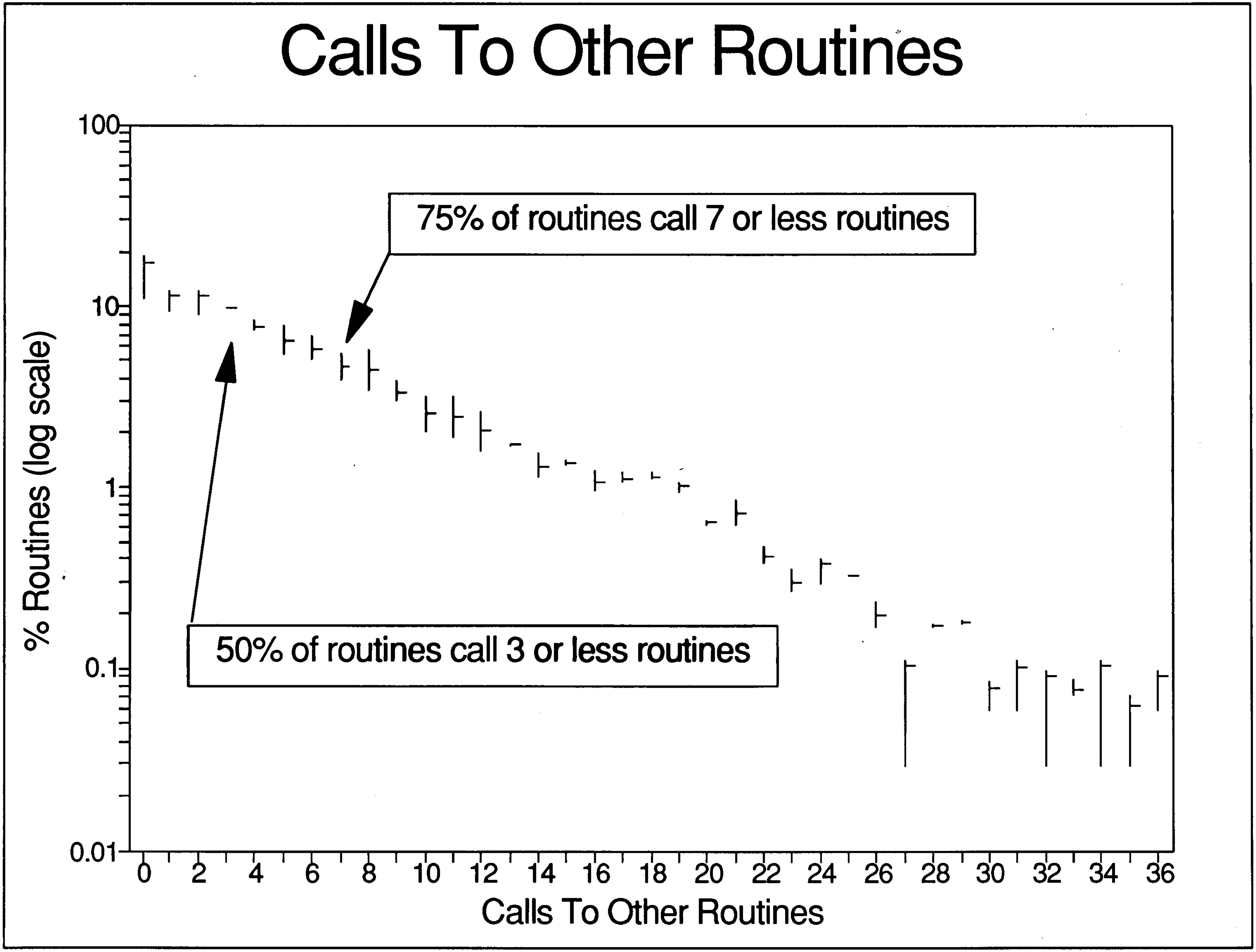
- exists and is separate from function
- big impact on performance and maintenance
- result from encapsulation mechanisms
- methods that assemble systems from components must also create architectures

Large Systems

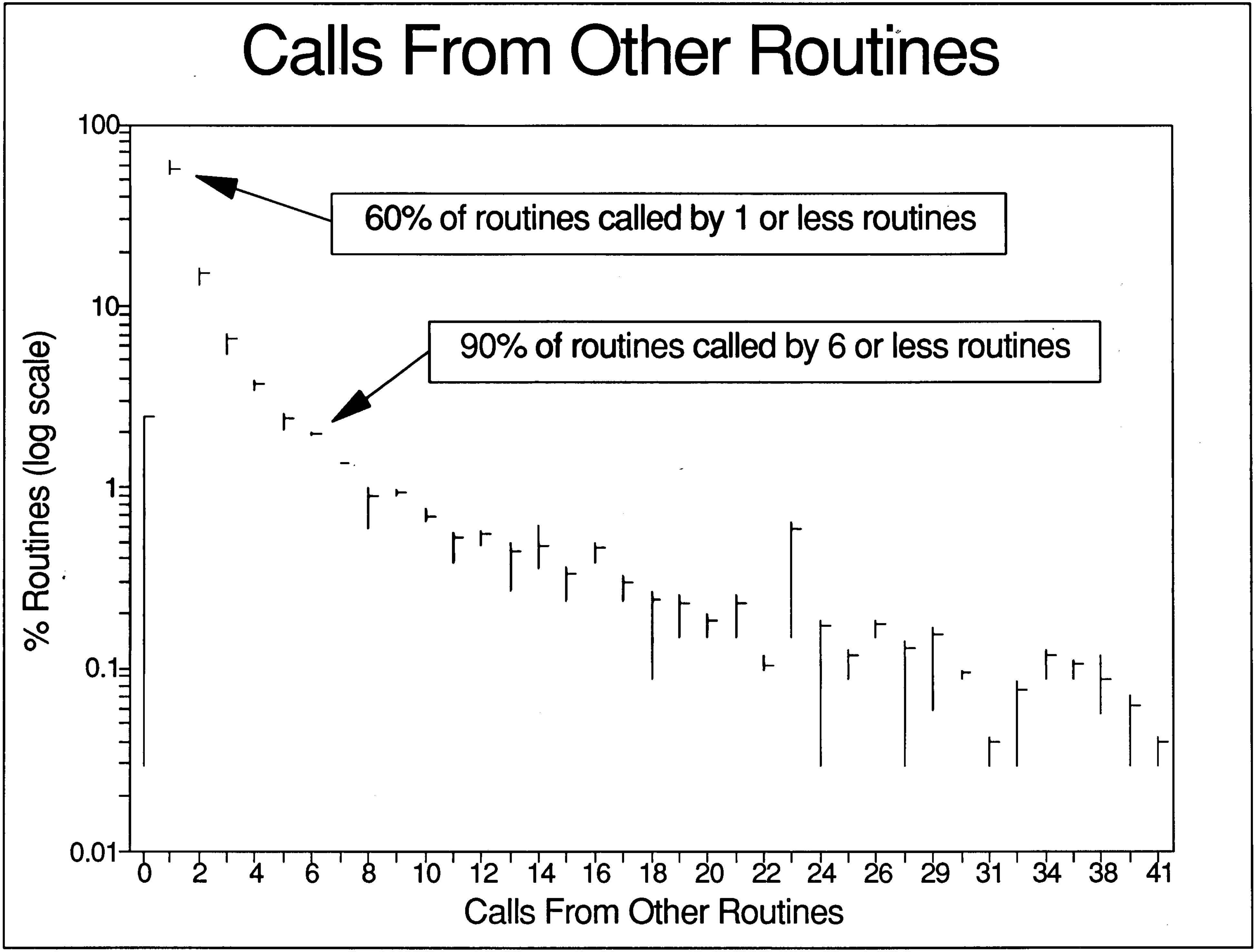
- motivation: how do they get them to work?
- scale, nature and location
- research method
- interconnection results
- identification of subsystems using coupling and cohesion

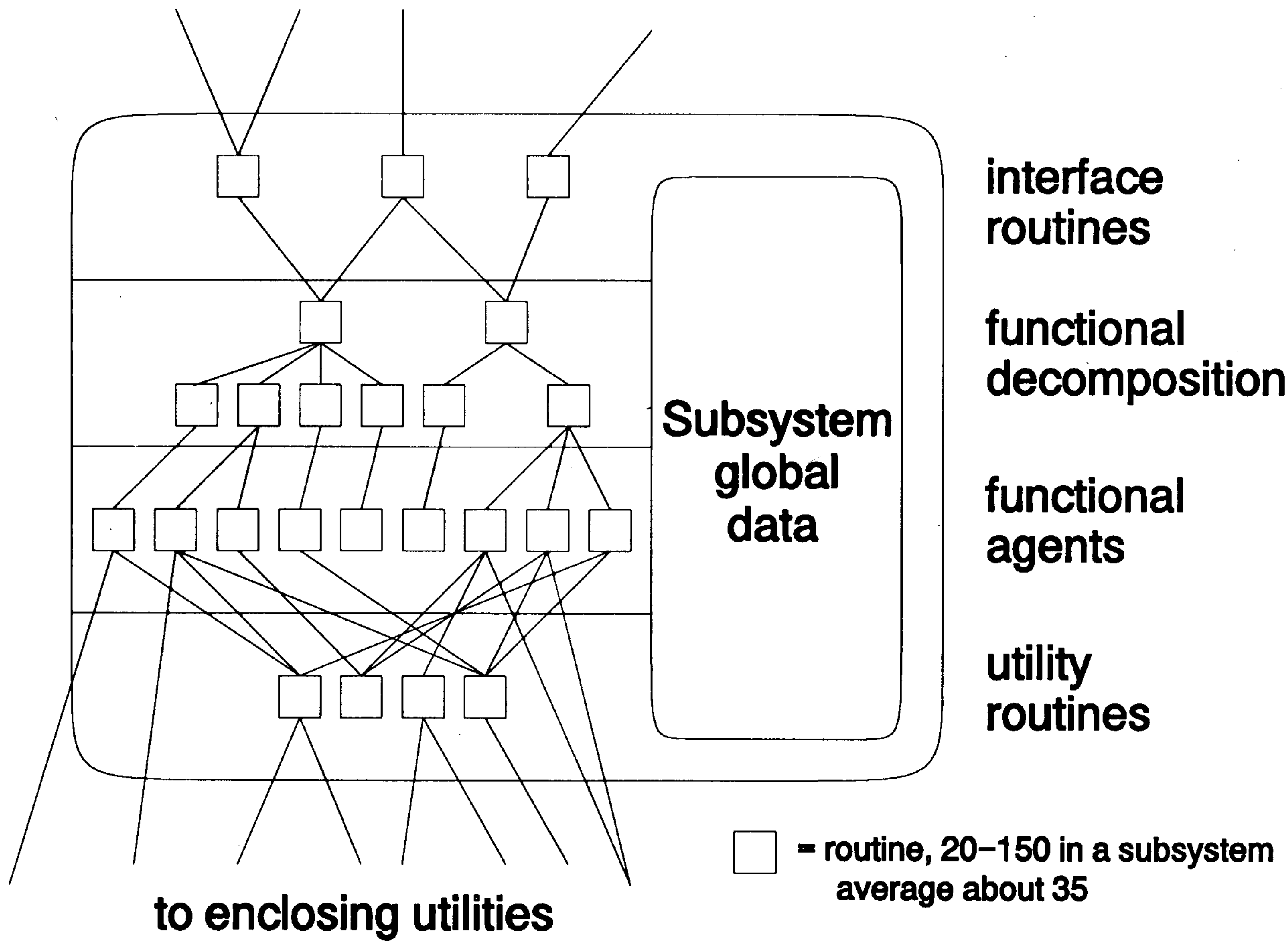


- establishing control



Calls To Other Routines
75% of routines call 7 or less routines
50% of routines call 3 or less routines
% Routines (log scale)
100
10
1
0.1
0.01
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
Calls To Other Routines


Calls From Other Routines
60% of routines called by 1 or less routines
90% of routines called by 6 or less routines
% Routines (log scale)
100
10
1
0.1
0.01
0
2
4
6
8
10
12
14
16
18
20
22
24
26
29
31
34
38
41
Calls From Other Routines


Subsystem global data
interface routines
functional decomposition
functional agents
utility routines
= routine, 20–150 in a subsystem average about 35
to enclosing utilities

ENTER ROUTINE (IN SINGLE QUOTES), %DOWN, %UP

- establishing control of a large system
  - staff level: 20K lines source per programmer
  - identify tightly coupled modules
  - form tightly coupled modules into subsystems
  - assign 10K-30K source lines in subsystems to programmer
- module interconnection languages (MILs)
  - PS programming language
  - PS resource description language
  - PL resource flow language

Lessons from Large Systems

- system architecture important for extension and maintenance
- issues change from small systems
- MILs are required and usually custom made
- subsystem concept must be used in assembling systems from components

Automatic Programming and Program Generation

- motivation: techniques and effects of very high levels of abstraction
- automatic programming: strong mechanism, general knowledge
- program generation: weak mechanism, problem domain specific knowledge

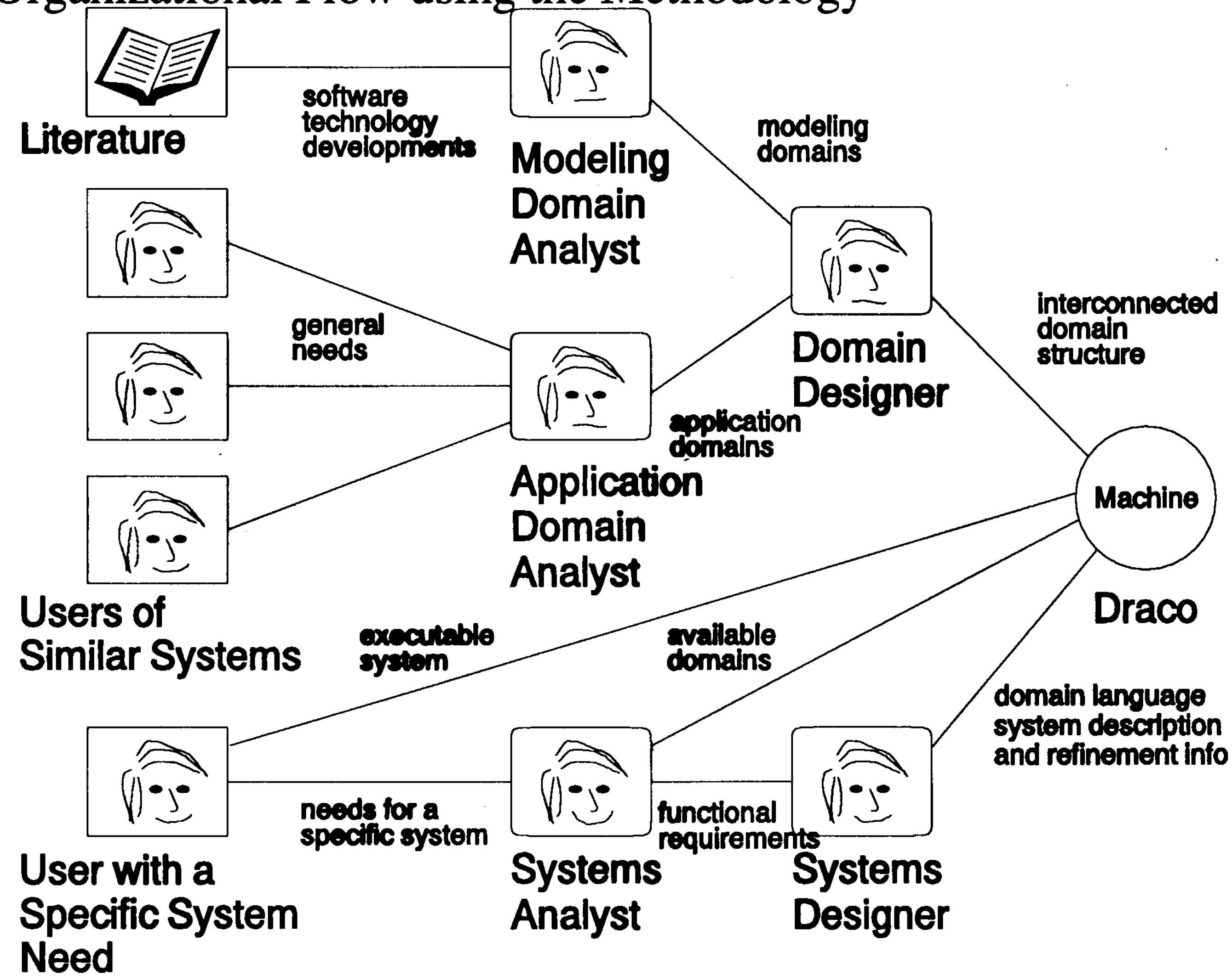
Lessons from Automatic Programming and Program Generation

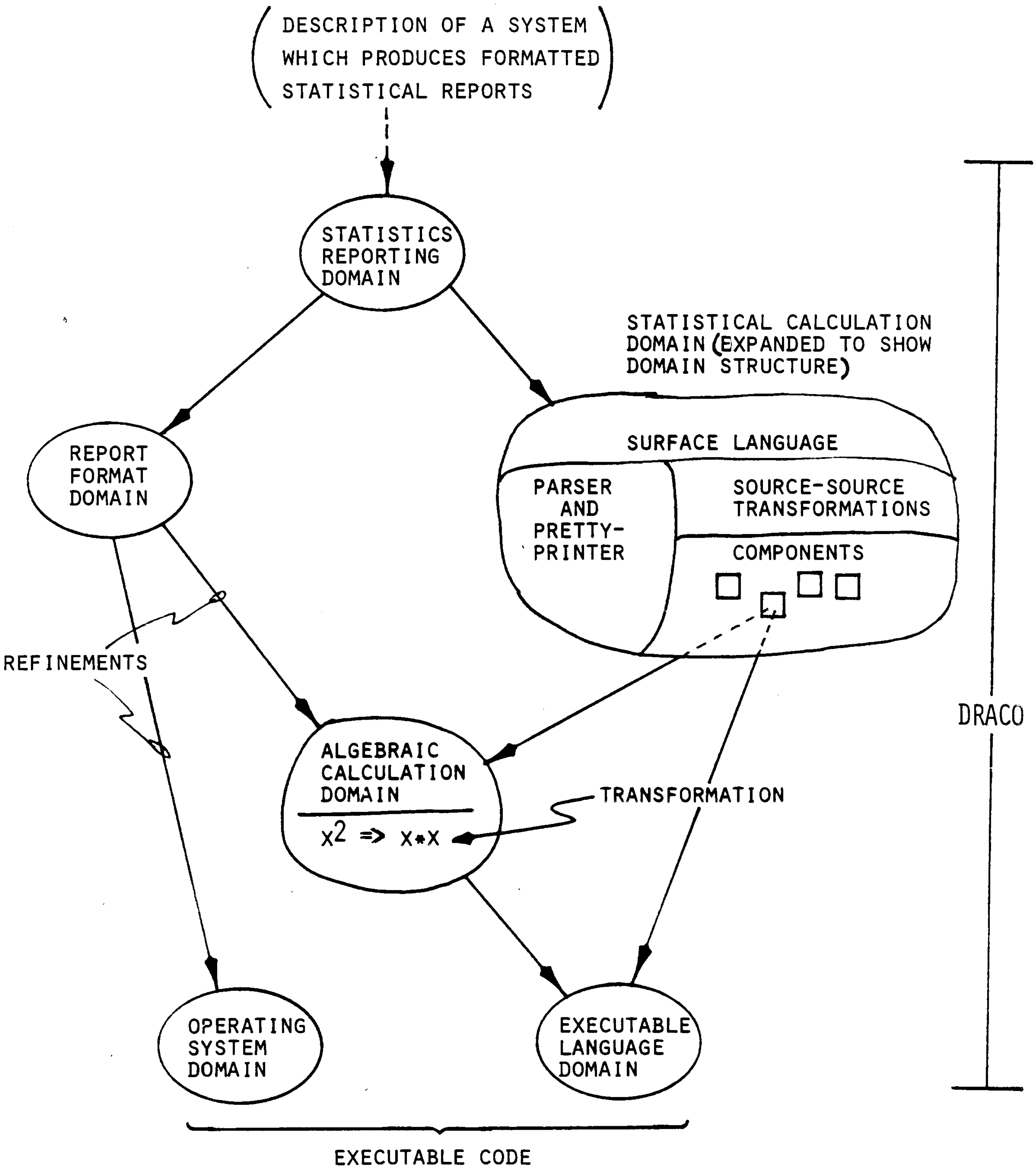
- domain-specific languages an aid, notations not a problem
- domain-specific knowledge with weak mechanisms powerful but inflexible
- general knowledge with strong mechanisms weak but flexible
- power of assembly mechanism must be balanced against the ability to plan using the mechanism

Methodology Requirements

1. problem domain specific objects and operations
2. hierarchy of domains (modeling domains)
3. optimization in domain independent of refining implementations
4. burden of search for implementing components removed from user
5. simple optimization and refinement mechanisms
6. refinement mechanism must also provide good system architectures
7. refinement mechanism must cope with pre-refined large subsystems

Organizational Flow using the Methodology





HOW DRACO WORKS

Parts of a Domain Description

1. parser and schema
2. printer
3. optimizations
4. components
   - one for each object and operation
   - multiple refinements (implementations) for each
5. generators
6. analyzers

```
q931  { InitialState = U00_Null;  [ Q.931 User Side FSM ]

U00_Null ::

     recv(Resume,user) -> CallRefSelection,
                 send(Resume,net), StartTimer(T318) >> U17_ResumeReq;
     recv(SetUp,net)  -> CheckSetUpMsg {
                   SetUpOk                -> send(SetUpInd,user) >> U06_CallPresent;
                   SetUpManElementMissing -> send(ReleaseComp(96),net) >> = ;
                   SetUpManElementError   -> send(ReleaseComp(100),net) >>  =
                 };
     recv(SetUp,user)  -> CheckSetUpMsg {
                   SetUpOk -> CallRefSelection, send(SetUp,net),
                              StartTimer(T303) >> U01_CallInitiated;
                   SetUpManElementMissing -> send(ReleaseComp(96),net) >> =;
                   SetUpManElementError   -> send(ReleaseComp(100),net) >> =
                 };
     recv(Status,net) -> CheckStatusCsField {
                   CsZero    -> nullaction >> =;
                   CsNotZero -> RelOption {
                                  RelOpt -> send(Release(101),net), StartTimer(T308)
                                            >> U19_ReleaseReq;
                                  RelCompOpt -> send(ReleaseComp(101),net) >> =
                                }
                };
     recv(Release,net)         -> send(ReleaseComp(0),net), RelCallRef >> = ;
     recv(ReleaseComp,net)     -> nullaction >> = ;
     timeout(default) |
     recv(default,user) |
     recv(default,net)   |
     recv(UnrecognizedMsg,net) ->
                          RelOption {
                            RelOpt     -> send(Release(81),net),
                                          StartTimer(T308) >> U19_ReleaseReq;
                            RelCompOpt -> send(ReleaseComp(81),net) >> =
                          };
     recv(StatusEnquiry,net) -> send(Status(0),net) >> = ;
     recv(RestartReq,user)   -> restartuser: StopAllTimers,
                                send(ReleaseInd,user), RelCallRef,
                                send(RestartConf,user) >> U00_Null;
     recv(DL_Rel_Ind,net)    -> nullaction >> = ;
     recv(DL_Est_Conf,net)   -> goto DLEstConf_label;
     timeout(T309)           -> t309tout: send(DataLinkFailureInd,user),
                                RelCallRef >> U00_Null
```

Experience with Methodology

- works but has problems
- produces efficient programs making small (20K line) systems
- pre-refined major subsystems are important
- ability to refine major subsystems is important
- academic generalists
- industry specialists
- future work

Conclusions

- Domain Analysis a big success
  - process of defining problem domain
  - education of new people on problem domain
  - checking template for new systems
- lack of modeling domains a big problem
- academic projects must deal with modeling domains issue or face complexity failure
- industry projects must use modeling domains or risk becoming program generators
- joint academic and industry work a necessity
  - academics know modeling domains
  - industry knows problem domains
- problem of constructing software from reusable components has become the problem of constructing modeling domain hierarchy