Design of Software Systems (Ontwerp van SoftwareSystemen)

3 Metrics and Software Visualization

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OSS 2014-2015

Adapted, with permission, from Prof. Dr. Michele Lanza
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Lecture 04

Metrics & Problem Detection

You cannot control what you cannot measure

Tom de Marco

Metrics are functions that assign **numbers** to *products, processes* and *resources*

Software metrics are **measure**ments which relate to software **systems**, **processes** or related **documents**

Metrics compress system properties and traits into numbers

Let's see some examples..

Examples of size metrics

- NOM - Number of Methods
- NOA - Number of Attributes
- LOC - Number of Lines of Code
- NOS - Number of Statements
- NOC - Number of Children

Chidamber & Kemerer, 1994
Lorenz & Kidd, 1994

Cyclomatic Complexity (CYCLO)

- The McCabe cyclomatic complexity (CYCLO) counts the number of independent paths through the code of a function
  - Good: it reveals the minimum number of tests to write
  - Bad: its interpretation does not directly lead to improvement actions

McCabe, 1976

Weighted Method Count (WMC)

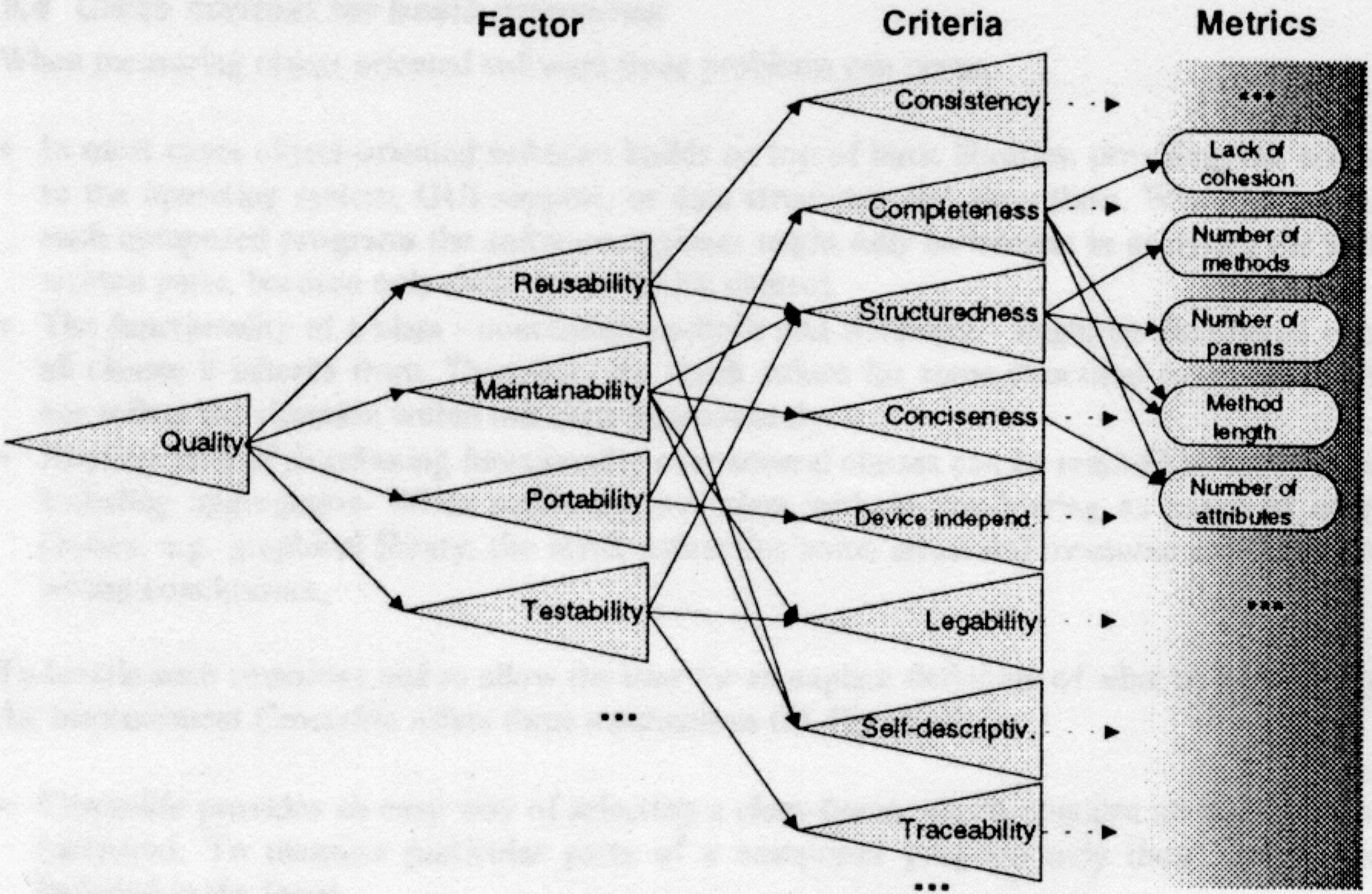
- WMC sums up the complexity of a class' methods (measured by the metric of your choice, usually CYCLO)
  - Good: It is configurable, thus adaptable to our precise needs
  - Bad: Its interpretation does not directly lead to improvement actions

Chidamber & Kemerer, 1994

Coupling Between Objects (CBO)

- CBO shows the number of classes from which methods or attributes are used.
  - Good: CBO takes into account real dependencies, not just declared ones
  - Bad: No differentiation of types and/or intensity of coupling

Chidamber & Kemerer, 1994



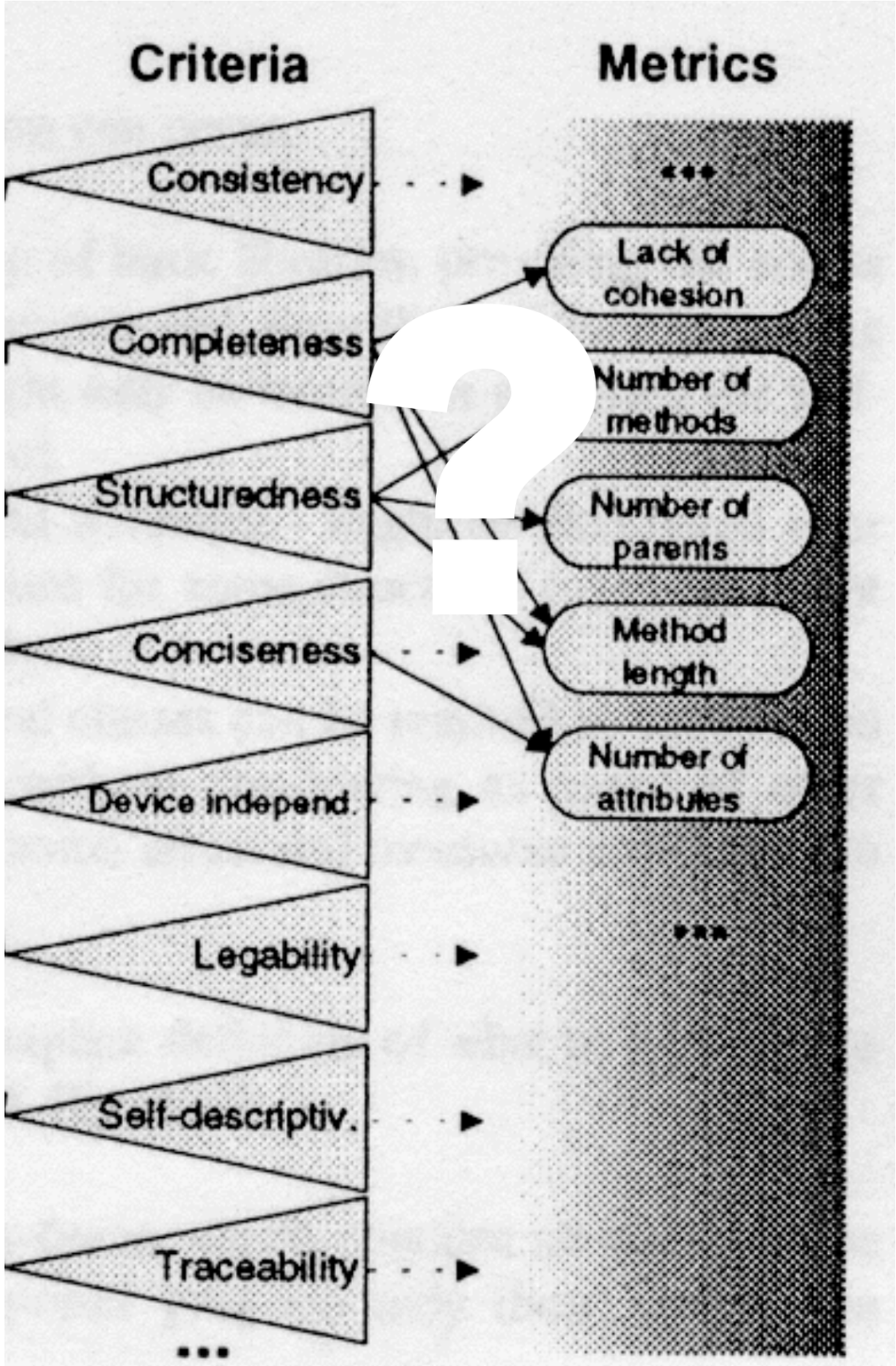
McCall, 1977
Boehm, 1978

Metrics help to assess and improve quality!

Do they?

Problems..

- Metrics granularity
  - metrics capture symptoms,not causes of problems
  - in isolation, metrics do not lead to improvement actions
- Implicit Mapping
  - we do not reason in terms of metrics, but in terms of design (principles)



McCall, 1977
Boehm, 1978

2 big obstacles in using metrics:

Thresholds make metrics hard to interpret

Granularity makes metrics hard to use in isolation

How do I get an initial understanding of a system?

Metric	Value
LOC	35175
NOM	3618
NOC	384
CYCLO	5579
NOP	19
CALLS	15128
FANOUT	8590
AHH	0,12
ANDC	0,31

Metric	Value
LOC	35175
NOM	3618
NOC	384
CYCLO	5579
NOP	
CALLS	
FAN	8590
A	0,12
AHDC	0,31

And now what?

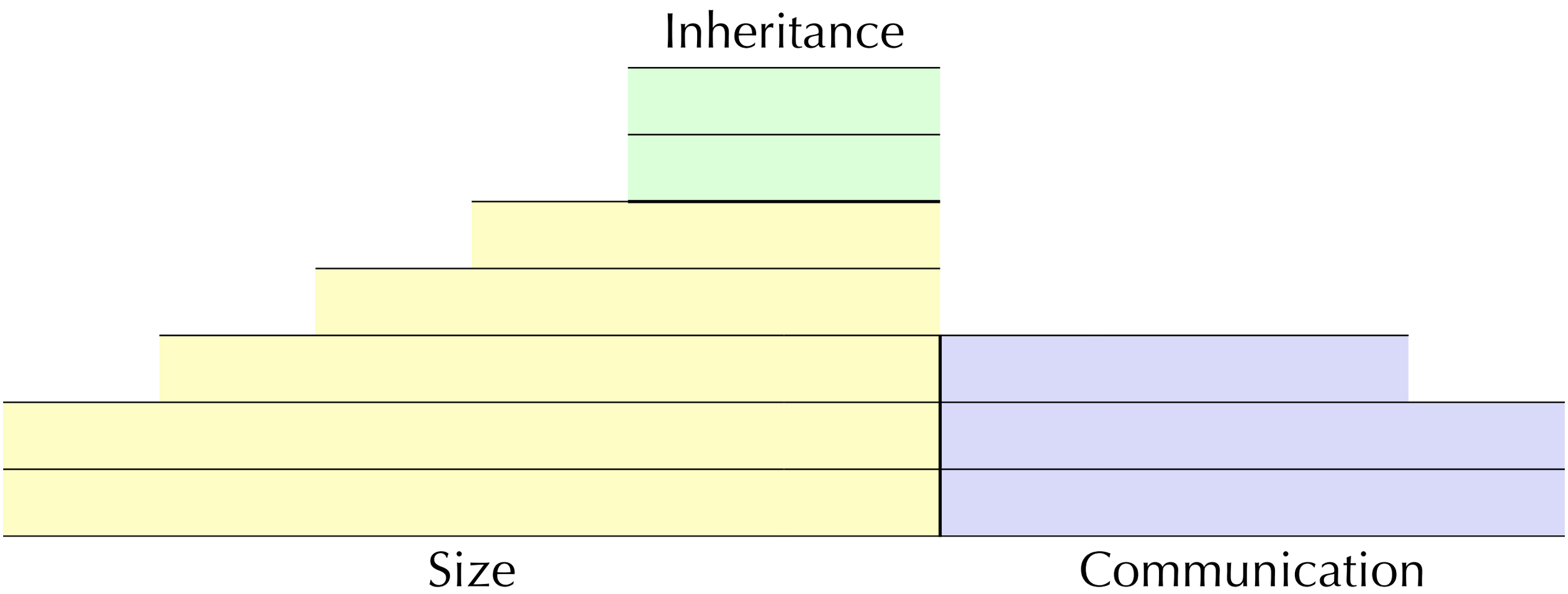
coupling?

We need means to compare

hierarchies?

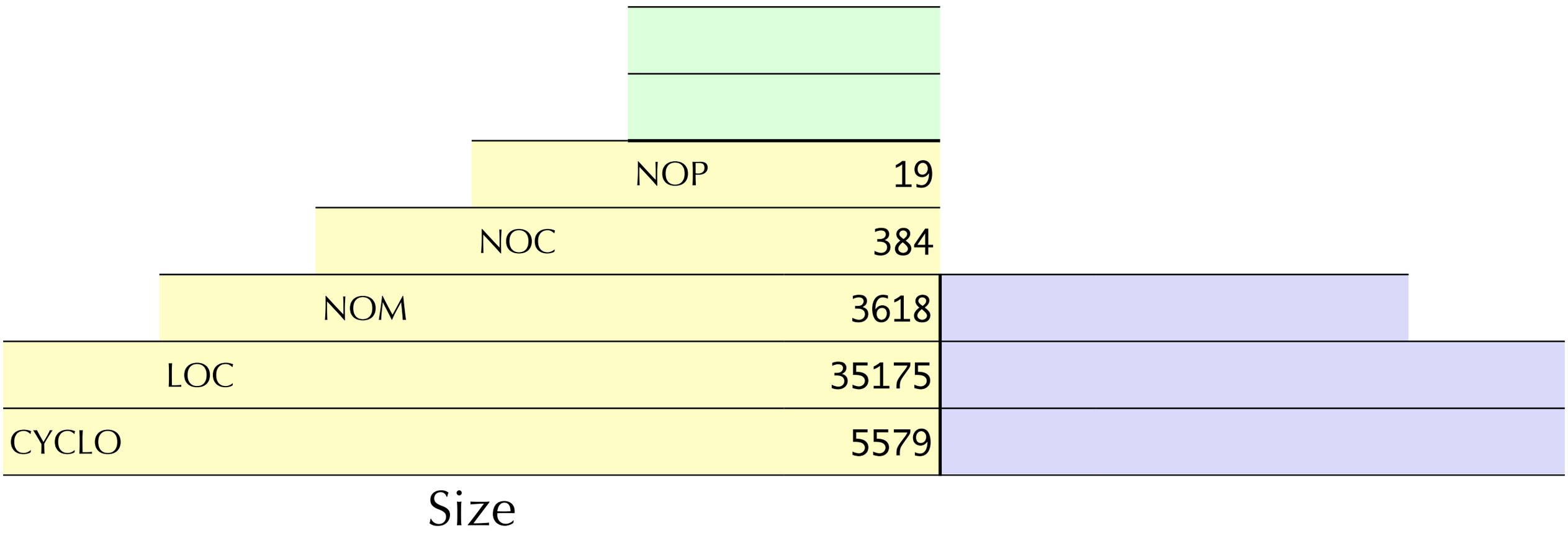
Characterizing Systems with Metrics

The Overview Pyramid provides a metrics overview



Lanza & Marinescu, 2006

The Overview Pyramid provides a metrics overview



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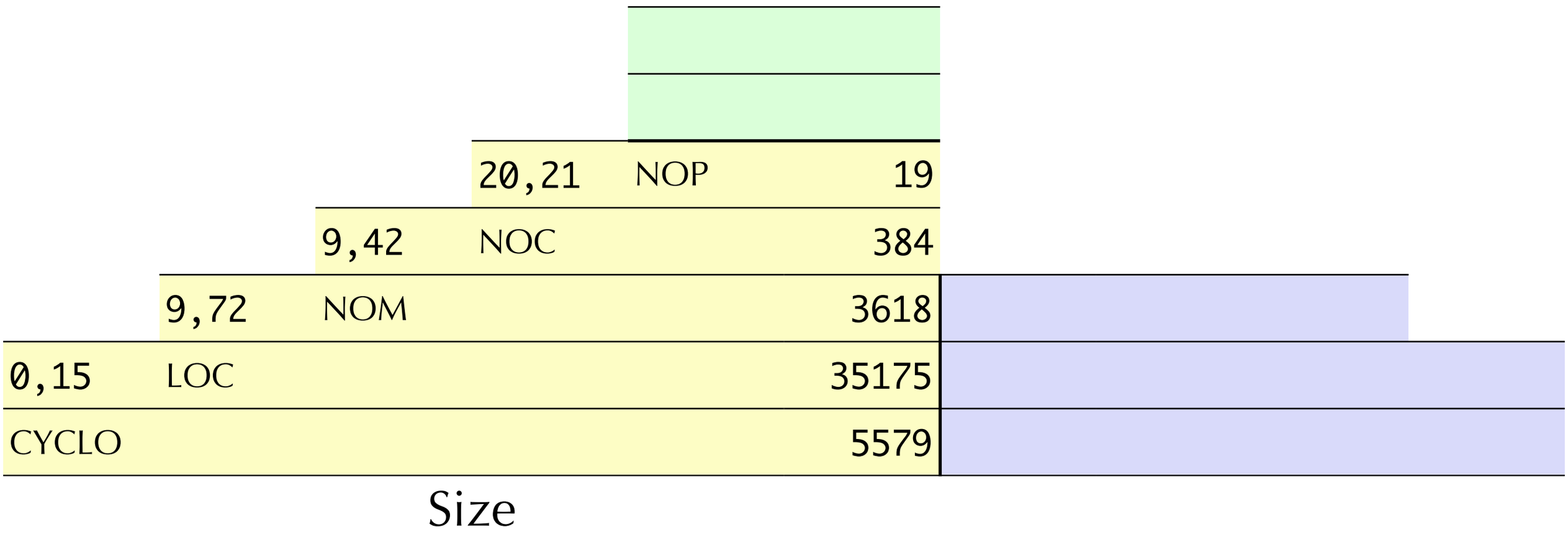
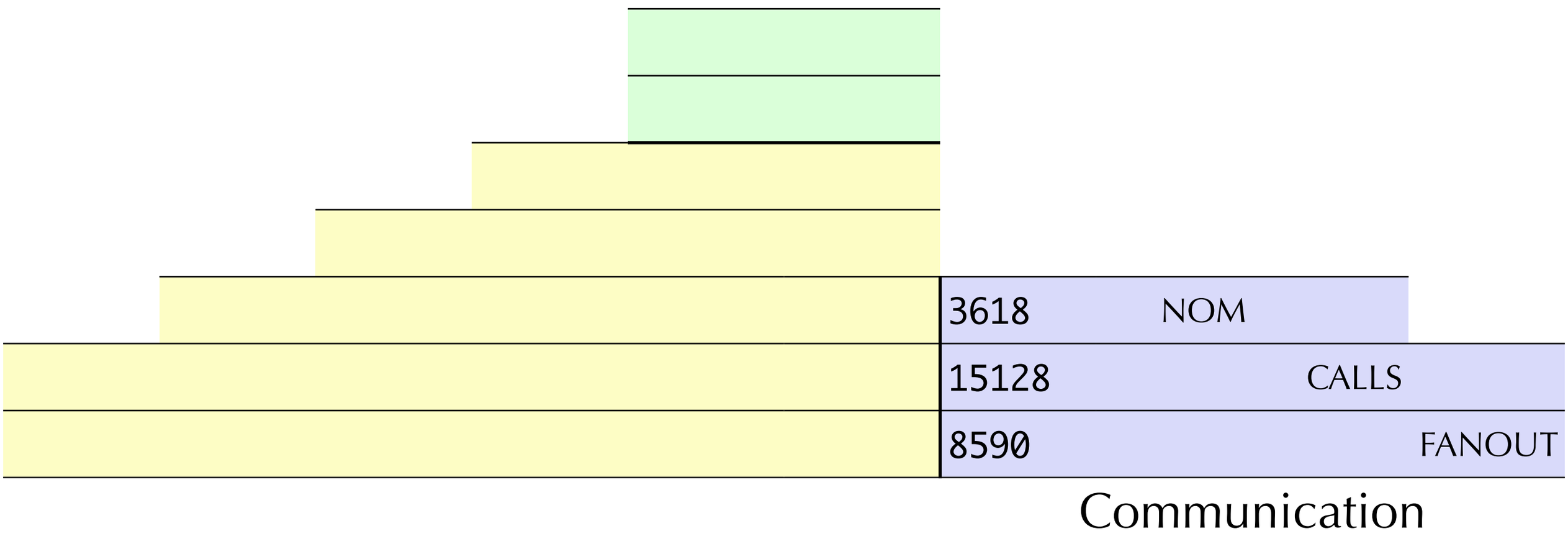


The Overview Pyramid provides a metrics overview



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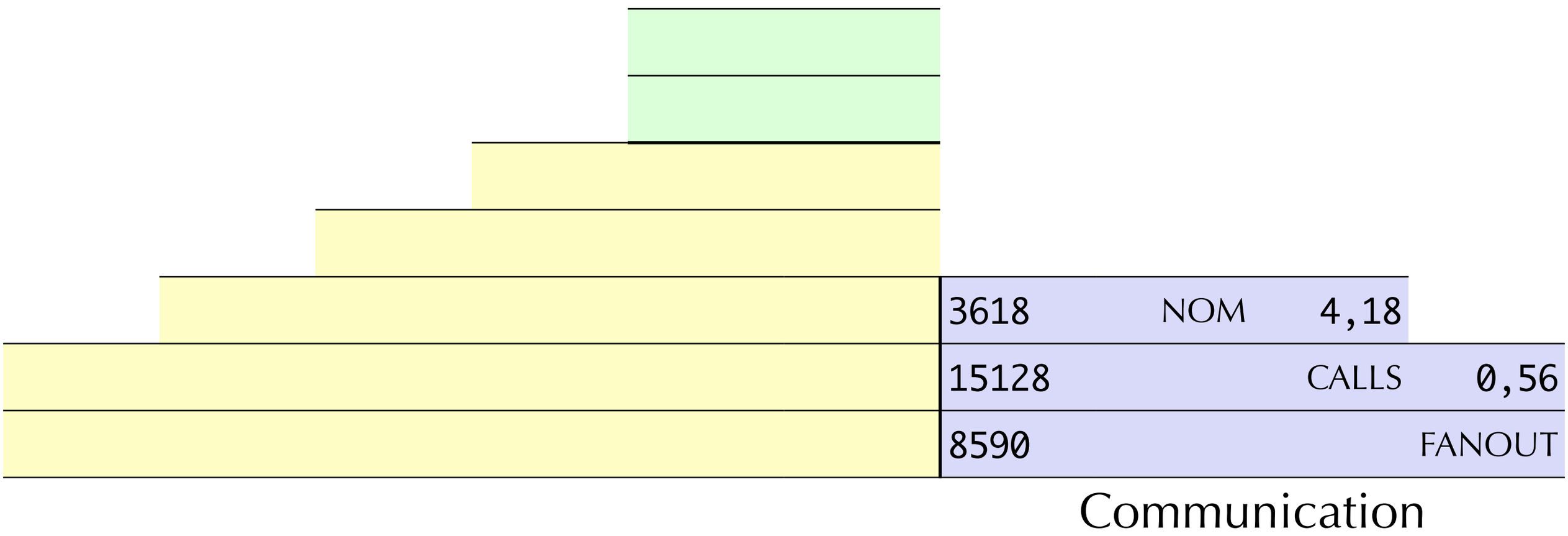

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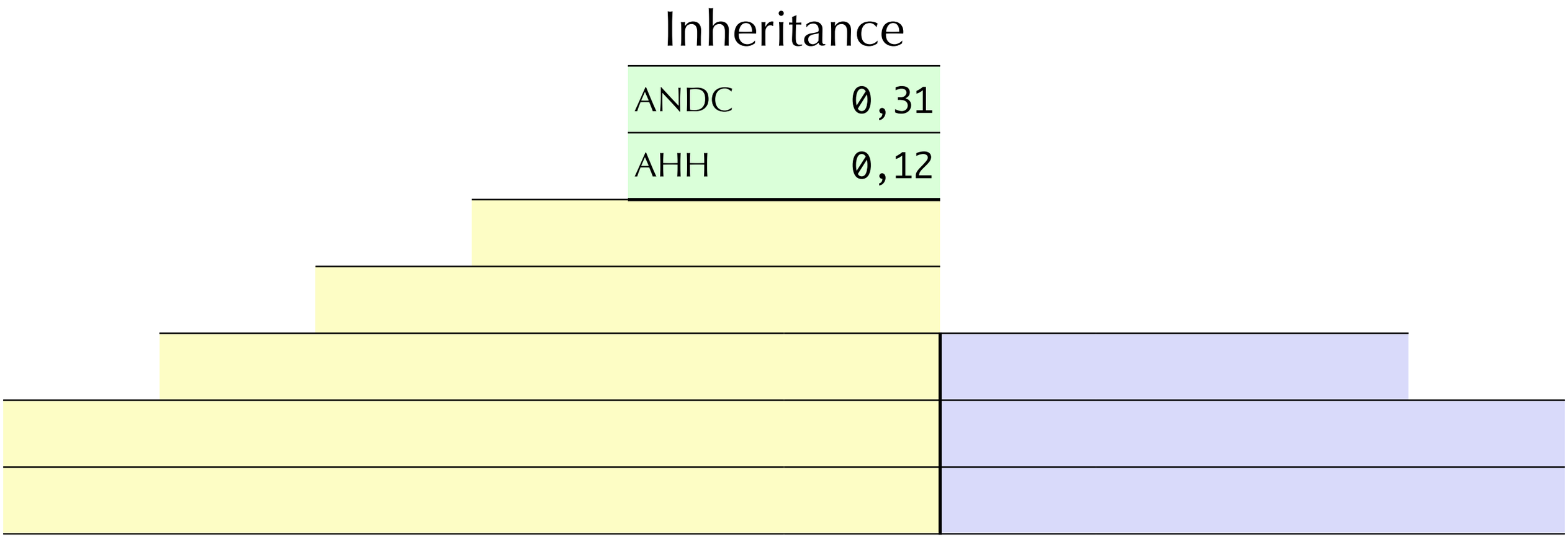

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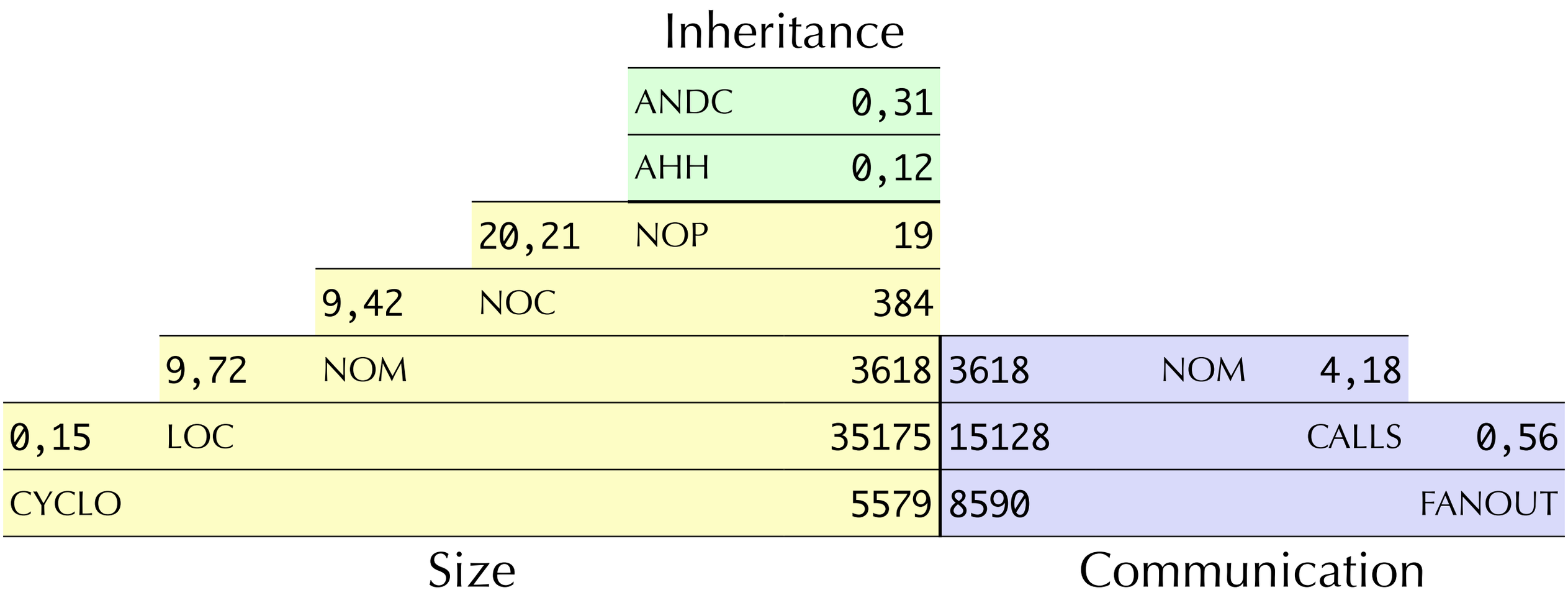
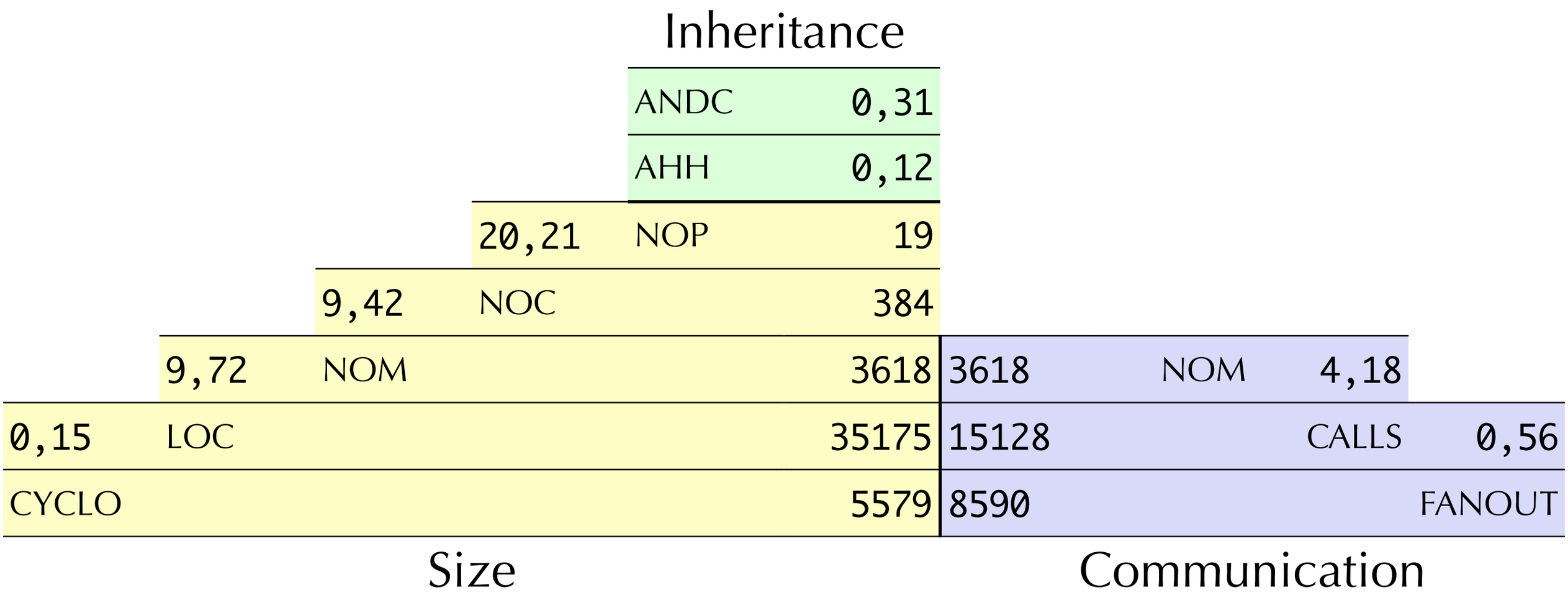


Obtaining Thresholds

	Java			C++		
	LOW	AVG	HIGH	LOW	AVG	HIGH
CYCLO/ LOC	0,16	0,2	0,24	0,2	0,25	0,3
LOC/NOM	7	10	13	5	10	16
NOM/NOC	4	7	10	4	9	15
...						

The Overview Pyramid provides a metrics overview



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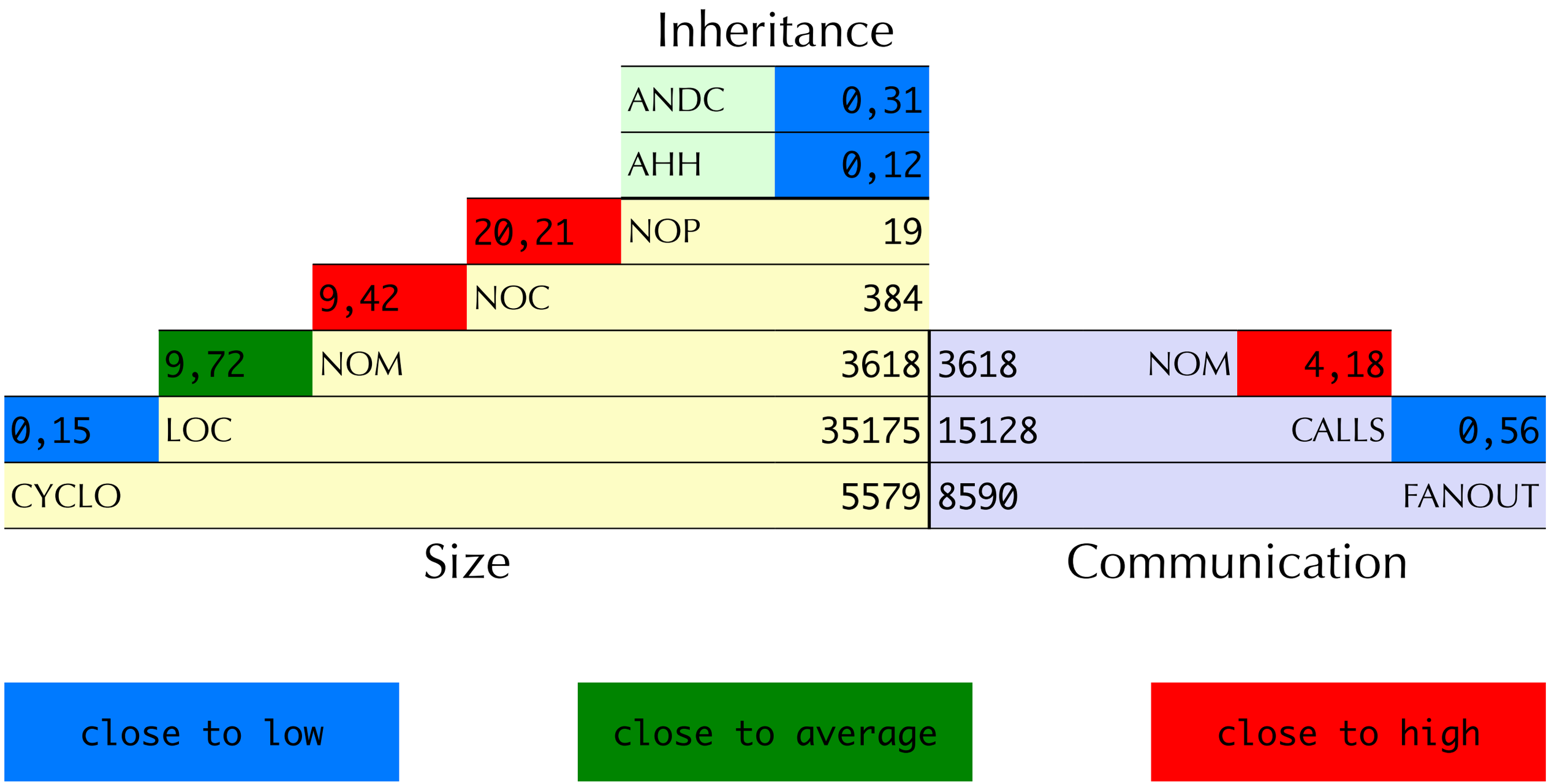

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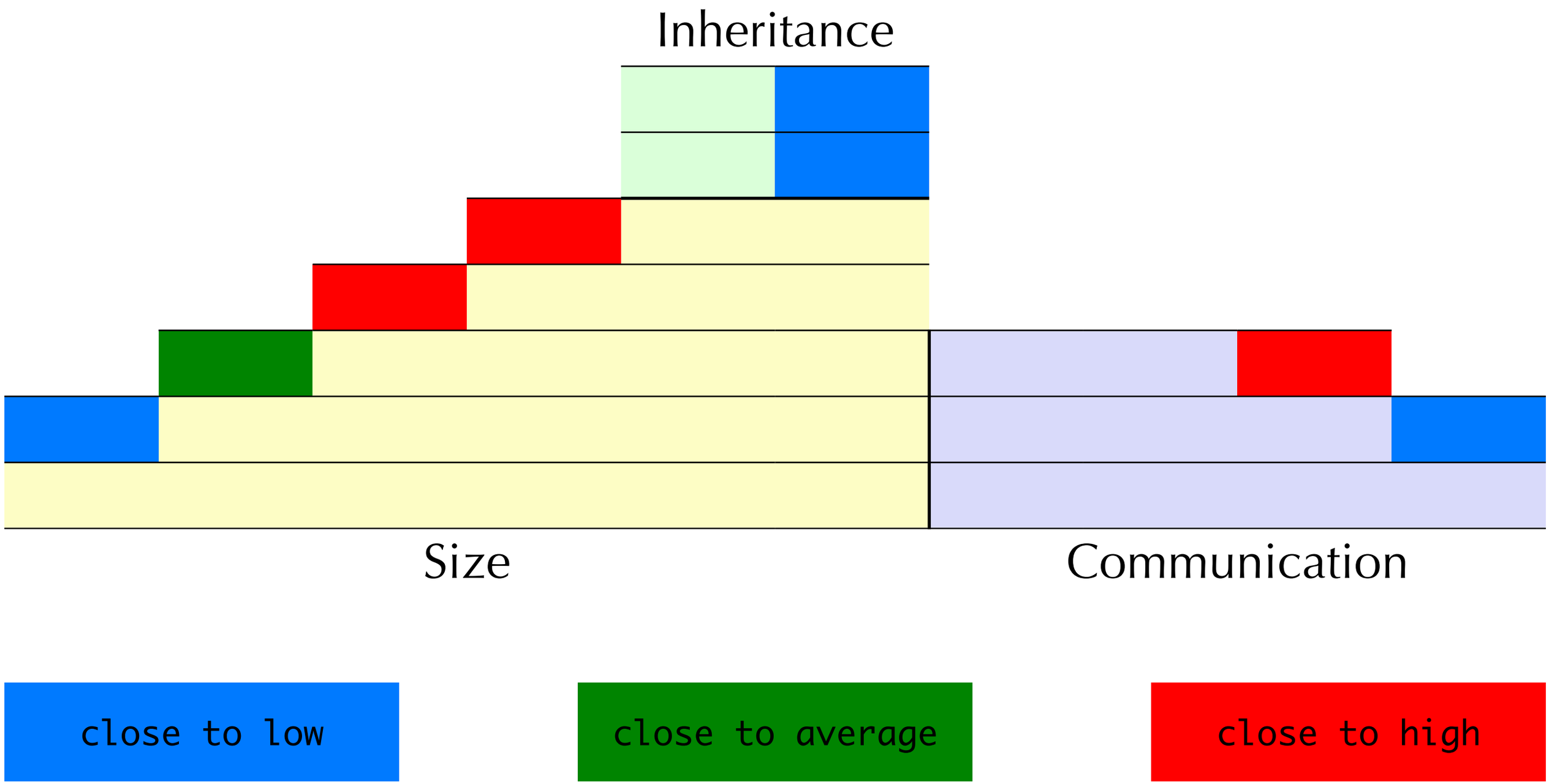


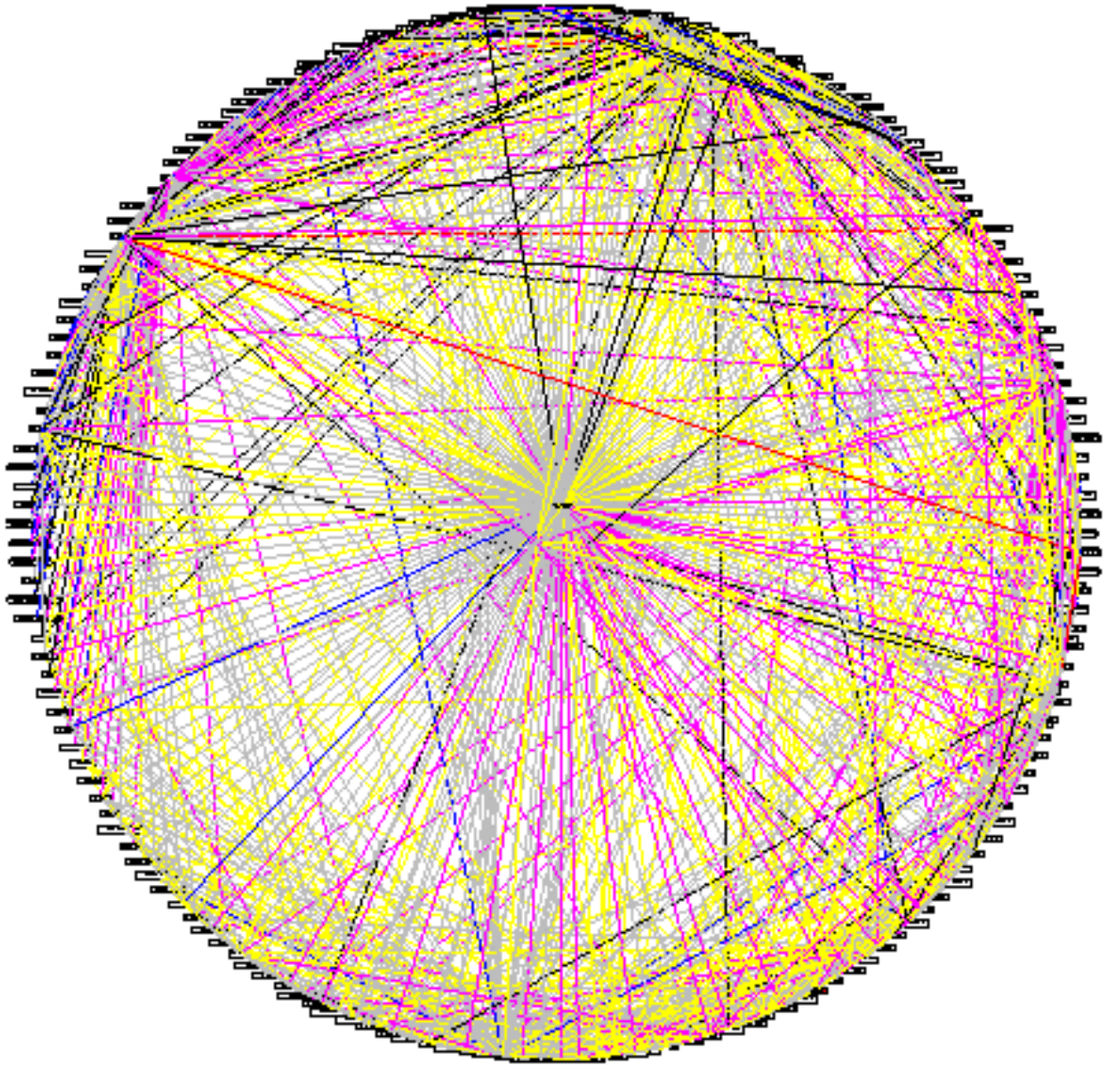
How do I improve my code?

- Quality is more than zero bugs
- Quality is about design principles, design heuristics, and best practices
- Breaking them leads to
  - Code deterioration
  - Design problems ~ Maintenance problems

Imagine...

You change a small design fragment...

...and one third of all classes require changes!



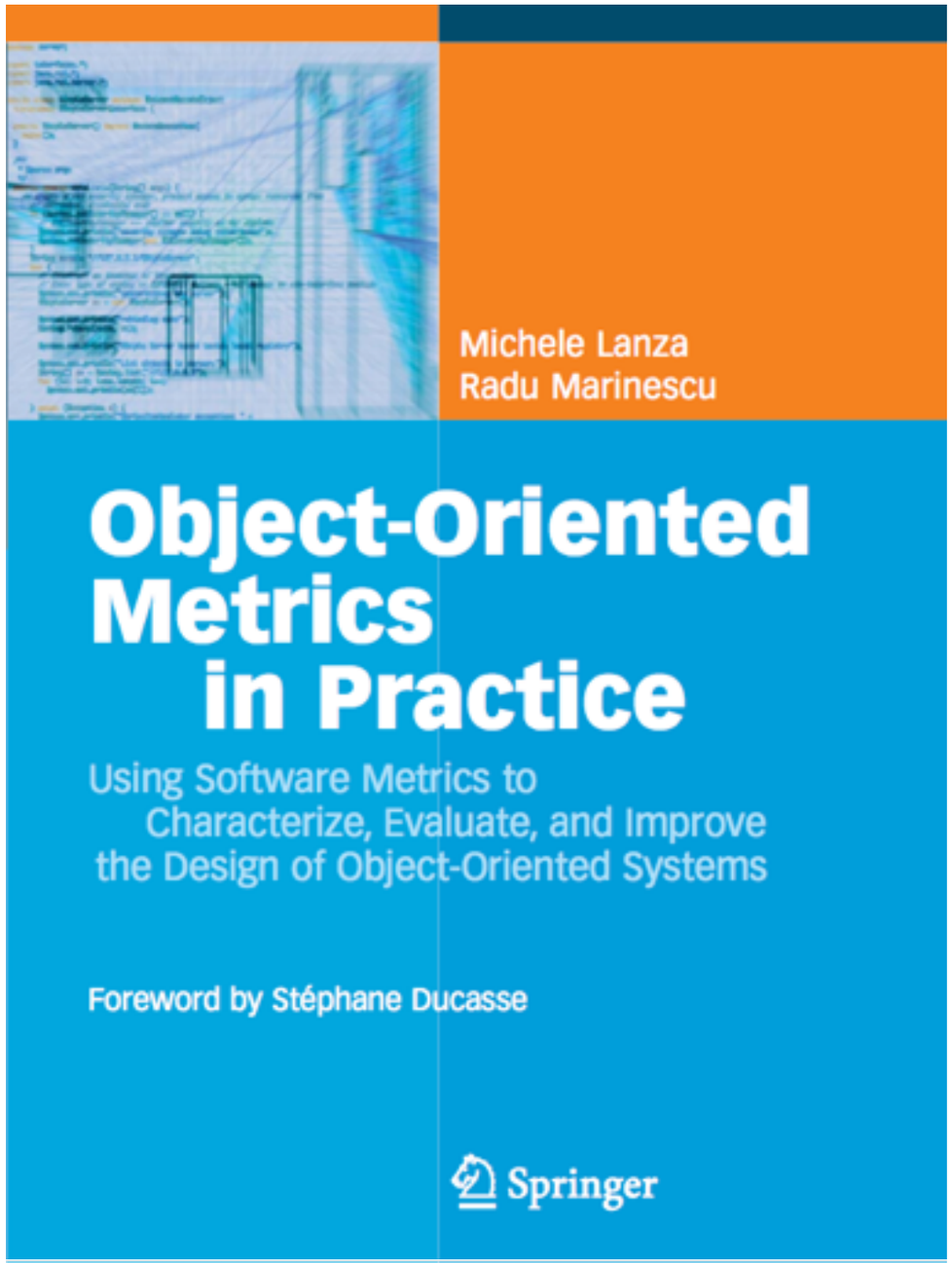
Design Problems

- Expensive
- Frequent
- Unavoidable
- How can we detect and eliminate them?

Reference

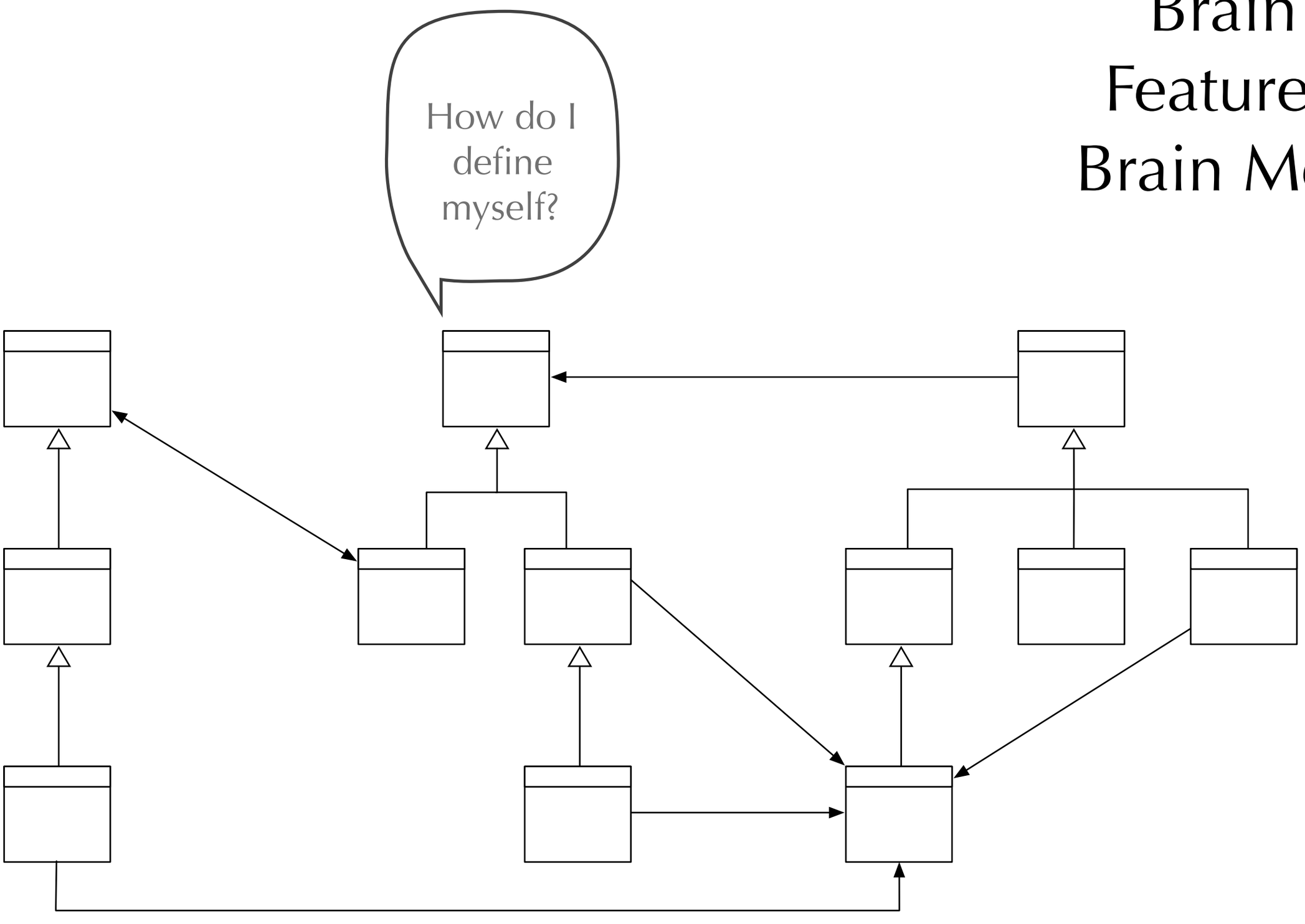
M. Lanza, R. Marinescu
“Object-Oriented Metrics in Practice”

Springer, 2006
ISBN 3-540-24429-8



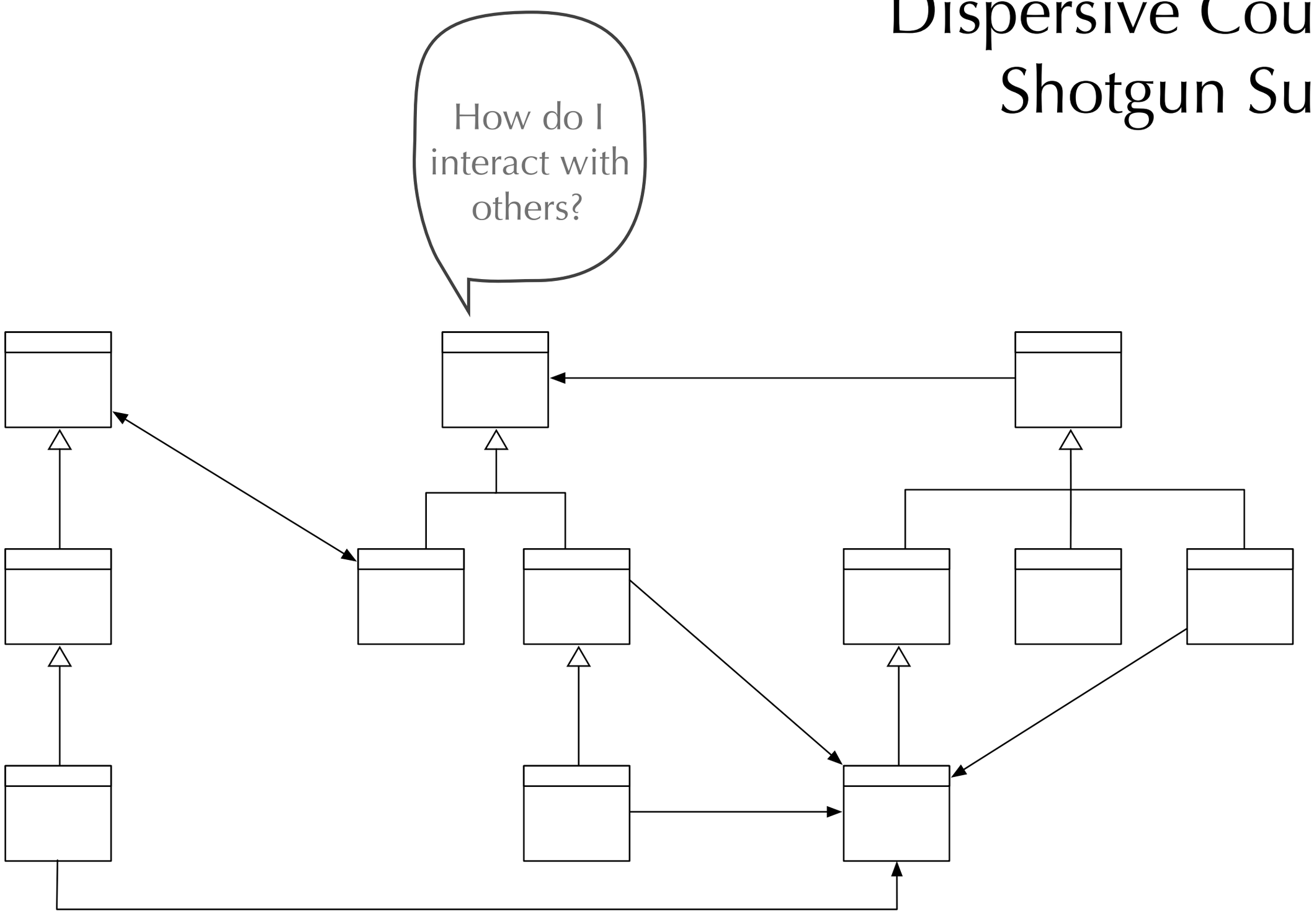
Identity Disharmony

God Class
Data Class
Brain Class
Feature Envy
Brain Method



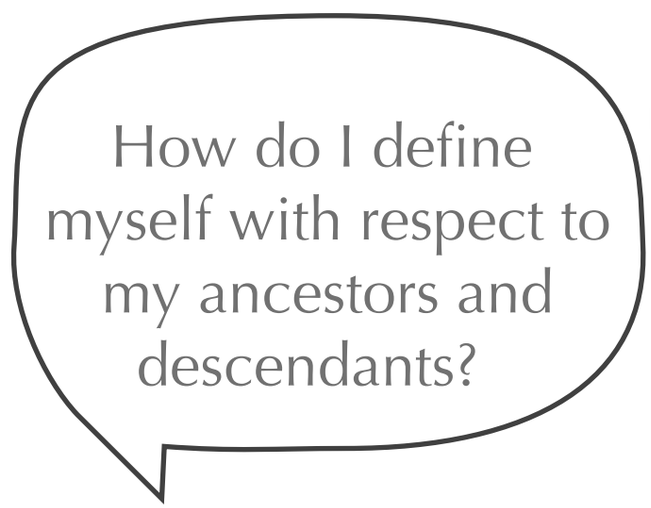
Collaboration Disharmony

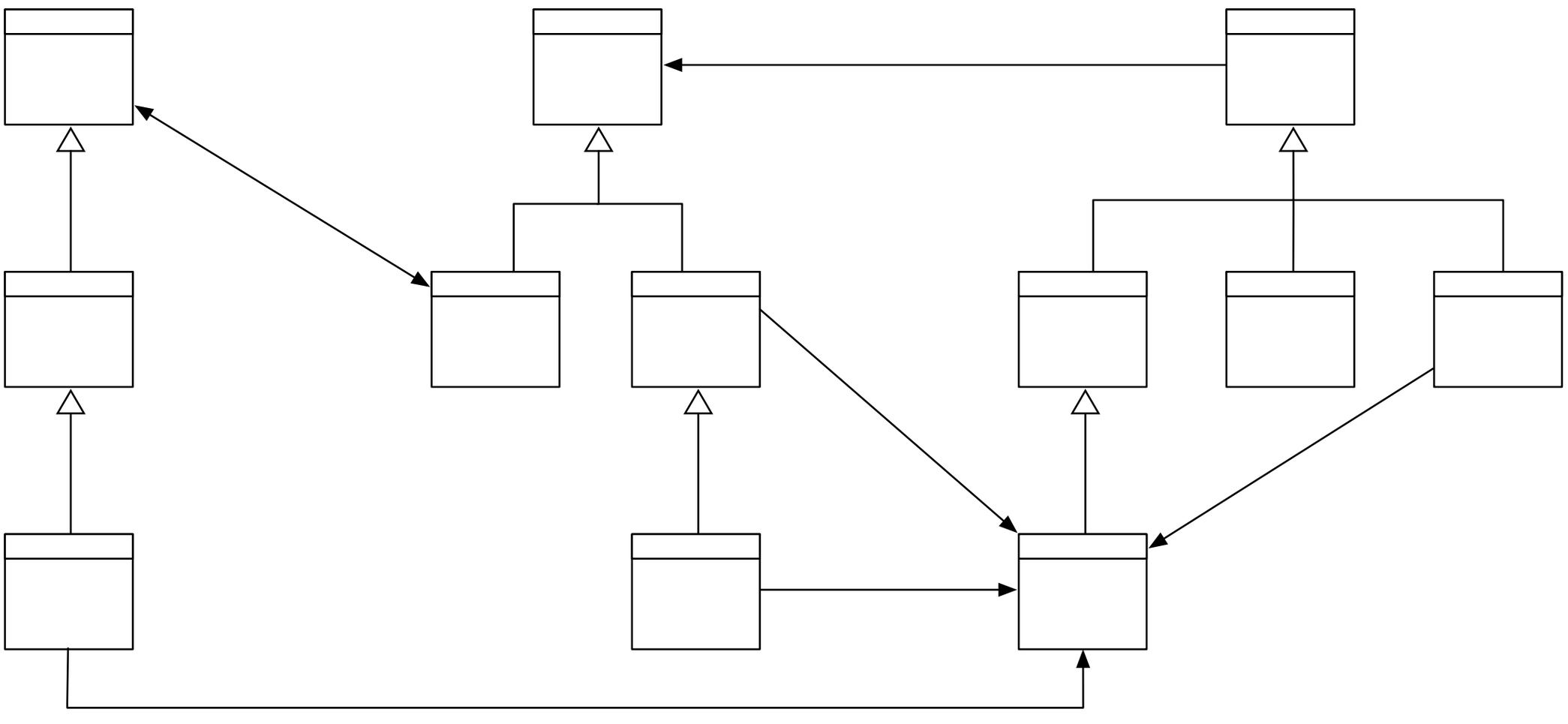
Intensive Coupling
Dispersive Coupling
Shotgun Surgery



Classification Disharmony

Futile Hierarchy
Tradition Breaker
Refused Parent Bequest

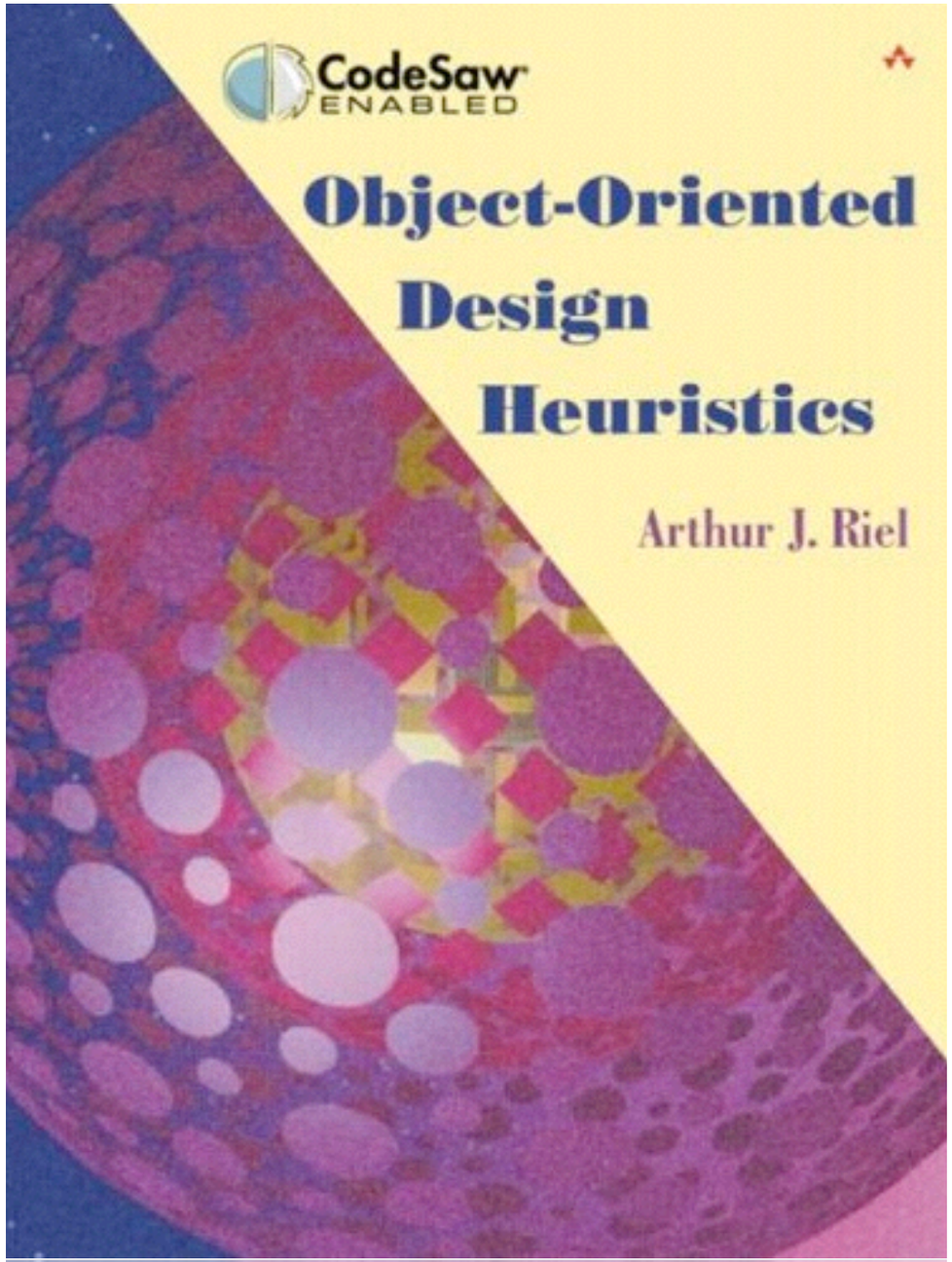




God Class

"In a good object-oriented design the intelligence of a system is uniformly distributed among the top-level classes."

Arthur Riel, 1996



God Classes

- God Classes tend to centralize the intelligence of the system, to do everything and to use data from small data-classes
- God Classes tend
  - to centralize the intelligence of the system
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- God Classes
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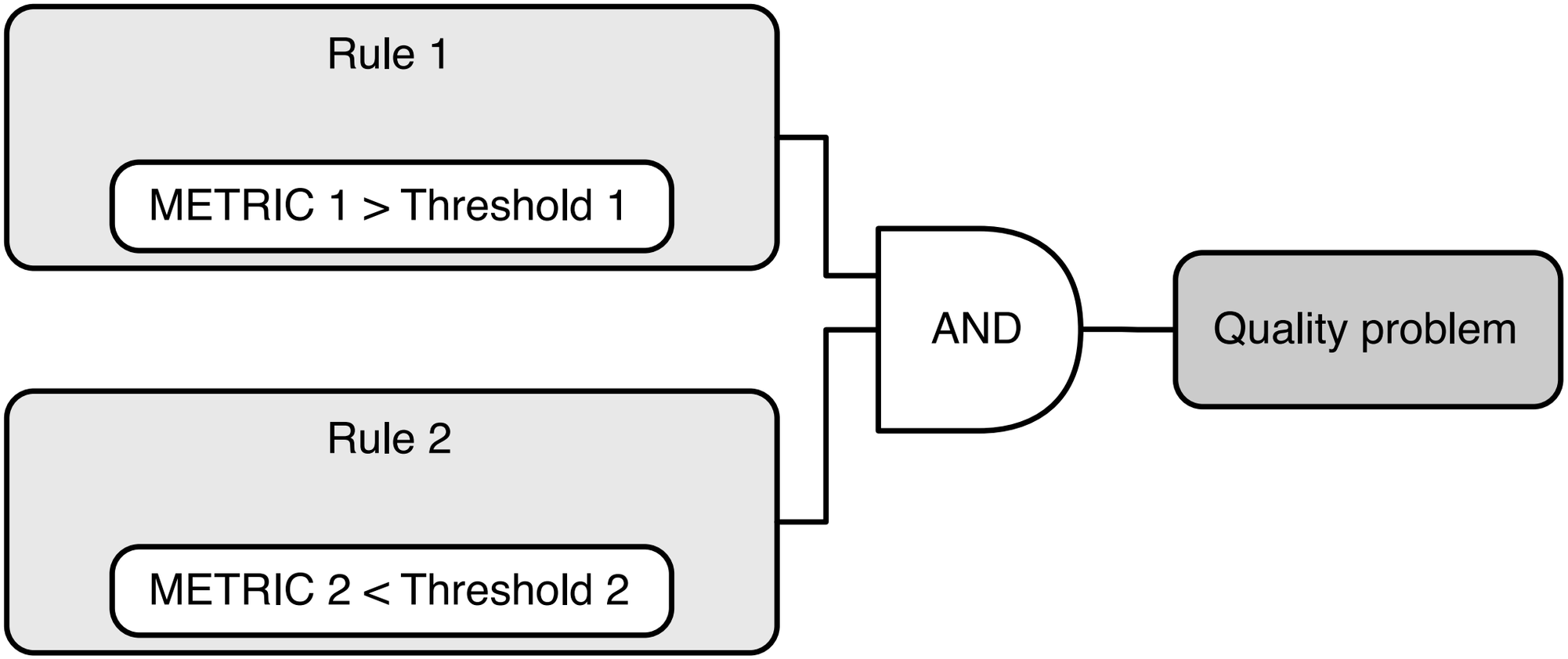
God Classes

- God Classes
  - centralize the intelligence of the system
  - do everything
  - use data from small data-classes
- God Classes
  - are complex: high WMC
  - are not cohesive: low TCC
  - access external data: ATFD

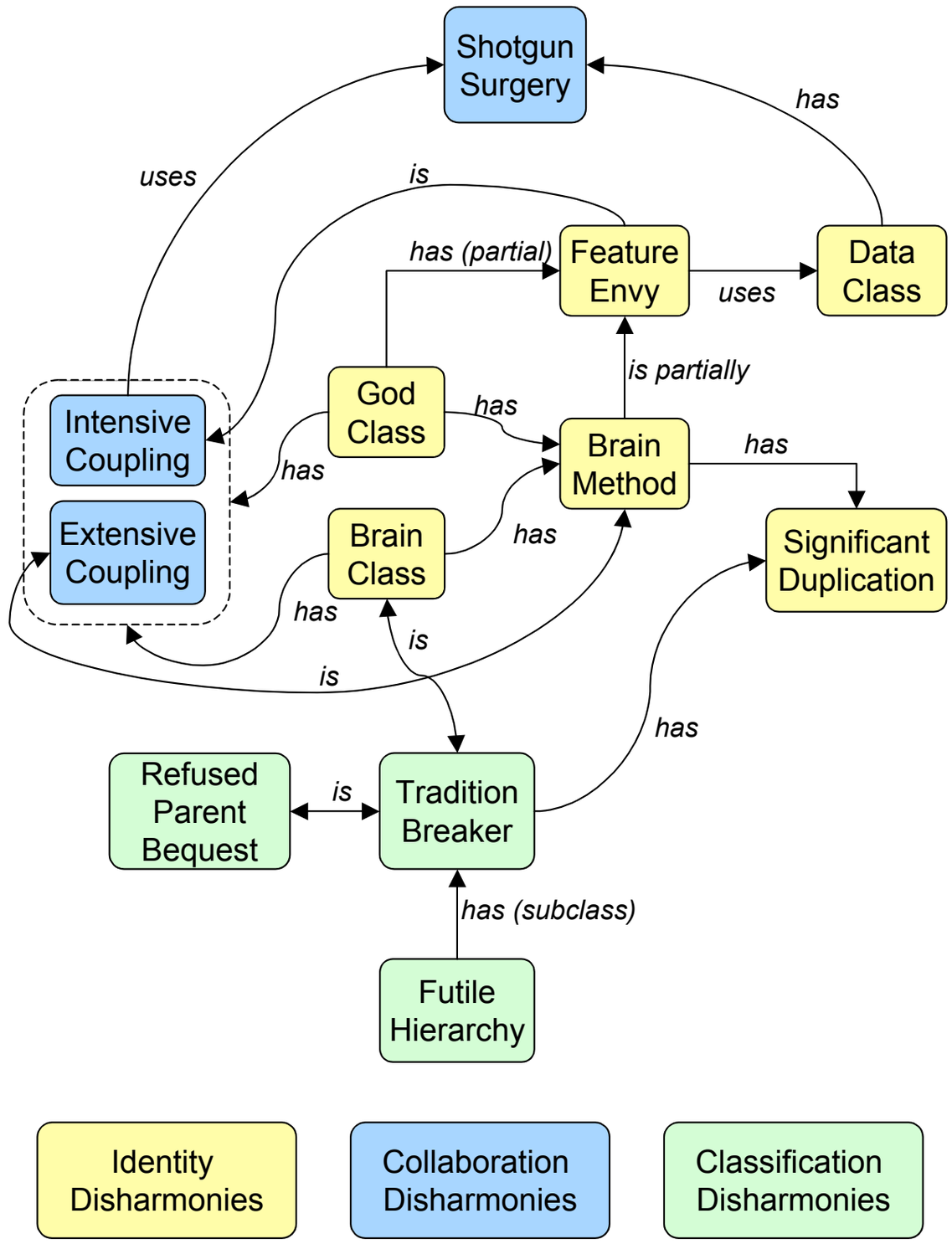
Compose metrics into queries
using logical operators

Detection Strategies

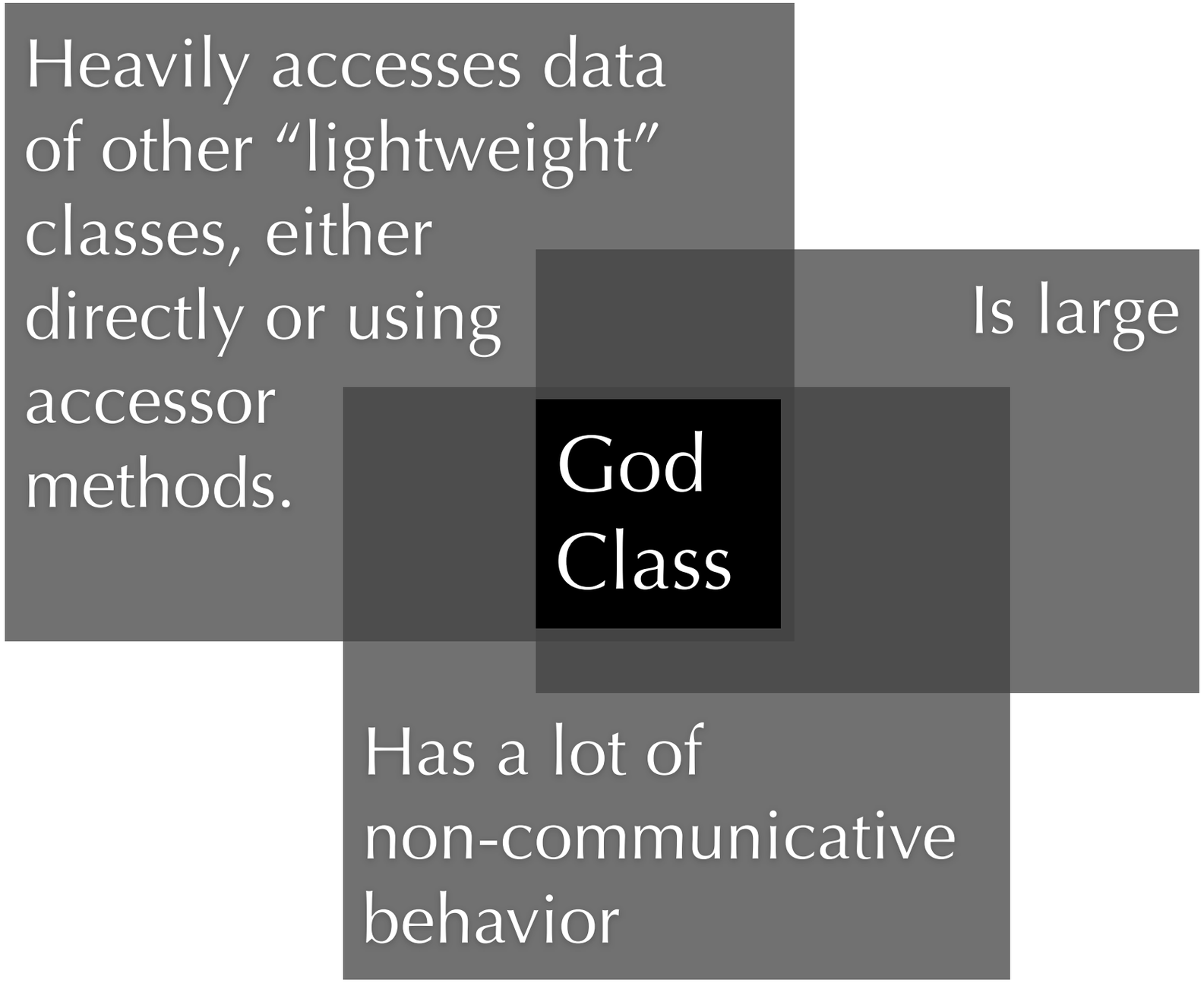
- Detection strategies are metric-based queries to detect design flaws



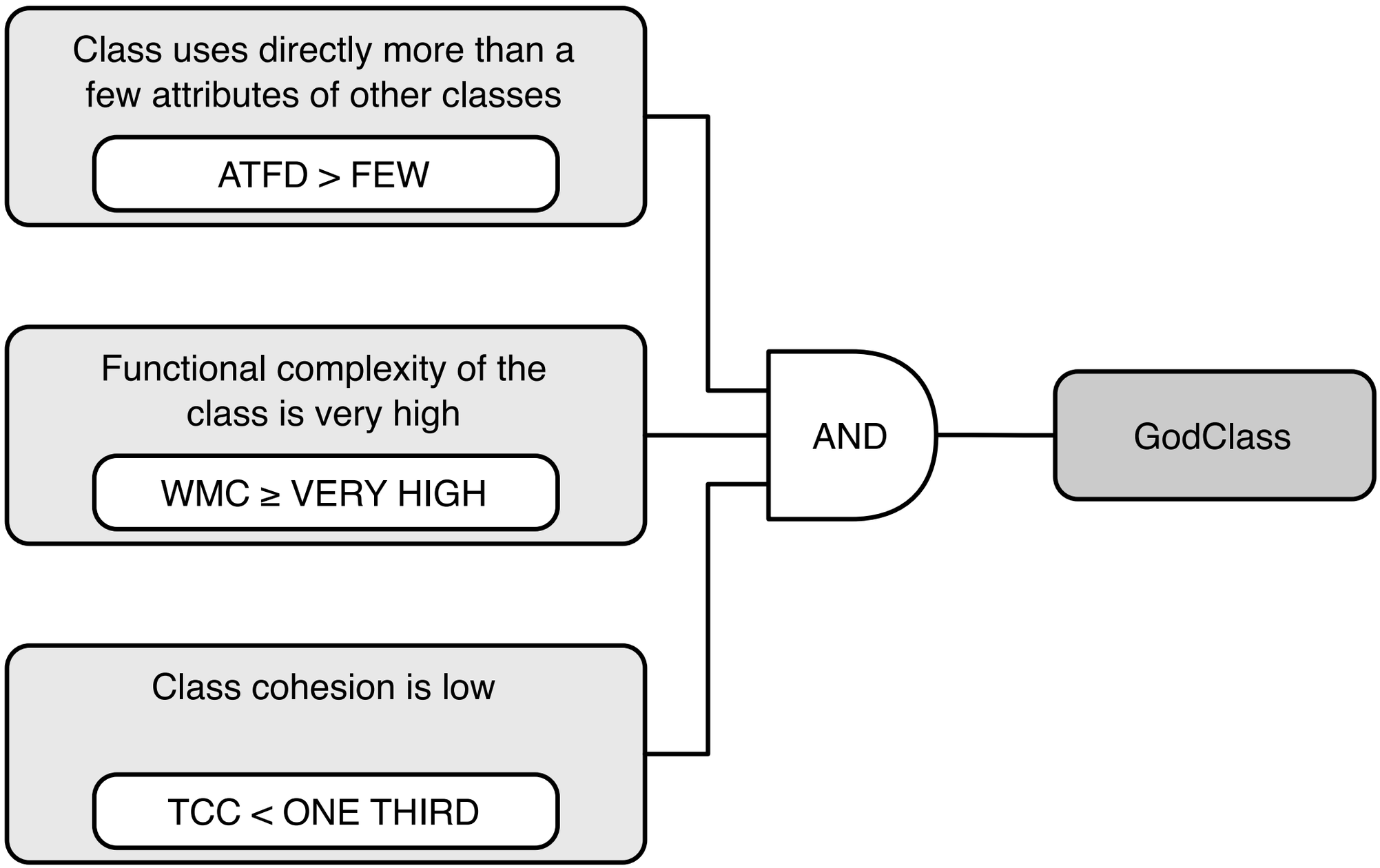
Design Flaws do not come alone



Characteristics of a God Class

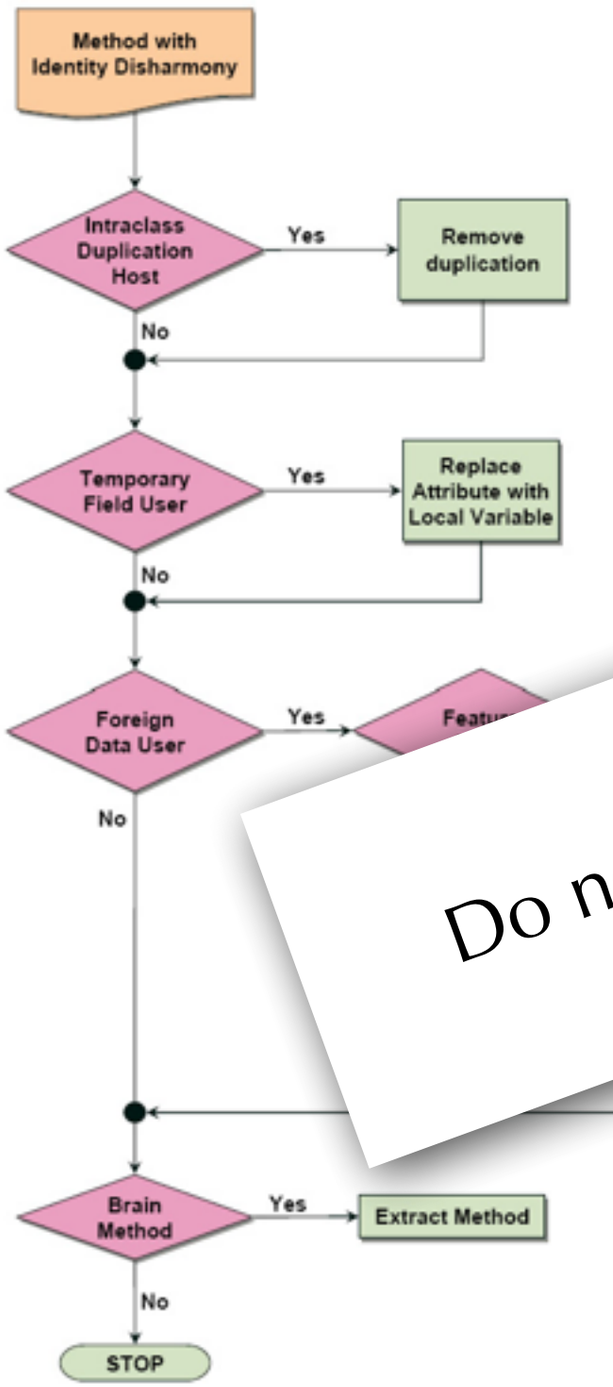


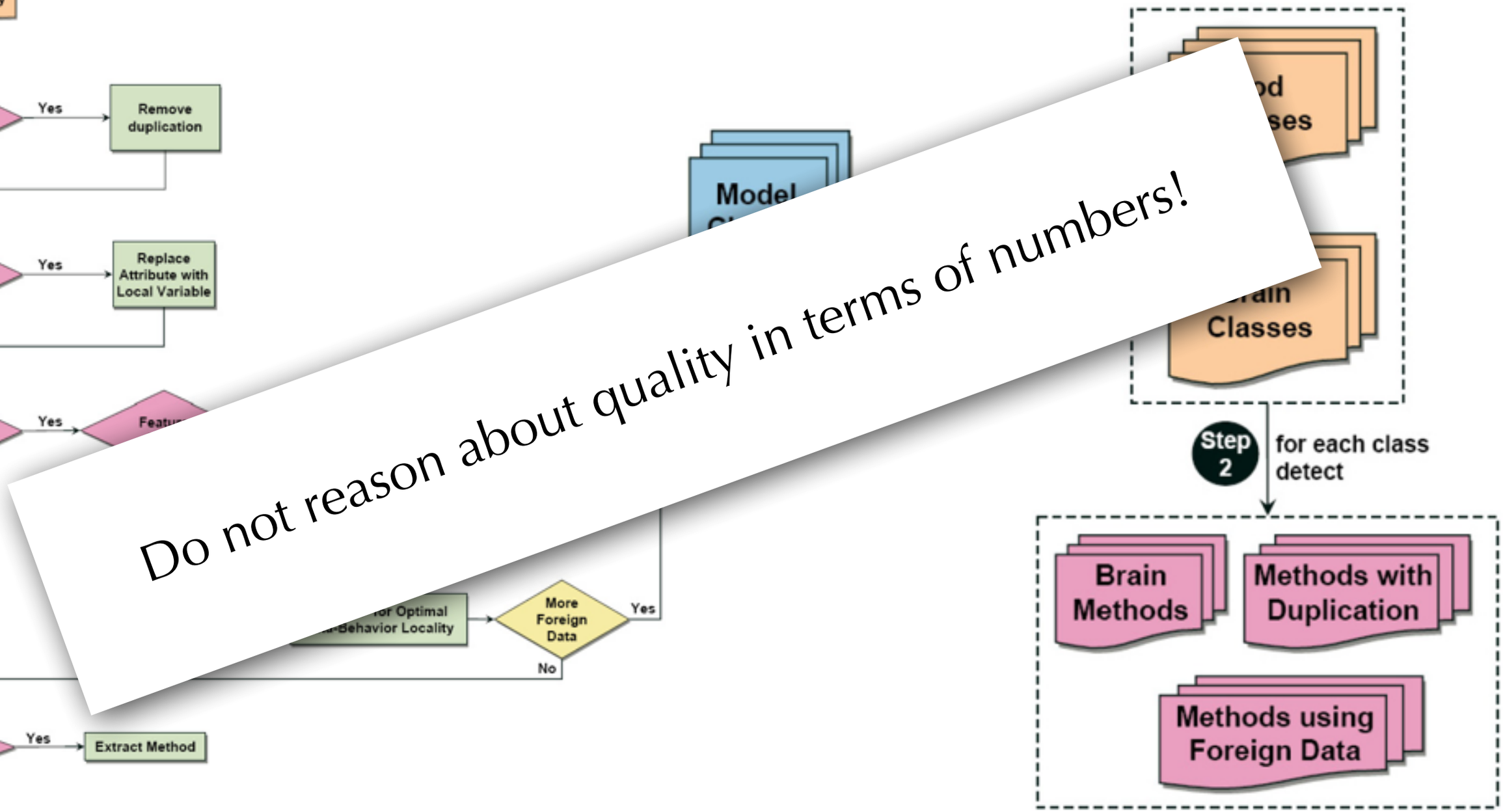
God Class Detection Strategy



And Now?

Follow A Clear and Repeatable Process





Metrics are only half the truth

Can we understand the beauty of a painting by measuring its frame and counting its colors?

Lecture 05

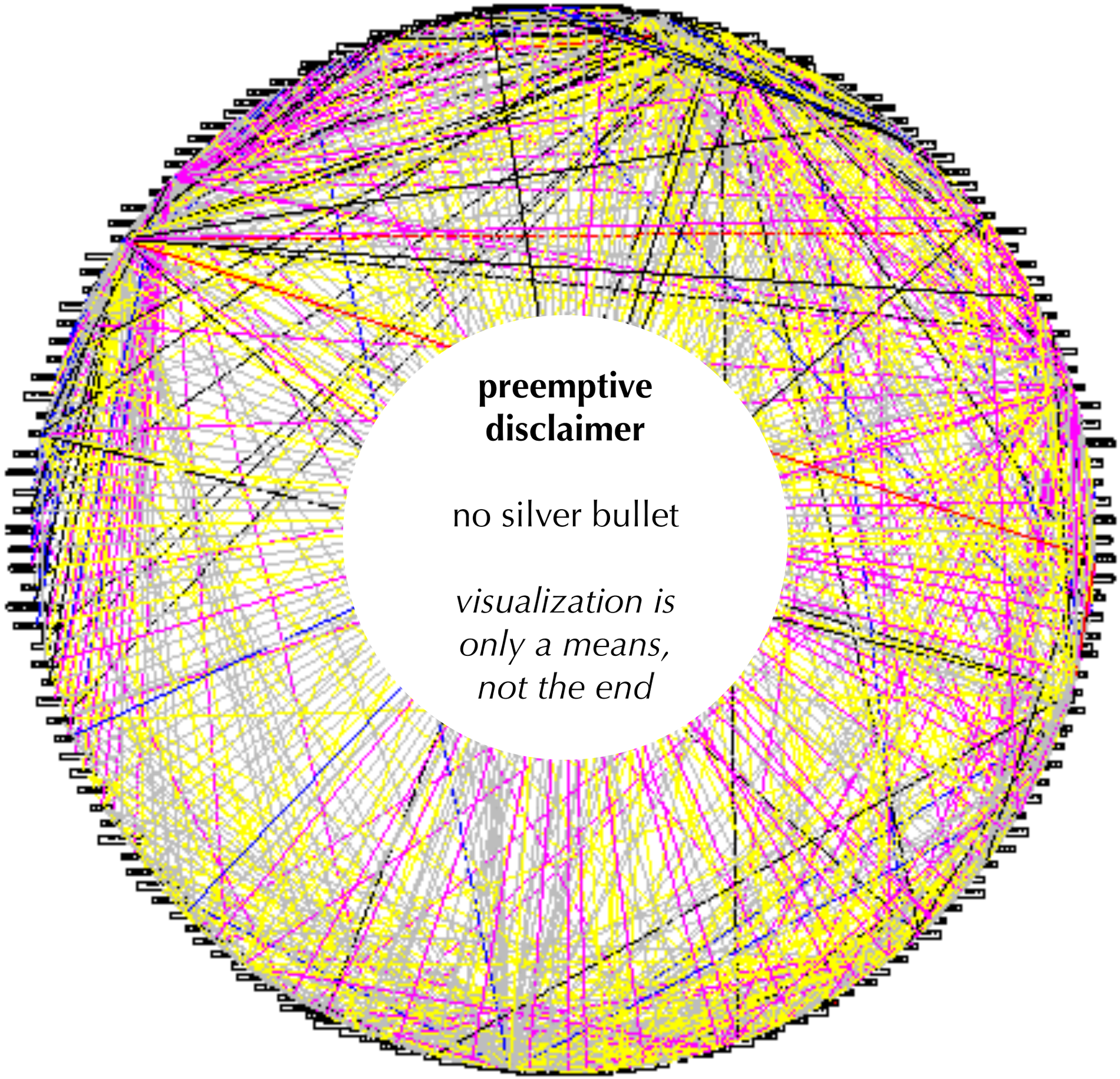
Software Visualization

Source Code = Text

Programming = Writing

```
/***************************************************************************/
/*                              micro-Max,                                 */
/* A chess program smaller than 2KB (of non-blank source), by H.G. Muller  */
/***************************************************************************/
/* version 3.2 (2000 characters) features:                                 */
/* - recursive negamax search                                              */
/* - quiescence search with recaptures                                     */
/* - recapture extensions                                                  */
/* - (internal) iterative deepening                                        */
/* - best-move-first 'sorting'                                             */
/* - a hash table storing score and best move                              */
/* - full FIDE rules (expt minor ptomotion) and move-legality checking     */

#define F(I,S,N) for(I=S;I<N;I++)
#define W(A) while(A)
#define K(A,B) *(int*)(T+A+(B&8)+S*(B&7))
#define J(A) K(y+A,b[y])-K(x+A,u)-K(H+A,t)

#define U 16777224
struct _ {int K,V;char X,Y,D;} A[U];           /* hash table, 16M+8 entries*/

int V=112,M=136,S=128,I=8e4,C=799,Q,N,i;       /* V=0x70=rank mask, M=0x88 */

char O,K,L,
w[]={0,1,1,3,-1,3,5,9},                        /* relative piece values    */
o[]={-16,-15,-17,0,1,16,0,1,16,15,17,0,14,18,31,33,0, /* step-vector lists */
     7,-1,11,6,8,3,6,                          /* 1st dir. in o[] per piece*/
     6,3,5,7,4,5,3,6},                         /* initial piece setup      */
b[129],                                        /* board: half of 16x8+dummy*/
T[1035],                                       /* hash translation table   */

n[]=".?+nkbrq?*?NKBRQ";                        /* piece symbols on printout*/

D(k,q,l,e,J,Z,E,z,n)    /* recursive minimax search, k=moving side, n=depth*/
int k,q,l,e,J,Z,E,z,n;  /* (q,l)=window, e=current eval. score, E=e.p. sqr.*/
{                       /* e=score, z=prev.dest; J,Z=hashkeys; return score*/
 int j,r,m,v,d,h,i=9,F,G;
 char t,p,u,x,y,X,Y,H,B;
 struct _*a=A;
                                              /* lookup pos. in hash table*/
 j=(k*E^J)&U-9;                               /* try 8 consec. locations  */
 W((h=A[++j].K)&&h-Z&&--i);                   /* first empty or match     */
 a+=i?j:0;                                    /* dummy A[0] if miss & full*/
 if(a->K)                                     /* hit: pos. is in hash tab */
 {d=a->D;v=a->V;X=a->X;                       /* examine stored data      */
  if(d>=n)                                    /* if depth sufficient:     */
  {if(v>=l|X&S&&v<=q|X&8)return v;            /* use if window compatible */
   d=n-1;                                     /* or use as iter. start    */
  }X&=~M;Y=a->Y;                              /*      with best-move hint */
  Y=d?Y:0;                                    /* don't try best at d=0    */
 }else d=X=Y=0;                               /* start iter., no best yet */
 N++;                                         /* node count (for timing)  */
 W(d++<n|z==8&N<1e7&d<98)                     /* iterative deepening loop */
 {x=B=X;                                      /* start scan at prev. best */
  Y|=8&Y>>4;                                  /* request try noncastl. 1st*/
  m=d>1?-I:e;                                 /* unconsidered:static eval */
  do{u=b[x];                                  /* scan board looking for   */
   if(u&k)                                    /*  own piece (inefficient!)*/
   {r=p=u&7;                                  /* p = piece type (set r>0) */
    j=o[p+16];                                /* first step vector f.piece*/
    W(r=p>2&r<0?-r:-o[++j])                   /* loop over directions o[] */
    {A:                                       /* resume normal after best */
     y=x;F=G=S;                               /* (x,y)=move, (F,G)=castl.R*/
     do{H=y+=r;                               /* y traverses ray          */
      if(Y&8)H=y=Y&~M;                        /* sneak in prev. best move */
      if(y&M)break;                           /* board edge hit           */
      if(p<3&y==E)H=y^16;                     /* shift capt.sqr. H if e.p.*/
      t=b[H];if(t&k|p<3&!(r&7)!=!t)break;     /* capt. own, bad pawn mode */
      i=99*w[t&7];                            /* value of capt. piece t   */
      if(i<0||E-S&&b[E]&&y-E<2&E-y<2)m=I;     /* K capt. or bad castling  */
      if(m>=l)goto C;                         /* abort on fail high       */
      if(h=d-(y!=z))                          /* remaining depth(-recapt.)*/
      {v=p<6?b[x+8]-b[y+8]:0;                 /* center positional pts.   */
       b[G]=b[H]=b[x]=0;b[y]=u&31;            /* do move, strip virgin-bit*/
       if(!(G&M)){b[F]=k+6;v+=30;}            /* castling: put R & score  */
       if(p<3)                                /* pawns:                   */
       {v-=9*(((x-2)&M||b[x-2]!=u)+           /* structure, undefended    */
              ((x+2)&M||b[x+2]!=u)-1);        /*        squares plus bias */
        if(y+r+1&S){b[y]|=7;i+=C;}            /* promote p to Q, add score*/
       }
       v=-D(24-k,-l-(l>e),m>q?-m:-q,-e-v-i,   /* recursive eval. of reply */
            J+J(0),Z+J(8)+G-S,F,y,h);         /* J,Z: hash keys           */
       v-=v>e;                                /* delayed-gain penalty     */
       if(z==9)                               /* called as move-legality  */
       {if(v!=-I&x==K&y==L)                   /*   checker: if move found */
        {Q=-e-i;O=F;return l;}                /*   & not in check, signal */
        v=m;                                  /* (prevent fail-lows on    */
       }                                      /*   K-capt. replies)       */
       b[G]=k+38;b[F]=b[y]=0;b[x]=u;b[H]=t;   /* undo move,G can be dummy */
       if(Y&8){m=v;Y&=~8;goto A;}             /* best=1st done,redo normal*/
       if(v>m){m=v;X=x;Y=y|S&G;}              /* update max, mark with S  */
      }                                       /*          if non castling */
      t+=p<5;                                 /* fake capt. for nonsliding*/
      if(p<3&6*k+(y&V)==S                     /* pawn on 3rd/6th, or      */
          ||(u&~24)==36&j==7&&                /* virgin K moving sideways,*/
          G&M&&b[G=(x|7)-(r>>1&7)]&32         /* 1st, virgin R in corner G*/
          &&!(b[G^1]|b[G^2])                  /* 2 empty sqrs. next to R  */
      ){F=y;t--;}                             /* unfake capt., enable e.p.*/
      }W(!t);                                 /* if not capt. continue ray*/
     }}}W((x=x+9&~M)-B);                      /* next sqr. of board, wrap */
C:if(m>I/4|m<-I/4)d=99;                       /* mate is indep. of depth  */
  m=m+I?m:-D(24-k,-I,I,0,J,Z,S,S,1)/2;        /* best loses K: (stale)mate*/
  if(!a->K|(a->X&M)!=M|a->D<=d)               /* if new/better type/depth:*/
  {a->K=Z;a->V=m;a->D=d;A->K=0;               /* store in hash,dummy stays*/
   a->X=X|8*(m>q)|S*(m<l);a->Y=Y;             /* empty, type (limit/exact)*/
  }                                           /*    encoded in X S,8 bits */
/*if(z==8)printf("%2d ply, %9d searched, %6d by (%2x,%2x)
\n",d-1,N,m,X,Y&0x77);*/
 }
 if(z&8){K=X;L=Y&~M;}
 return m;
}

main()
{
 int j,k=8,*p,c[9];

 F(i,0,8)
 {b[i]=(b[i+V]=o[i+24]+40)+8;b[i+16]=18;b[i+96]=9;   /* initial board setup*/
  F(j,0,8)b[16*j+i+8]=(i-4)*(i-4)+(j-3.5)*(j-3.5);   /* center-pts table   */
 }                                                   /*(in unused half b[])*/
 F(i,M,1035)T[i]=random()>>9;

 W(1)                                                /* play loop          */
 {F(i,0,121)printf(" %c",i&8&&(i+=7)?10:n[b[i]&15]); /* print board        */
  p=c;W((*p++=getchar())>10);                        /* read input line    */
  N=0;
  if(*c-10){K=c[0]-16*c[1]+C;L=c[2]-16*c[3]+C;}else  /* parse entered move */
   D(k,-I,I,Q,1,1,O,8,0);                            /* or think up one    */
  F(i,0,U)A[i].K=0;                                  /* clear hash table   */
  if(D(k,-I,I,Q,1,1,O,9,2)==I)k^=24;                 /* check legality & do*/
 }
}
```

Software... Visualization?



preemptive disclaimer

no silver bullet

visualization is only a means, not the end

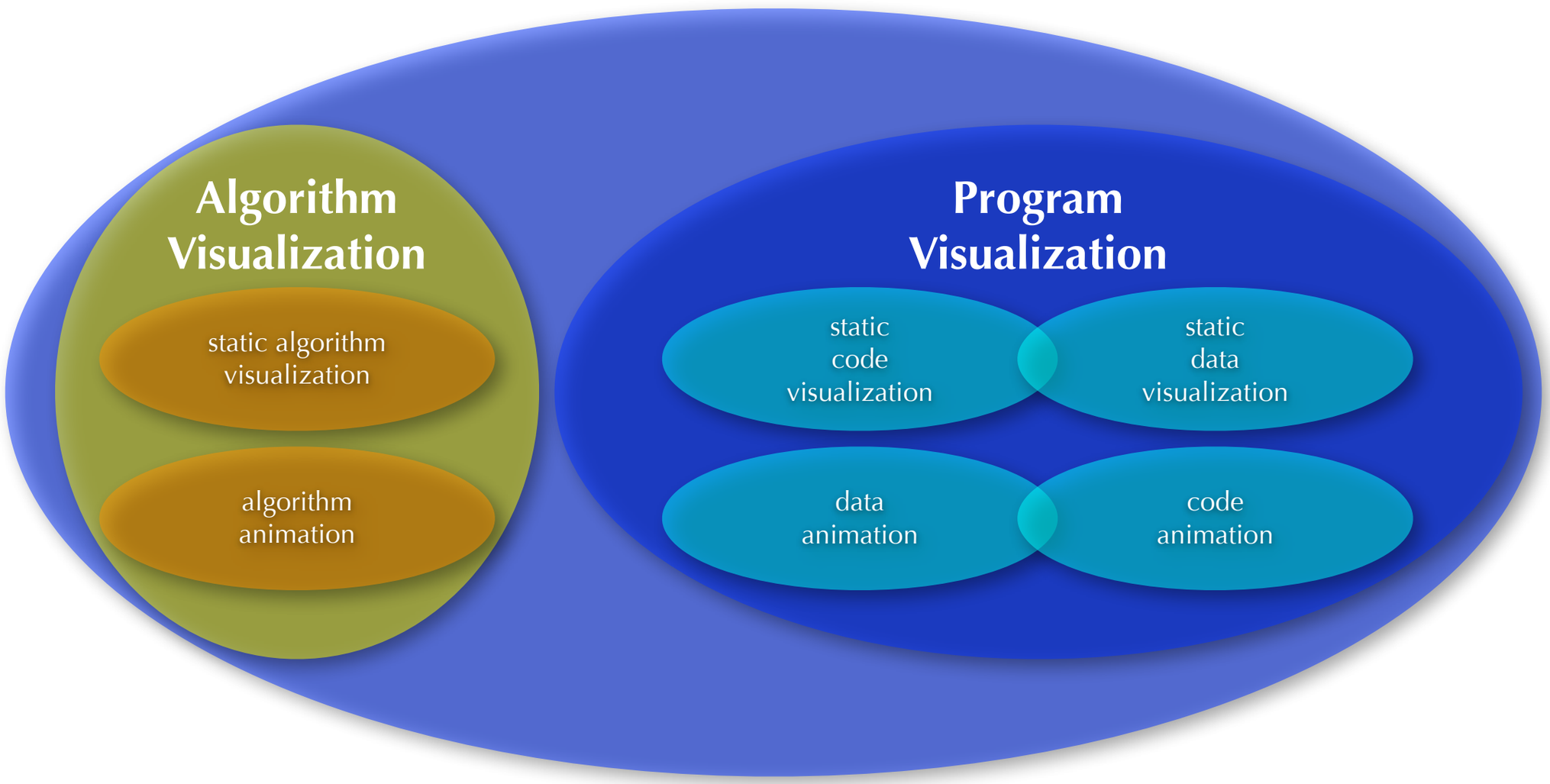
```
#include                                        <math.h>
#include                                      <sys/time.h>
#include                                       <X11/Xlib.h>
#include                                      <X11/keysym.h>
                                               double L ,o ,P
                                              ,_=dt,T,Z,D=1,d,
                                              s[999],E,h= 8,I,
                                              J,K,w[999],M,m,O
                                             ,n[999],j=33e-3,i=
                                             1E3,r,t, u,v ,W,S=
                                             74.5,l=221,X=7.26,
                                             a,B,A=32.2,c, F,H;
                                             int N,q, C, y,p,U;
                                            Window z; char f[52]
                                          ; GC k; main(){ Display*e=
 XOpenDisplay( 0); z=RootWindow(e,0); for (XSetForeground(e,k=XCreateGC                                  ,0))
; scanf("%lf%lf%lf",y +n,w+y, y+s)+1; y ++); XSelectInput(e,z= XCre                                      400,
0,0,WhitePixel(e,0) ),KeyPressMask); for(XMapWindow(e,z); ; T=                                            1e6}
; K= cos(j); N=1e4; M+= H*_; Z=D*K; F+=_*P; r=E*K; W=cos( O                                                B=
sin(j); a=B*T*D-E*W; XClearWindow(e,z); t=T*E+ D*B*W;                                                      W+Z
*T*B,E*d/K *B+v+B/K*F*D)*_; p<y; ){ T=p[s]+i; E=c-                                                         [s
]== 0|K <fabs(W=T*r-I*E +D*P) |fabs(D=t *D+Z *                                                            e2/ K
 *D; N-1E4&& XDrawLine(e ,z,k,N ,U,q,C); N=                                                               *1+M *M;
  XDrawString(e,z,k ,20,380,f,17); D=w                                                                  u *=CS!=N){
```

not software visualization

```
                                                  /1;
                                                 1,1*H
                                                M+a*X)*_; H
                                               =A*r+v*X-F*1+(
                                               E=.1+X*4.9/1,t
                                               =T*m/32-I*T/24
                                                )/S; K=F*M+(
                                                h* 1e4/1-(T+
                                                E*5*T*E)/3e2
                                                )/S-X*d-B*A;
                                                a=2.63 /1*d;
                                                X+=( d*1-T/S
                                                 *(.19*E +a
                                                 *.64+J/1e3
                                                 )-M* v +A*
                                                 Z)*_; l +=
                                                 K *_; W=d;
                                                 sprintf(f,
                                                 "%5d  %3d"
                                                 "%7d",p =1
                                                /1.7,(C=9E3+
                                O*57.3)%0550,(int)i); d+=T*(.45-14/1*
                               X-a*130-J* .14)*_/125e2+F*_*v; P=(T*(47
                               *I-m* 52+E*94 *D-t*.38+u*.21*E) /1e2+W*
                               179*v)/2312; select(p=0,0,0,0,&G); v-=(
                                W*F-T*(.63*m-I*.086+m*E*19-D*25-.11*u
                                 )/107e2)*_; D=cos(o); E=sin(o); } }
```

Software Visualization

- Program Visualization: “The visualization of the actual program code or data structures in static or dynamic form”
- Algorithm Visualization: “The visualization of the higher-level abstractions which describe software”



Software Visualization in Context

- There are many good-looking visualizations, but...
- When it comes to maintenance & evolution, there are several issues:
  - Scalability
  - Information Retrieval
  - What to visualize
  - How to visualize
  - Limited time
  - Limited resources

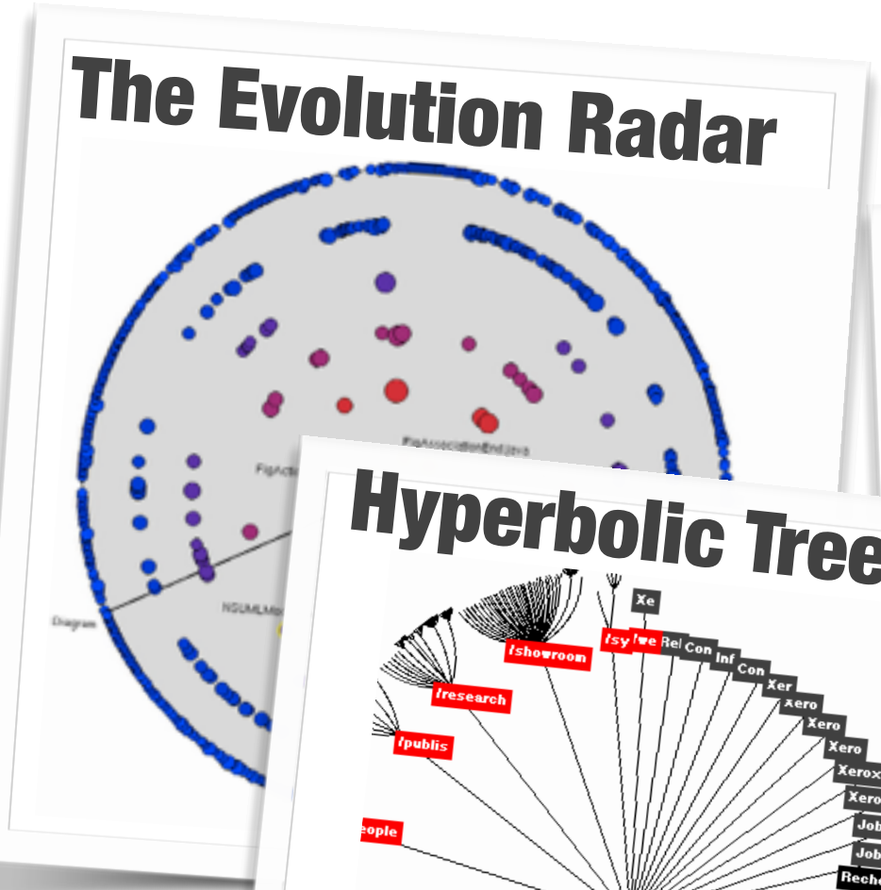
Program Visualization

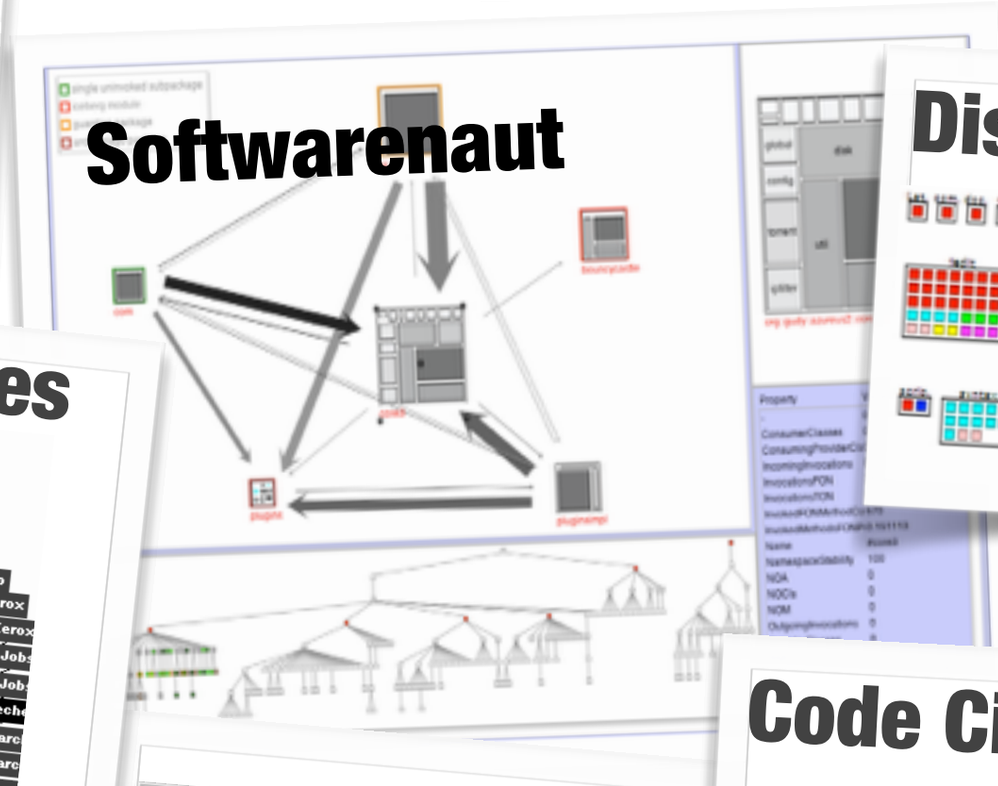
- "The visualization of the actual program code or data structures in either static or dynamic form"
- Overall goal: generate views of a system to understand it
- Surprisingly complex problem domain/research area
  - Visual Aspects: Efficient use of space, overplotting problems, layout issues, HCI issues, GUI issues, lack of conventions (colors, shapes, etc.)
  - Software Aspects
    - Granularity (complete systems, subsystems, modules, classes, etc.)
    - When to apply (first contact, known/unknown parts, forward engineering?)
    - Methodology

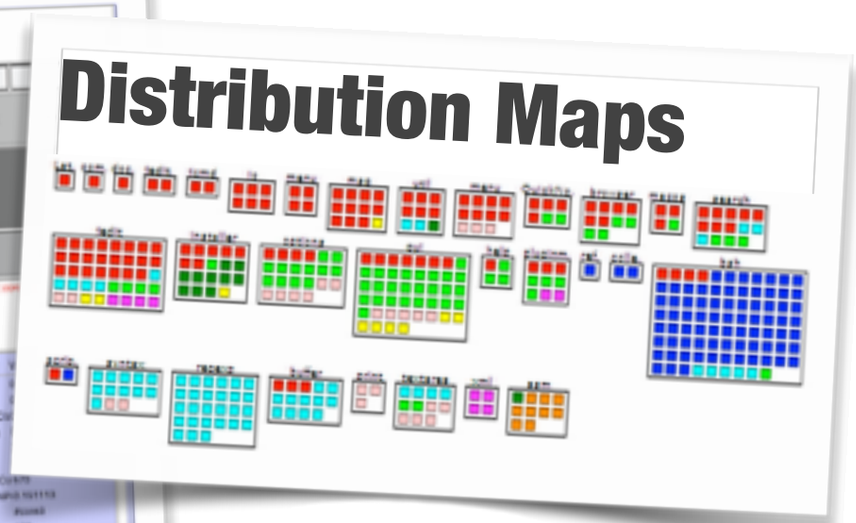
Static Code Visualization

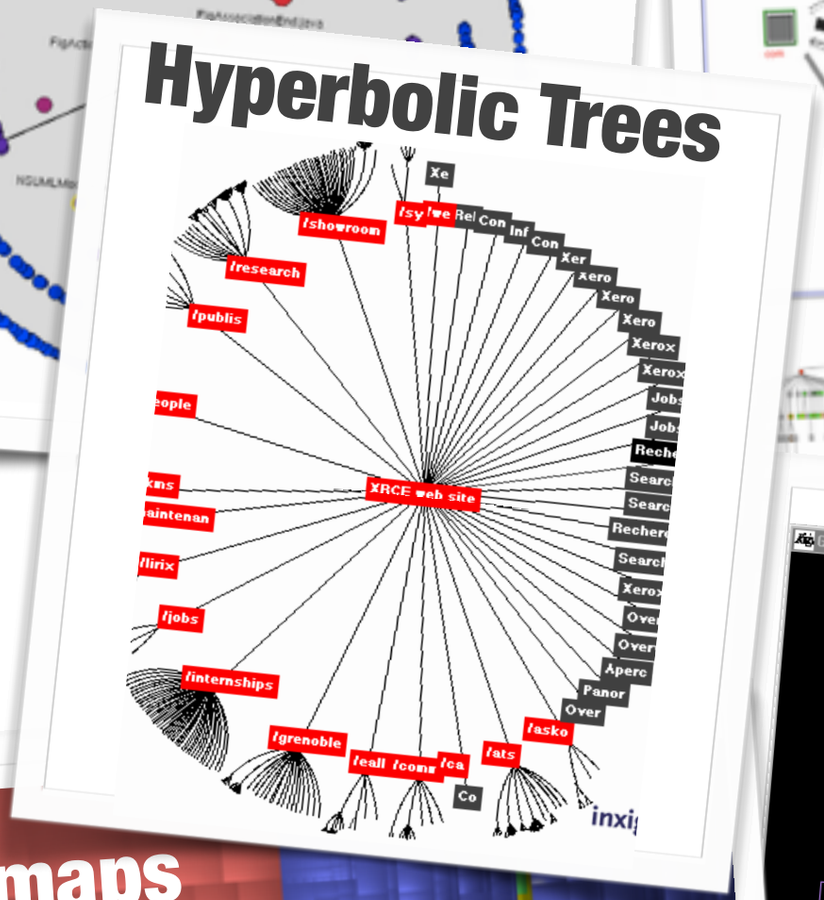
- The visualization of information that can be extracted from a system at “compile-time”
- Directly influenced by programming languages and their paradigms
  - Object-Oriented: classes, methods, attributes, inheritance, ...
  - Procedural: procedures, invocations, imports, ...
  - Functional: functions, function calls, ...

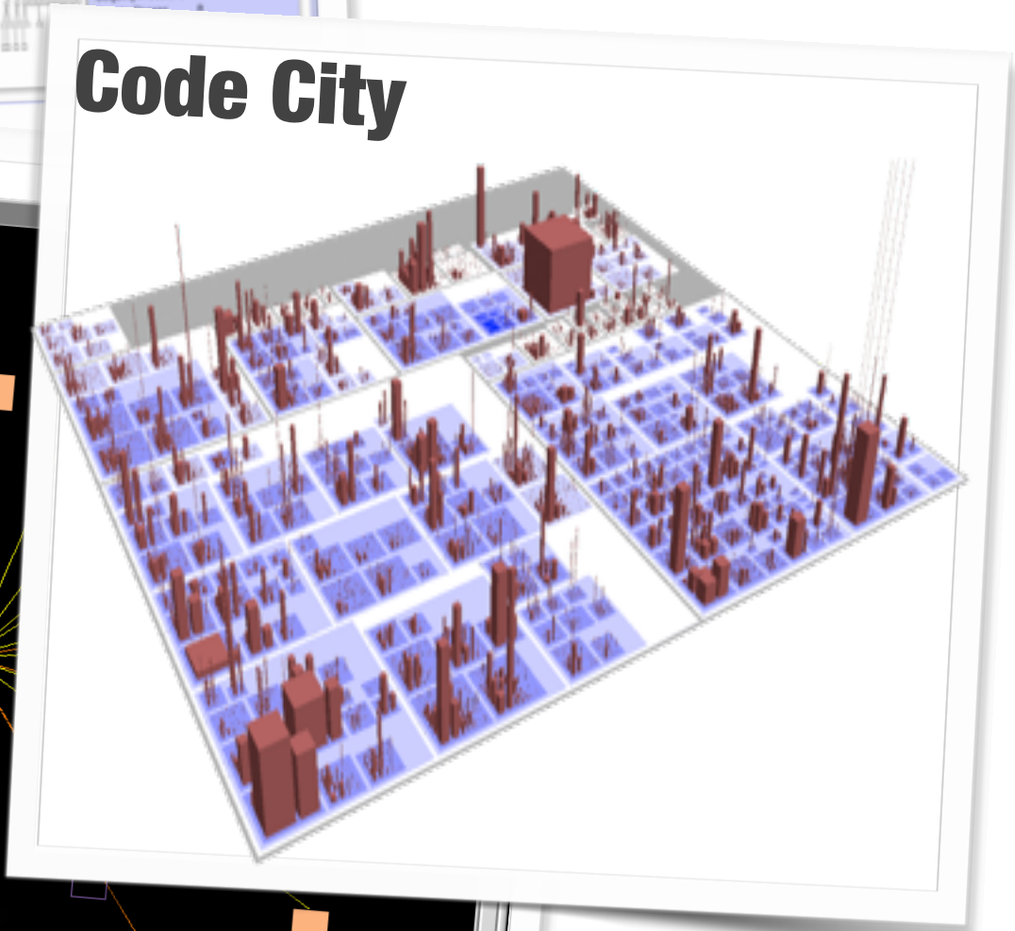
Examples

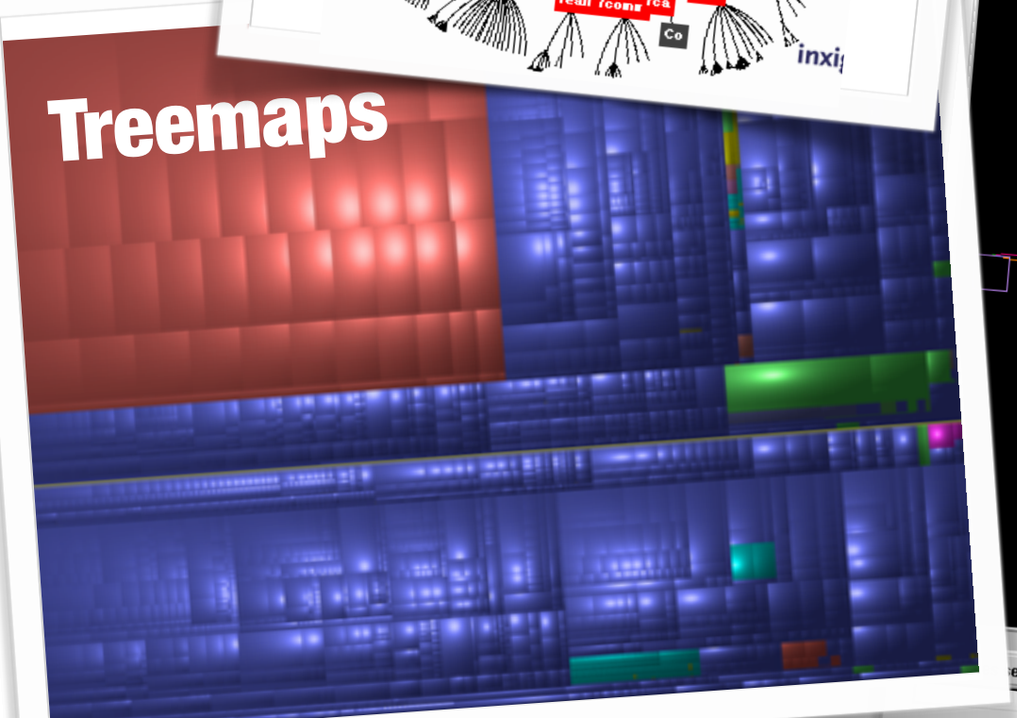

The Evolution Radar

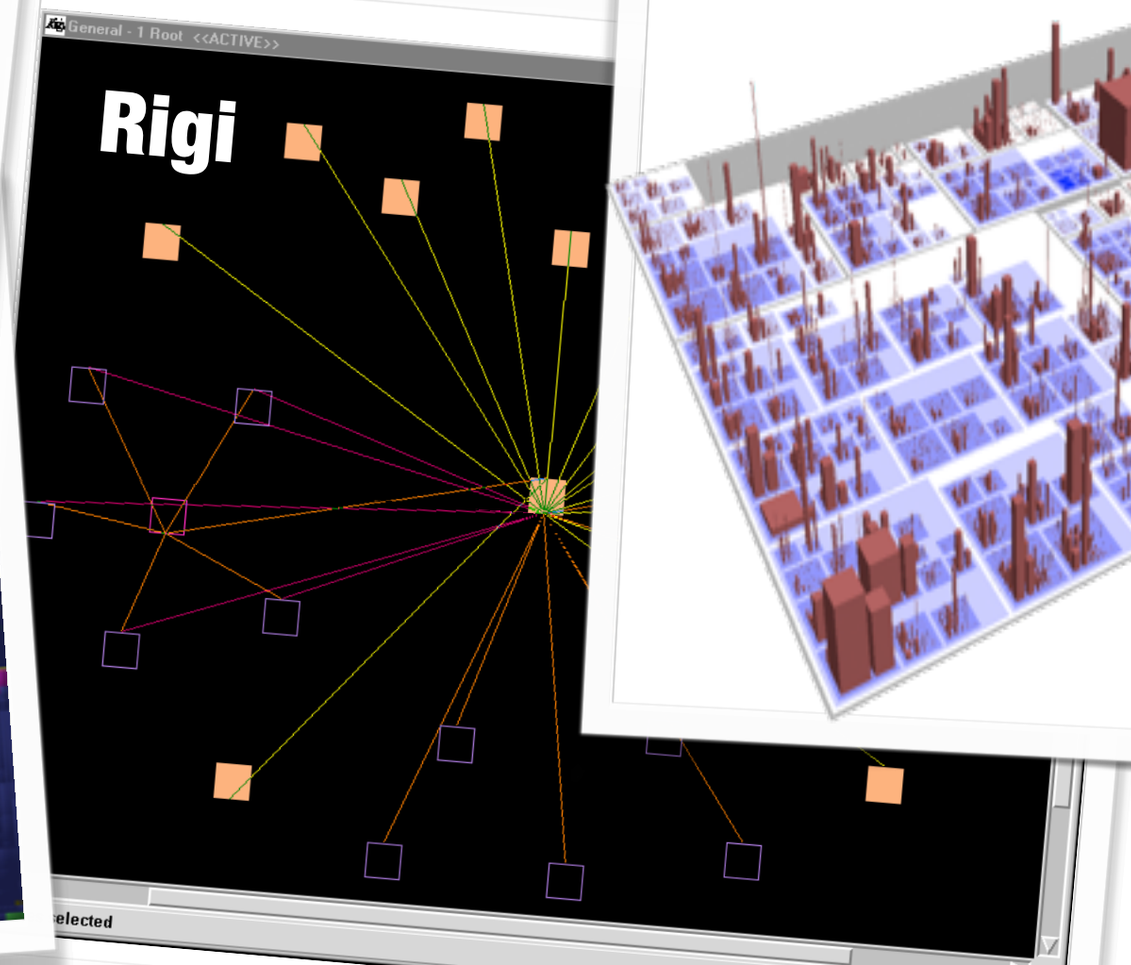

Softwarenaut


Distribution Maps

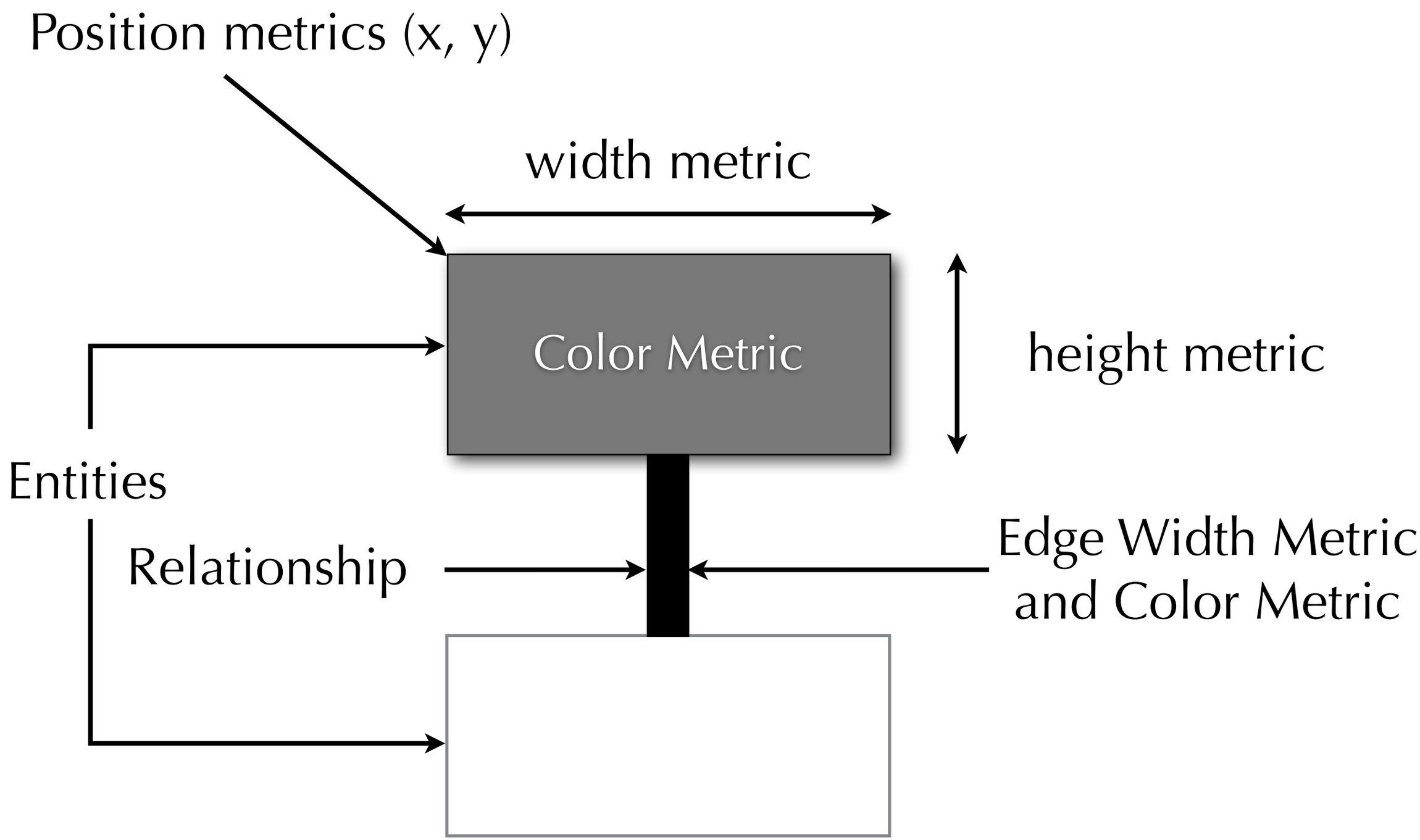

Hyperbolic Trees
XRCE web site


Code City

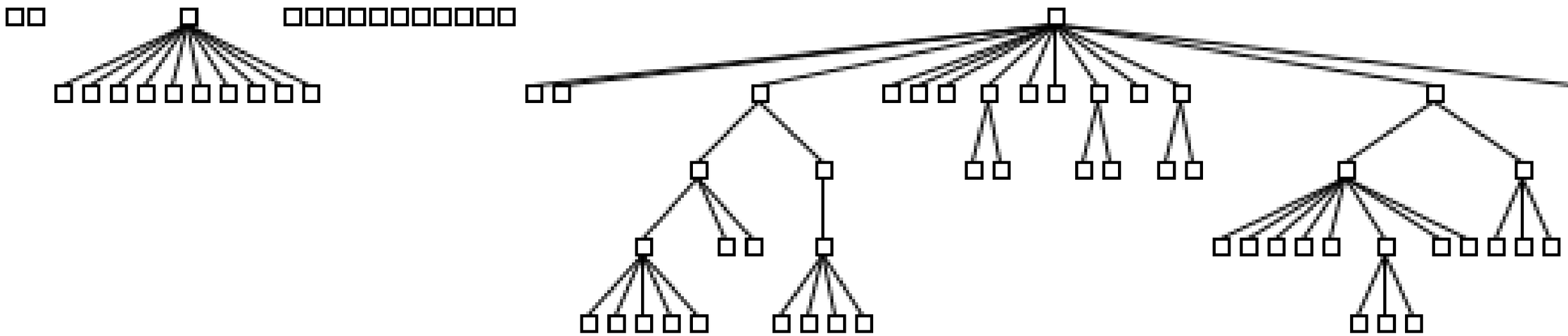

Treemaps


Rigi
General - 1 Root <<ACTIVE>>

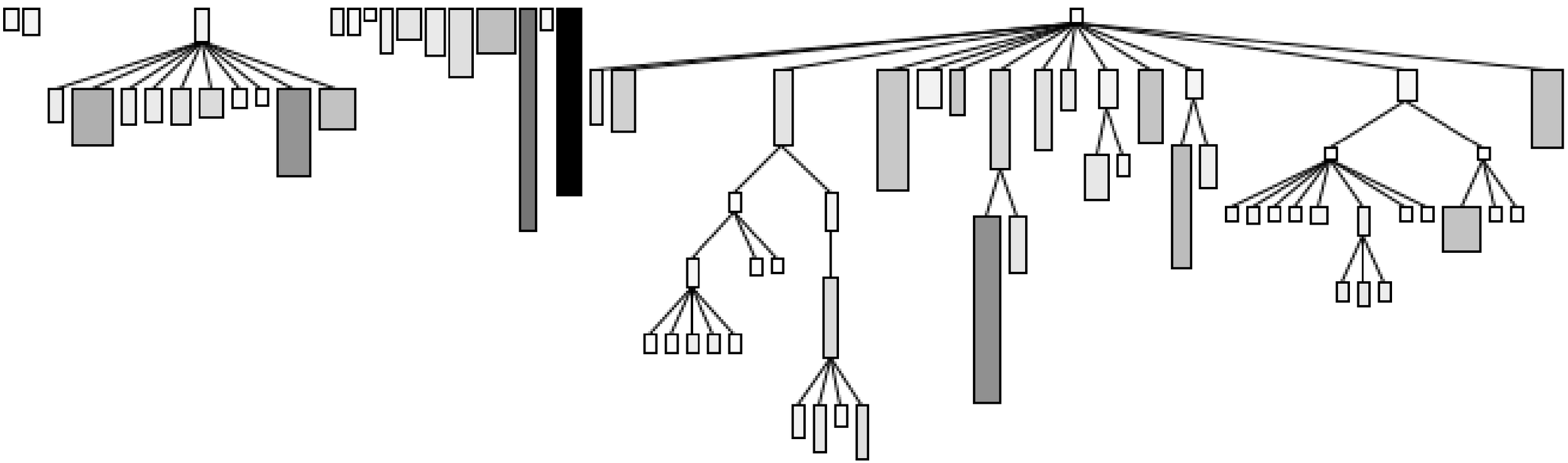
The Polymetric View Principle

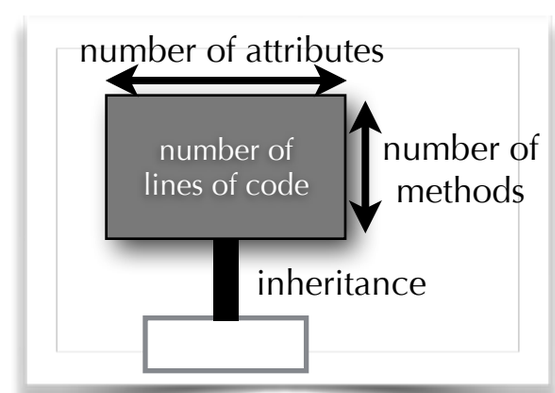


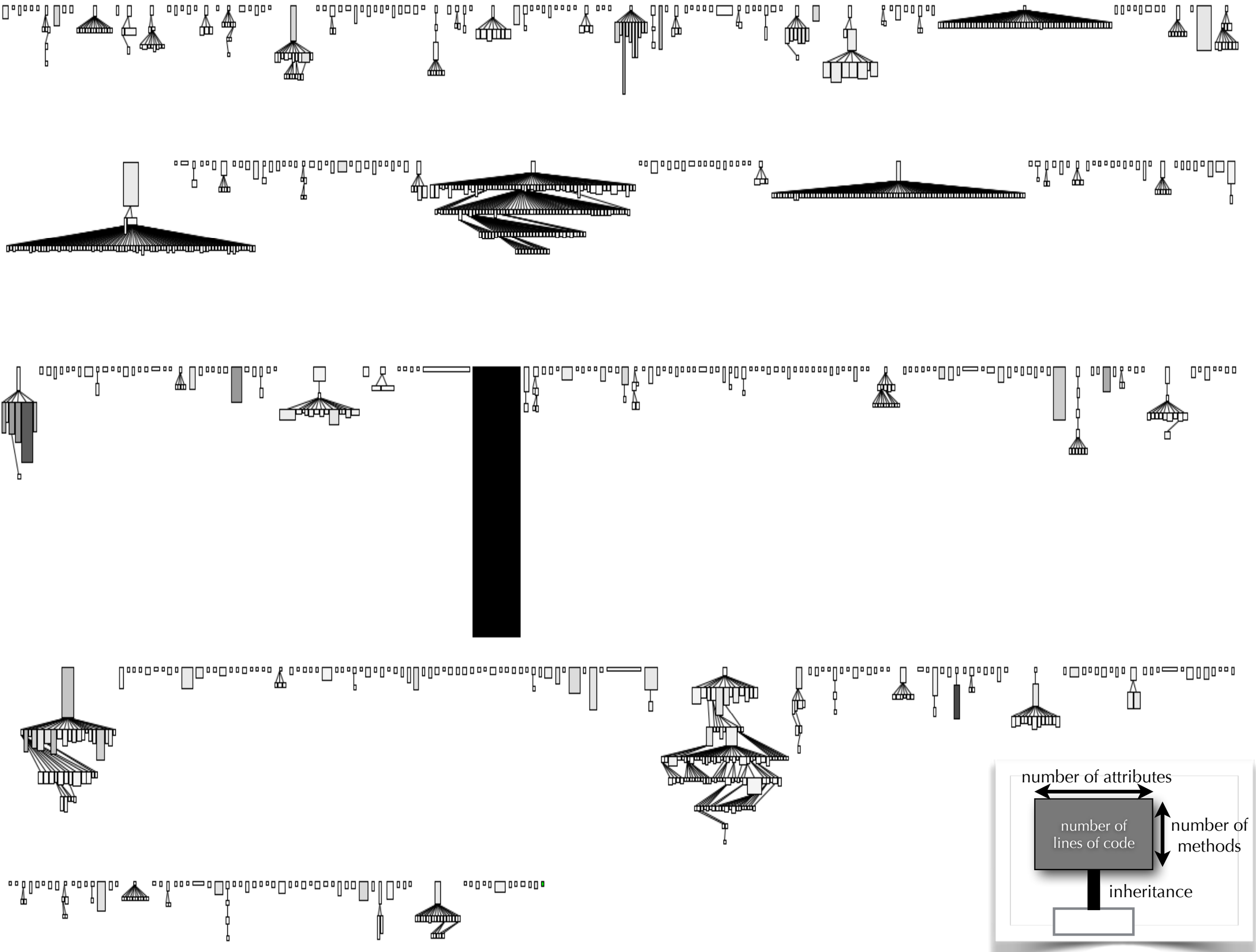
Class Hierarchy



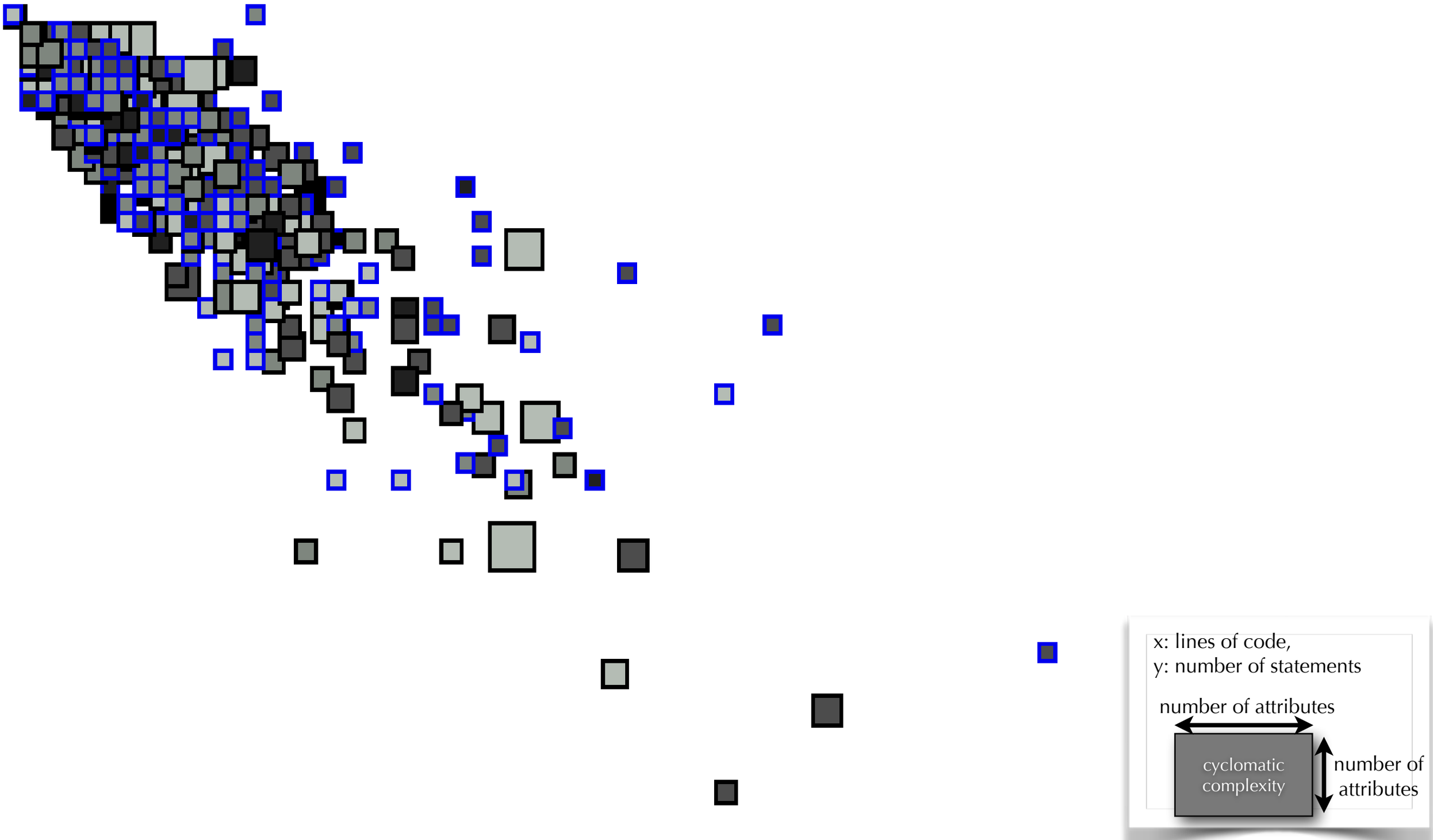
System Complexity View



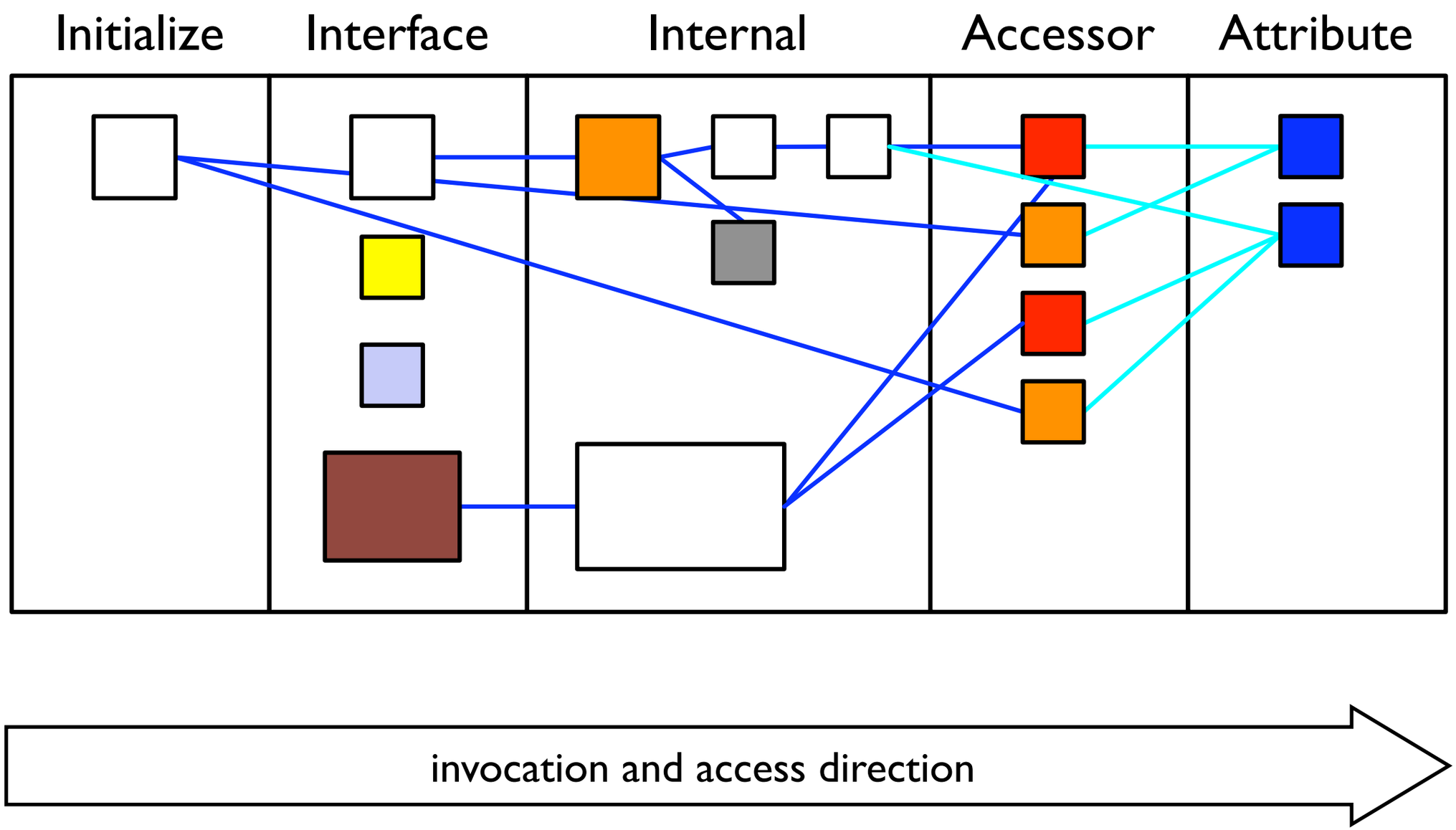



number of attributes
number of lines of code
number of methods
inheritance

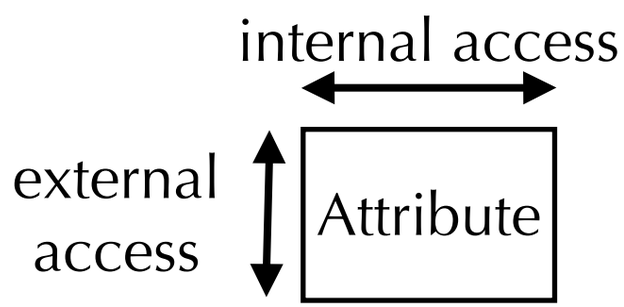
Method Structure Correlation View

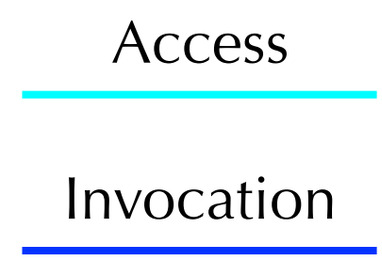


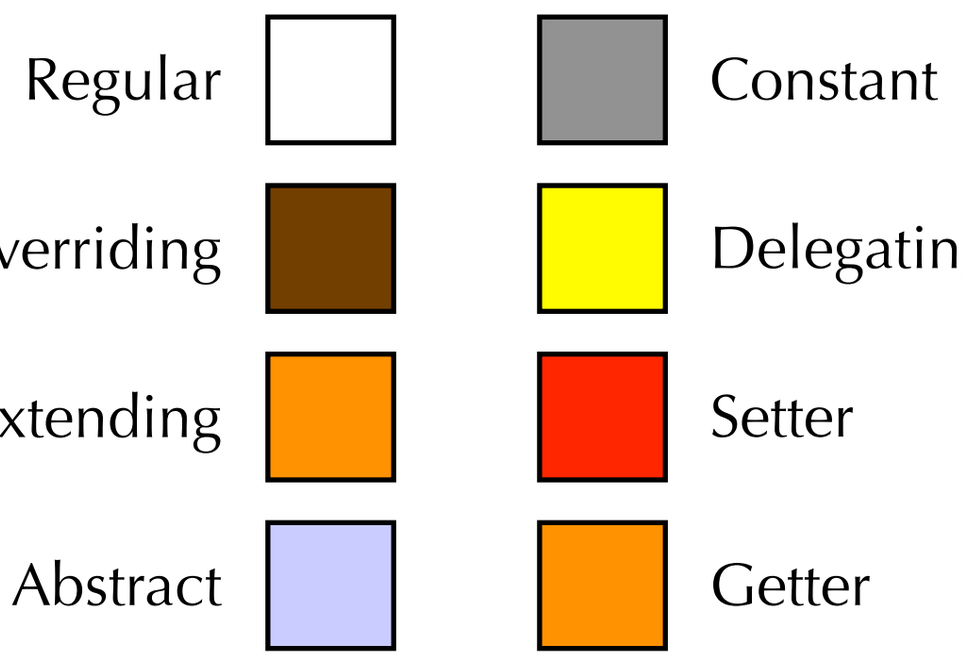
Increasing Information Granularity: The Class Blueprint

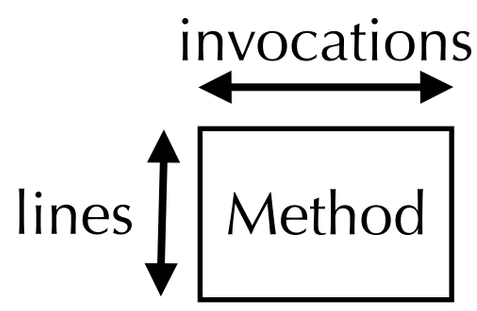


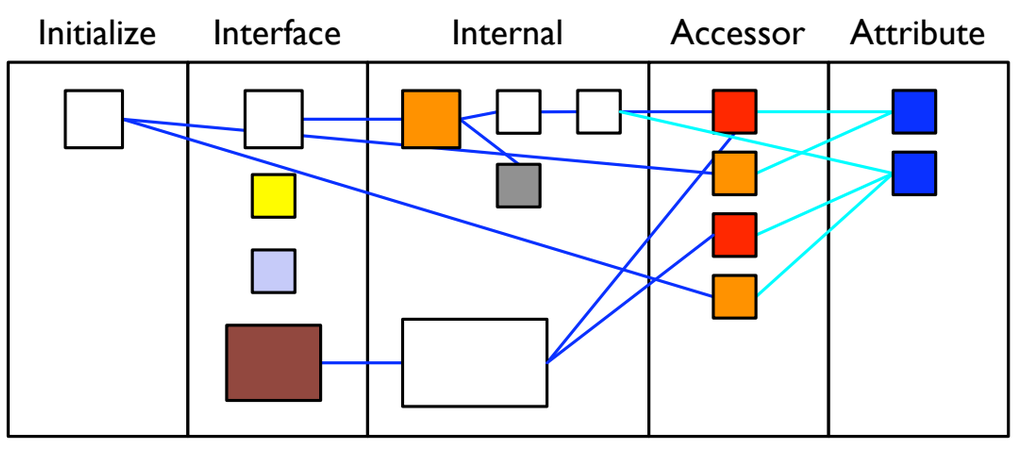
Detailing Class Blueprints



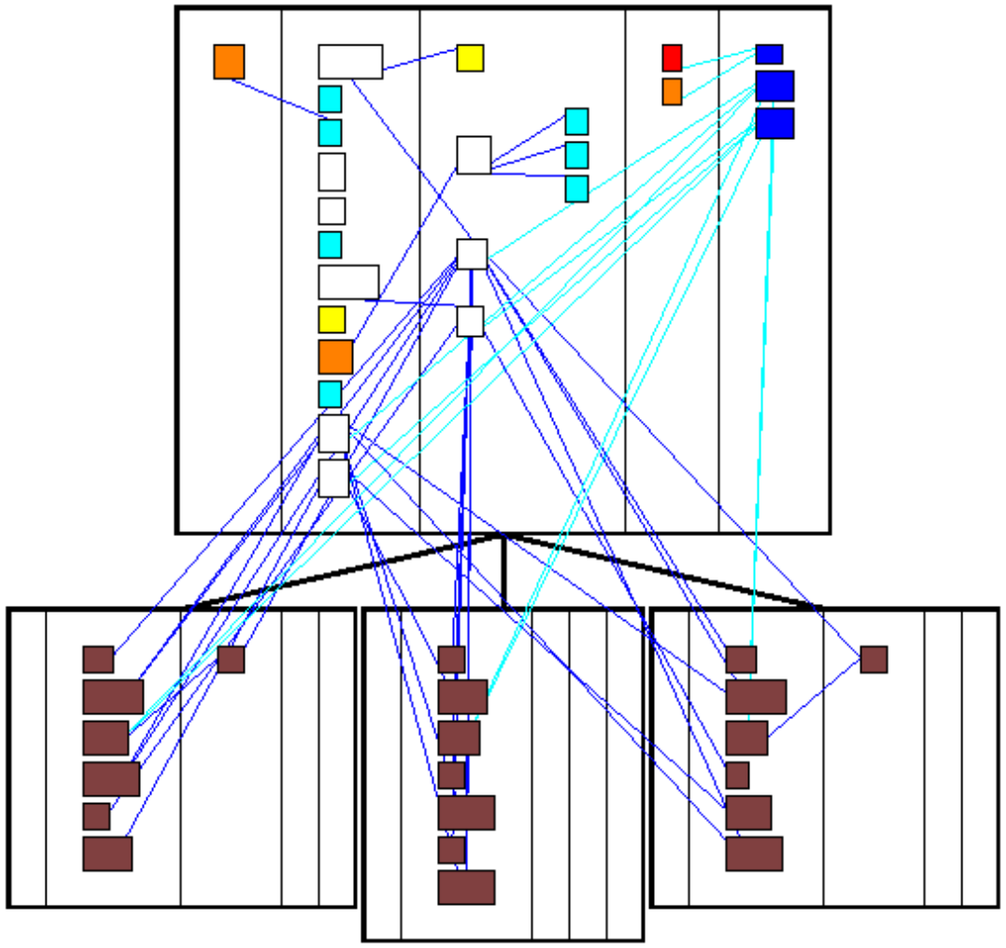


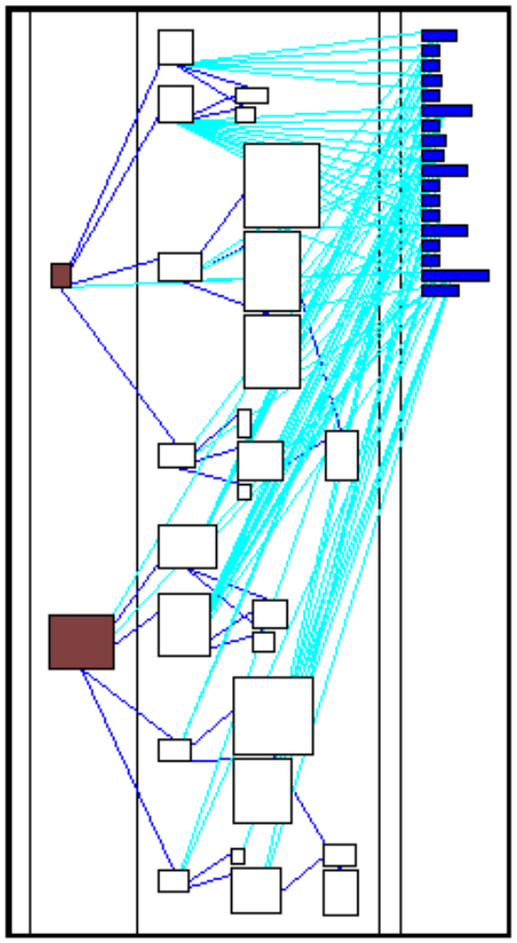






A Pattern Language based on Class Blueprints





Reflections on Static Visualization

- Pros
  - Intuitive
  - Aesthetically pleasing
- Cons
  - Several approaches are orthogonal to each other
  - No conventions
  - Too easy to produce meaningless results
  - Scaling up is possible at the expense of semantics
- Orthogonally
  - Without programming knowledge it's only colored boxes and arrows..

References

- M. Lanza, R. Marinescu, *Object-Oriented Metrics in Practice*, Springer, 2006.
- M. Lanza, *Object-Oriented Reverse Engineering - Coarse-grained, Fine-grained, and Evolutionary Software Visualization*, Ph.D. Thesis, University of Berne, Switzerland, 2003.
  http://www.inf.usi.ch/faculty/lanza/Downloads/Lanz03b.pdf