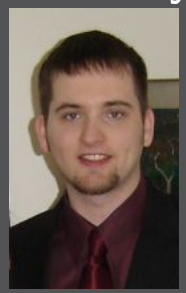
An Exploratory Study of the Design Impact of Language Features for Aspect-oriented Interfaces

Robert Dyer



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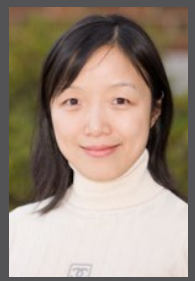
Yuanfang Cai



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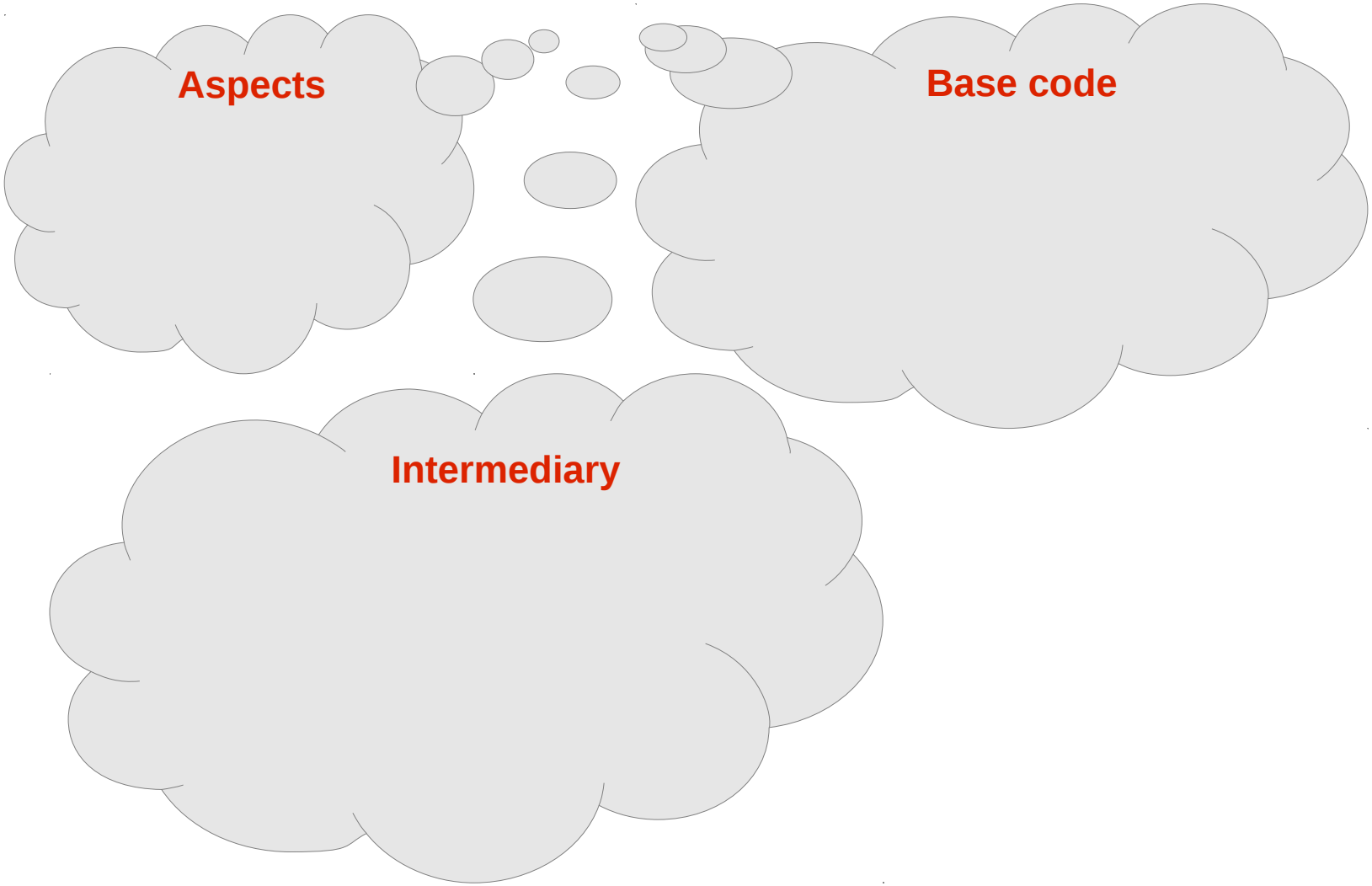
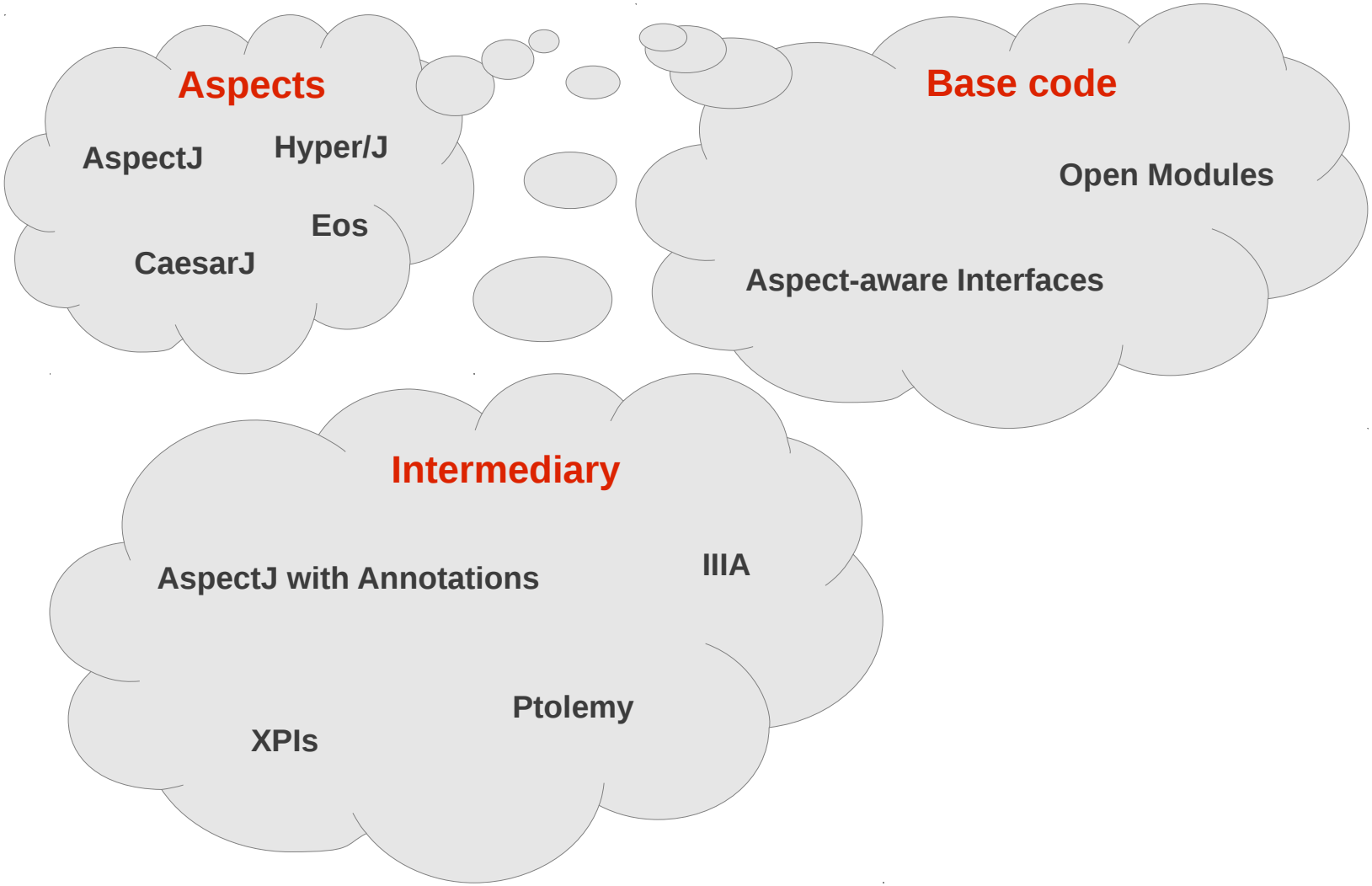
- Motivation: What issues affect AO interfaces?
- Approach: Case study...
  - AO Interfaces: pattern-based pointcuts (PCD), annotation-based pointcuts (@PCD), open modules (OM), and event types (EVT)
  - Systems: MobileMedia (MM) and Health Watcher (HW)
  - Measure: SE metrics (coupling, cohesion, size) and change propagation analysis
- Interesting Results
  - Quantification problems - all interfaces
  - Fragile pointcuts - only PCD
  - Non-uniform context access - all but EVT

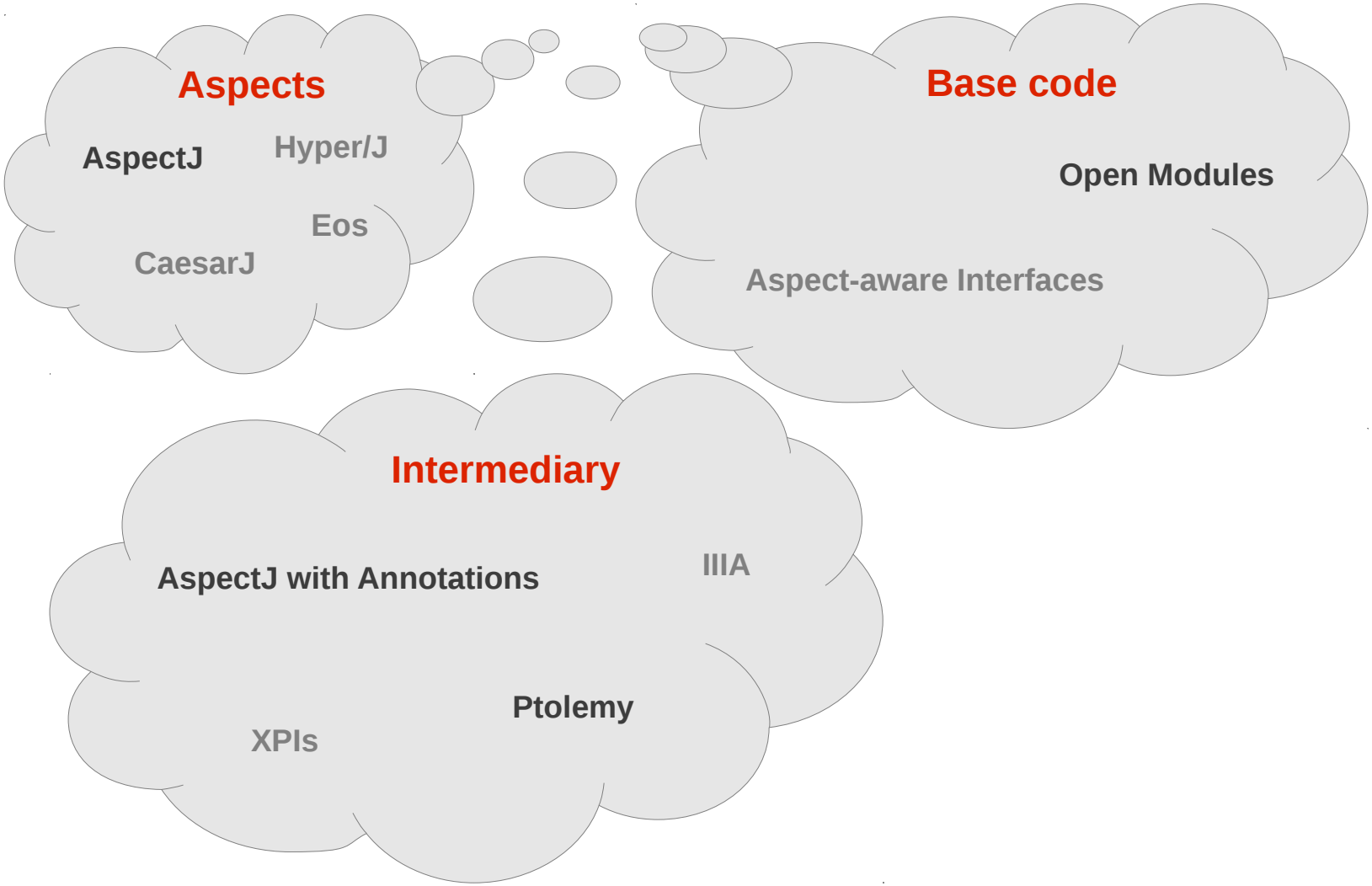
Who controls quantification?



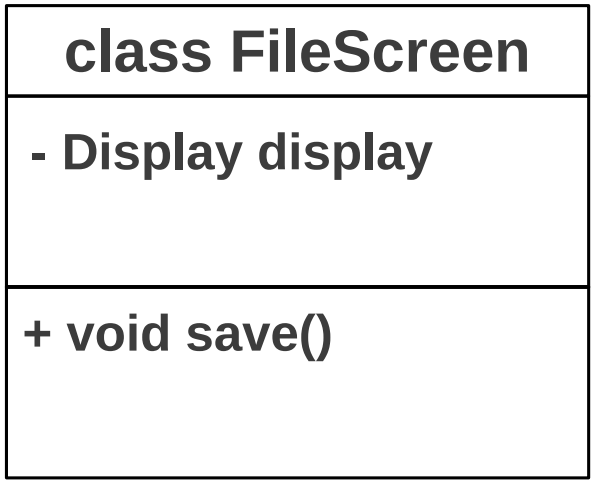
Who controls quantification?



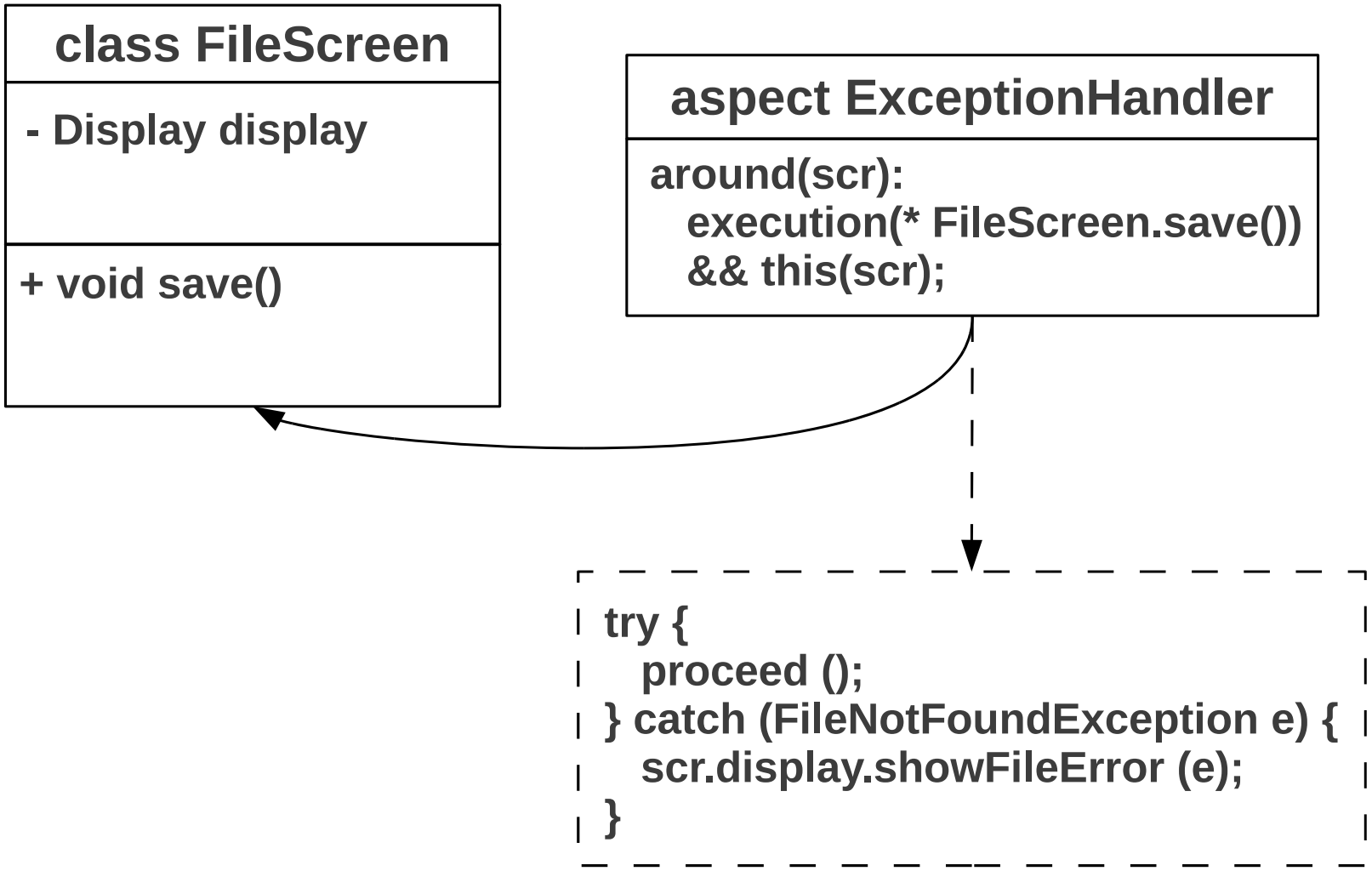
Who controls quantification?



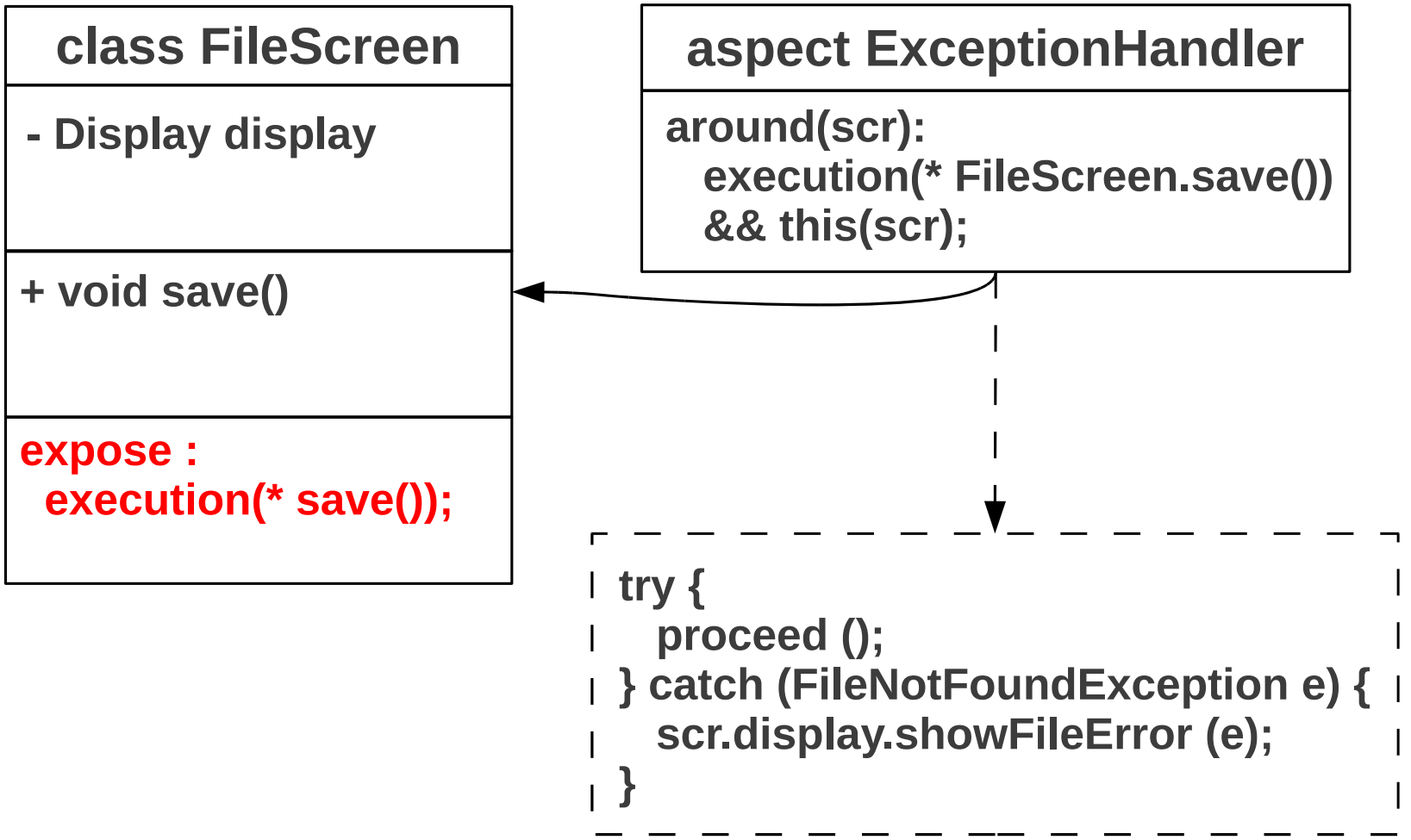
Running Example



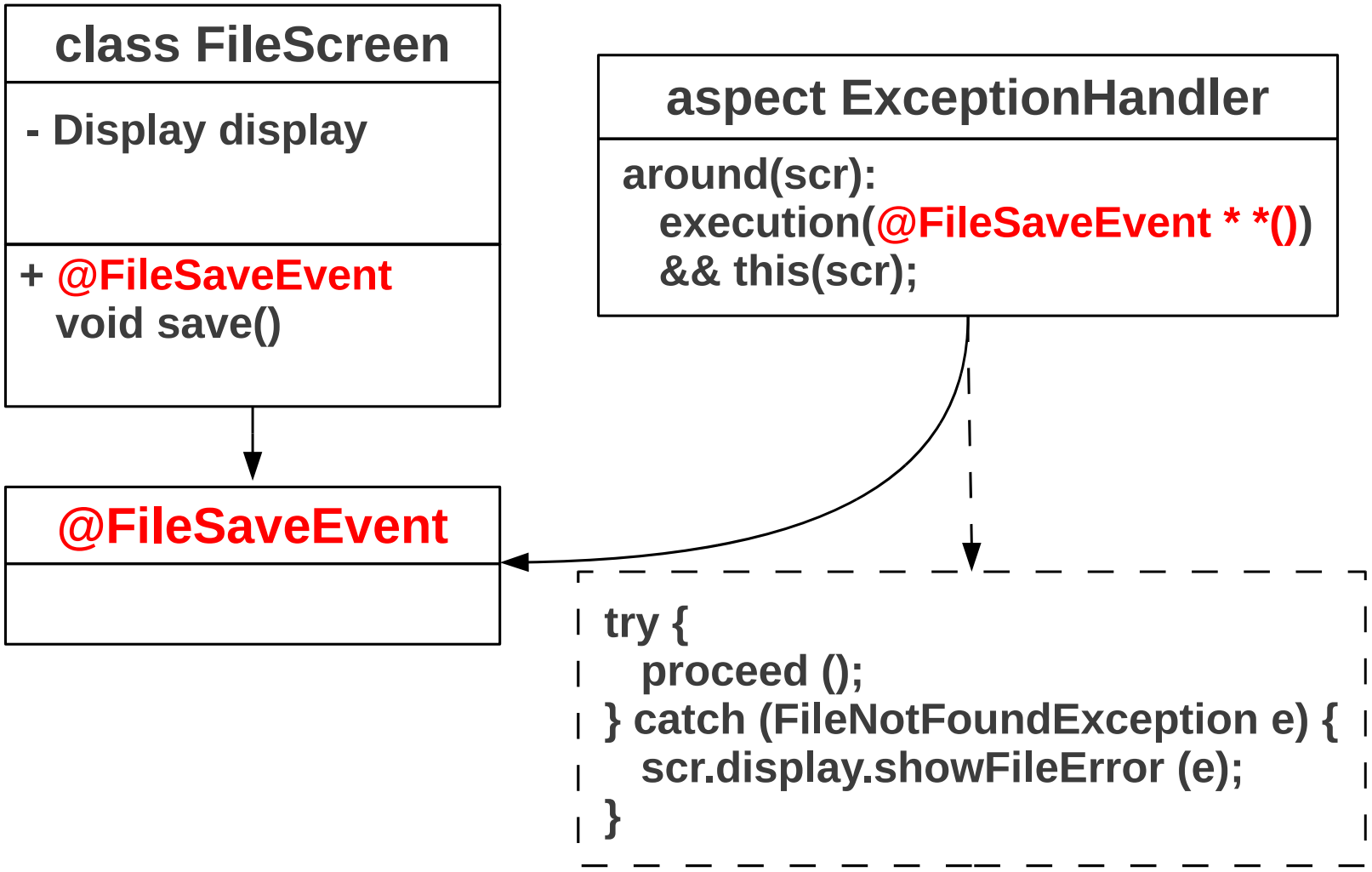
Pattern-based pointcuts (PCD)



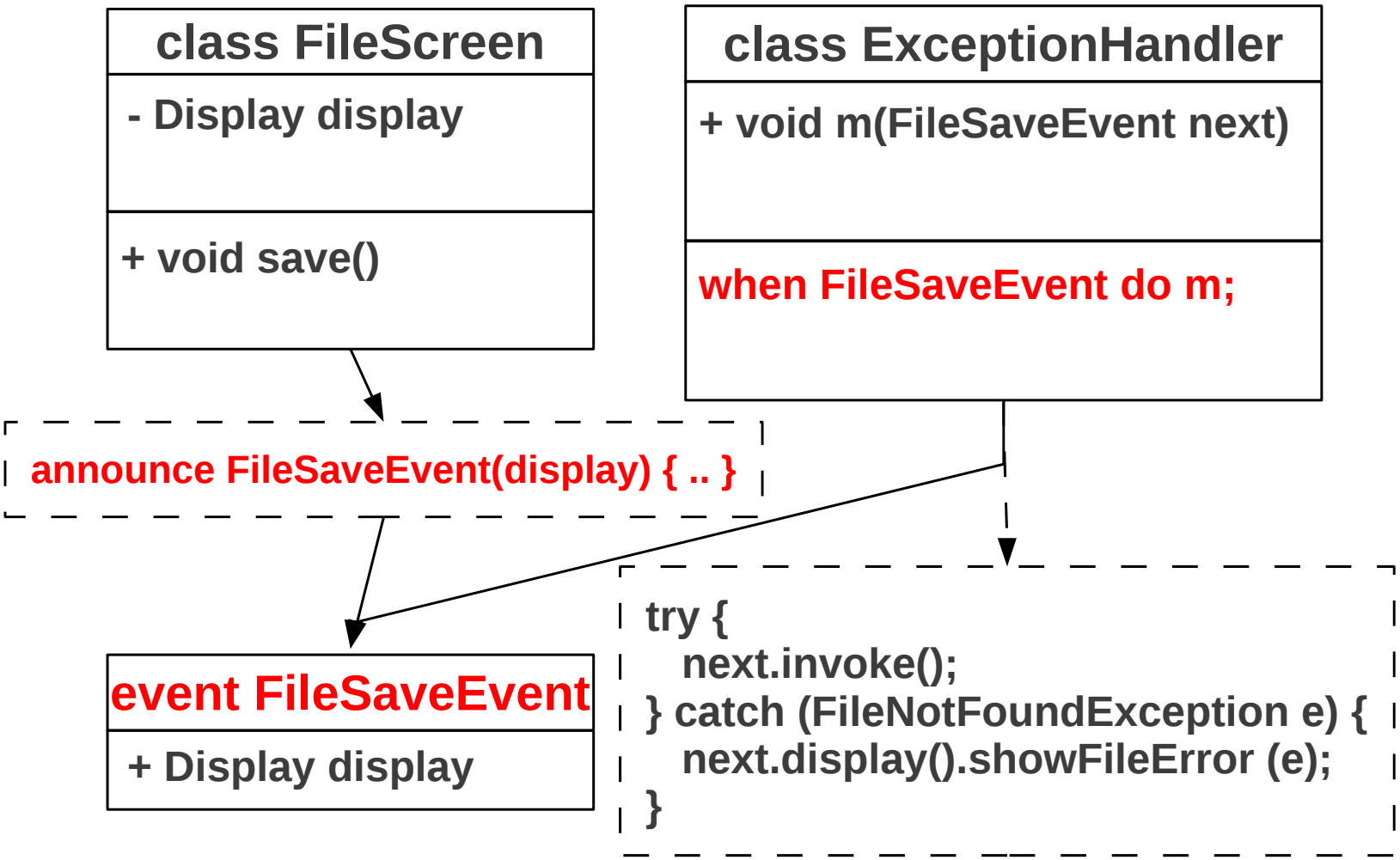
Open Modules (OM)



Annotation-based pointcuts (@PCD)



Quantified, Typed Events (EVT)



- Pattern-based pointcuts (PCD)
  - `execution (* save())`
- Annotation-based pointcuts (@PCD)
  - `execution (@FileSaveEvent * *())`
- Open Modules (OM)
  - `expose: execution(* save())`
- Quantified, Typed Events (EVT)
  - `when FileSaveEvent do handler;`

- How do these AO interfaces compare to each other?
- What problems occur, and for which interface(s)?

Need: explore via case studies!

Earlier Studies

- Kiczales and Mezini [*ECOOP 2005*]
  - Studied 7 AO interfaces
  - Only compared with a very simple example
- Figueiredo et al [*ICSE 2008*]
  - Studied MobileMedia, OO vs PCD
- Hoffman and Eugster [*ICSE 2008*]
  - Exception handling with AO
  - Studied only 2 AO interfaces
  - Only 1 type of crosscutting behavior

Our Study

- MobileMedia [*FIGUEIREDO 2008*]
  - Software to manipulate photos, music, video on mobile devices
- Health Watcher [*SOARES 2002*] [*KULESZA 2006*]
  - Web application for users to file health complaints

	OO	*PCD*	*@PCD*	*OM*	*EVT*
MM	Existing	Existing	**New**[1]	**New**[2]	**New**
HW	Existing	Existing	**New**[1]	**New**[2]	**New**

Total size of study: 400k LOC

[1] Based on recommendations of Kiczales and Mezini, ECOOP 2005

[2] Based on recommendations of Ongkingco *et al.*, AOSD 2006

Software Engineering Metrics

- Coupling
  - method call or field access
  - naming an event type
  - naming an annotation
- Cohesion
- Number of: lines, components, attributes, and operations

Change Propagation

- Detects: Adds, Removes, and Changes in
  - Classes, Aspects, Pointcuts, Event Types, and Annotations

What were some interesting results?

	PCD	@PCD	OM	EVT
Quantificaton Failure	?	?	?	?
Less Expressive Quantificaton	?	?	?	?
Fragile Pointcuts	?	?	?	?
Non-uniform Context	?	?	?	?

Quantification Failure

What if we want to advise the for loop?

```
void m() {
  ..
  for (int i = 0 ..) { .. }
  ..
}
```

Not possible in PCD, @PCD, or OM. **Must extract as method.**

Quantification Failure

	PCD	@PCD	OM	EVT
Quantificaton Failure	*yes*	*yes*	*yes*	**no**
Less Expressive Quantificaton	?	?	?	?
Fragile Pointcuts	?	?	?	?
Non-uniform Context	?	?	?	?

- In MobileMedia, 5% of advised points

Less Expressive Quantification

```
private interface SynchronizedClasses {};

declare parents: ComplaintRepositoryArray
                 implements SynchronizedClasses;

Object around(Object o): this(o) &&
    execution(* SynchronizedClasses+.*(..))
{
  synchronized(o) { return proceed(o); }
}
```

What if a method is added to ComplaintRepositoryArray?

Less Expressive Quantification

	PCD	@PCD	OM	EVT
Quantificaton Failure	*yes*	*yes*	*yes*	**no**
Less Expressive Quantificaton	**no**	**no**	**no**	*yes*
Fragile Pointcuts	?	?	?	?
Non-uniform Context	?	?	?	?

- PCD, @PCD, and OM releases automatically advise new methods and sub-types
- EVT releases must manually maintain this design rule

Fragile Pointcuts

```
aspect ExceptionHandler {
  after(): execution(* FileScreen.save(..)) ..
}

class FileScreen {
  void save() { .. }
}
```

What if we rename the method?

```
  void export() { .. }
```

Fragile Pointcuts

	PCD	@PCD	OM	EVT
Quantificaton Failure	*yes*	*yes*	*yes*	**no**
Less Expressive Quantificaton	**no**	**no**	**no**	*yes*
Fragile Pointcuts	*yes*	**no**	**no**	**no**
Non-uniform Context	?	?	?	?

- Only PCD releases affected
- @PCD, OM, and EVT releases throw compiler errors if the interface changes

- Observed in 3 releases of MobileMedia
- 18% of all pointcut changes in MM were fragile

Non-uniform Context

```
class FileScreen {
  Display display;
  void save() { .. }
}
aspect ExceptionHandler {
  around(FileScreen scr):
    execution(* FileScreen.save ()) && this(scr)
  {
    try { proceed (); }
    catch (FileNotFoundException e) {
      scr.display.showFileError (e);
    }
  }
}
```

Pointcut can't directly access the display.

Non-uniform Context

	PCD	@PCD	OM	EVT
Quantificaton Failure	*yes*	*yes*	*yes*	**no**
Less Expressive Quantificaton	**no**	**no**	**no**	*yes*
Fragile Pointcuts	*yes*	**no**	**no**	**no**
Non-uniform Context	*yes*	*yes*	*yes*	**no**

- Problem occurred frequently in MobileMedia
- Required making fields public, adding public getters, or marking aspect privileged (which breaks encapsulation)
- Aspects become coupled to the advised class

Results Summary

	PCD	@PCD	OM	EVT
Quantificaton Failure	*yes*	*yes*	*yes*	**no**
Less Expresive Quantificaton	**no**	**no**	**no**	*yes*
Fragile Pointcuts	*yes*	**no**	**no**	**no**
Non-uniform Context	*yes*	*yes*	*yes*	**no**

- All interfaces had problems with quantification
- Only PCD had fragile pointcuts
- Only EVT had uniform context access

Future Work

- Can we quantify the value of each design?
  - Net-Options Value (NOV) analysis [*BALDWIN 2000*][3] [*SULLIVAN 2001*][4]
- Additional case study candidates
- Additional AO interfaces

[3] Baldwin and Clark, *Design Rules, Vol 1*, 2000

[4] Sullivan *et al.*, *The Structure and Value of Modularity in Software Design*, ESEC/FSE'01

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- Interesting Results

	PCD	@PCD	OM	EVT
Quantificaton Failure	*yes*	*yes*	*yes*	**no**
Less Expresive Quantificaton	**no**	**no**	**no**	*yes*
Fragile Pointcuts	*yes*	**no**	**no**	**no**
Non-uniform Context	*yes*	*yes*	*yes*	**no**

Questions?

http://ptolemy.cs.iastate.edu/design-study/

Inter-type Declarations

Add fields or methods to existing types or change the type hierarchy.

```
aspect A {
  int C.f = 5;
  void C.m() { .. }
  declare parents: C implements Serializable;
}
```

Available for PCD, @PCD, OM, and EVT.

Inter-type Declarations

- Extremely useful feature for AO languages

- MobileMedia R8 has ITDs in 50% of aspects
- Health Watcher uses declare parents in 25% of aspects

		R2	R3	R4	R5	R6	R7	R8
CBC	OO	32	40	40	65	80	103	131
	OM	35	50	59	94	121	159	217
	PCD	35	50	59	94	121	159	217
	@PCD	82	106	122	161	200	255	332
	EVT	74	100	120	159	203	271	371
LCOO	OO	123	194	224	241	296	311	365
	OM	147	244	266	259	369	502	534
	PCD	147	244	266	259	369	502	534
	@PCD	147	244	266	259	369	502	534
	EVT	123	162	171	257	365	426	539

		R2	R3	R4	R5	R6	R7	R8
LOC	OO	1159	1314	1363	1555	2051	2523	3016
	OM	1337	1570	1700	1928	2474	3207	3999
	PCD	1276	1494	1613	1834	2364	3068	3806
	@PCD	1452	1723	1852	2094	2664	3461	4257
	EVT	1427	1669	1781	2050	2646	3398	4254
NOC	OO	24	25	25	30	37	46	51
	OM	31	33	36	42	53	69	91
	PCD	27	29	32	38	46	59	75
	@PCD	51	60	64	72	85	109	130
	EVT	47	53	56	64	78	96	115
NOA	OO	62	71	74	75	106	132	165
	OM	82	99	108	112	149	187	237
	PCD	62	72	76	77	110	139	177
	@PCD	62	72	76	77	110	139	177
	EVT	71	92	96	101	144	175	217
NOO	OO	124	140	143	160	200	239	271
	OM	143	169	179	197	247	308	369
	PCD	143	169	179	197	247	308	369
	@PCD	143	169	179	197	247	308	369
	EVT	142	167	177	196	245	302	378

			R2	R3	R4	R5	R6	R7	R8	Total
Components	Added	OO	**9**	**1**	**0**	**5**	**7**	**10**	**6**	38
		OM	**17**	2	3	6	**11**	**17**	**22**	78
		PCD	13	2	3	6	8	14	16	62
		@PCD	13	2	3	6	8	14	16	62
		EVT	13	2	**2**	6	8	14	16	61
	Differences to PCD marked in BOLD blue									
	Removed	OO	**0**	0	0	0	0	1	**1**	2
		OM	1	0	0	0	0	1	0	2
		PCD	1	0	0	0	0	1	0	2
		@PCD	1	0	0	0	0	1	0	2
		EVT	1	0	0	0	0	1	0	2
	Changed	OO	5	**8**	**5**	**8**	**6**	**19**	**17**	68
		OM	5	**14**	**6**	**13**	**6**	**34**	**26**	104
		PCD	5	10	2	10	5	27	18	77
		@PCD	5	**8**	2	**11**	**7**	27	**20**	80
		EVT	5	**9**	**1**	**8**	5	**25**	**20**	73

Pointcuts		R2	R3	R4	R5	R6	R7	R8	Total
Add	OM	**87**	**19**	**18**	**6**	**21**	**53**	**58**	262
	PCD	64	12	13	4	15	39	43	190
	@PCD	64	12	13	4	15	39	43	190
Remove	**Differences to PCD marked in BOLD blue**								
	OM	0	0	0	0	**2**	**12**	**11**	25
	PCD	0	0	0	0	1	6	8	15
	@PCD	0	0	0	0	1	6	8	15
Change									
	OM	0	**10**	0	**29**	2	**104**	**9**	154
	PCD	0	9	0	18	2	74	4	107
	@PCD	0	**4**	0	**13**	2	**65**	4	88

Events/Anns		R2	R3	R4	R5	R6	R7	R8	Total
Add	@PCD	**24**	**7**	**1**	2	6	**11**	**5**	56
	EVT	16	4	0	2	6	5	3	36
	Differences to EVT marked in BOLD red								
Rem	@PCD	0	0	0	0	**1**	0	0	1
	EVT	0	0	0	0	0	0	0	0
Ch	@PCD	0	**1**	0	**0**	0	**0**	**0**	1
	EVT	0	2	0	1	0	12	1	16

		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
CBC	OO	281	318	352	365	369	375	417	424	571	586
	OM	262	300	326	327	327	330	373	374	486	502
	PCD	262	300	326	327	327	330	373	374	486	502
	@PCD	279	321	352	382	382	385	430	432	561	593
	EVT	333	379	437	476	476	479	521	525	649	688
LCOO	OO	791	802	519	568	624	604	604	604	779	827
	OM	764	779	588	599	599	599	599	597	730	809
	PCD	764	792	601	612	612	612	612	610	730	809
	@PCD	764	792	601	612	612	612	612	610	730	809
	EVT	767	803	612	633	633	633	633	630	745	804

		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
LOC	OO	5990	6371	6896	7048	7233	7296	7318	7357	8800	8697
	OM	5777	6202	6840	6944	6944	6994	7019	7027	7980	7937
	PCD	5712	6116	6718	6807	6807	6856	6881	6890	7853	7791
	@PCD	5851	6262	6891	7077	7077	7126	7161	7170	8167	8159
	EVT	5948	6369	7128	7371	7371	7422	7450	7464	8485	8551
NOC	OO	88	92	104	106	108	112	116	120	132	135
	OM	108	120	136	142	142	146	150	152	164	169
	PCD	103	114	130	135	135	139	143	145	157	162
	@PCD	116	129	147	155	155	159	164	166	178	190
	EVT	118	133	158	168	168	172	176	178	190	205
NOA	OO	187	215	218	221	223	225	227	228	248	256
	OM	205	236	252	256	256	258	260	260	278	296
	PCD	187	216	220	221	221	223	225	225	243	252
	@PCD	187	216	220	221	221	223	225	225	243	252
	EVT	199	233	305	311	311	313	315	315	333	347
NOO	OO	527	557	701	715	750	766	782	787	881	894
	OM	556	574	724	733	733	745	761	761	821	847
	PCD	556	574	724	733	733	745	761	761	821	847
	@PCD	556	574	724	733	733	745	761	761	821	847
	EVT	556	574	724	734	734	746	762	762	822	845

			R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Total
Components	Added	OO	**88**	**4**	**12**	**2**	**3**	4	4	**4**	12	**5**	138
		OM	**106**	**12**	16	**4**	0	4	4	2	12	6	166
		PCD	101	11	16	3	0	4	4	2	12	6	159
		@PCD	101	11	16	3	0	4	4	2	12	6	159
		EVT	**100**	**10**	16	3	0	4	4	2	12	6	157
	Differences to PCD marked in BOLD blue												
	Removed	OO	0	0	0	0	**1**	0	0	0	0	**2**	3
		OM	0	0	0	0	0	0	0	0	0	1	1
		PCD	0	0	0	0	0	0	0	0	0	1	1
		@PCD	0	0	0	0	0	0	0	0	0	1	1
		EVT	0	0	0	0	0	0	0	0	0	1	1
	Changed	OO	0	**22**	**6**	**15**	**16**	2	27	3	**23**	**48**	162
		OM	0	**27**	**9**	**9**	1	**3**	27	**5**	**23**	**55**	159
		PCD	0	25	8	7	1	2	27	3	22	52	147
		@PCD	0	**26**	8	**29**	1	2	27	3	**23**	**55**	174
		EVT	0	**26**	8	**32**	1	2	27	3	**23**	**54**	176

Pointcuts		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Total
Add	OM	**57**	**16**	**36**	**16**	0	0	0	6	0	**30**	161
	PCD	28	11	12	10	0	0	0	6	0	20	87
	@PCD	28	11	12	10	0	0	0	6	0	20	87
Remove	**Differences to PCD marked in BOLD blue**											
	OM	0	0	0	0	0	0	0	**6**	**6**	0	12
	PCD	0	0	0	0	0	0	0	4	4	0	8
	@PCD	0	0	0	0	0	0	0	4	4	0	8
Change												
	OM	0	4	0	0	0	0	1	**2**	**6**	3	16
	PCD	0	4	0	0	0	0	1	0	5	3	13
	@PCD	0	**1**	0	0	0	0	1	0	5	3	10

Events/Anns		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Total
Add	@PCD	**13**	**2**	**2**	**4**	0	0	**1**	0	0	**6**	28
	EVT	14	4	9	5	0	0	0	0	0	10	42
	Differences to EVT marked in BOLD red											
Rem	@PCD	0	0	0	0	0	0	0	0	0	0	0
	EVT	0	0	0	0	0	0	0	0	0	0	0
Ch	@PCD	0	**0**	0	0	0	0	0	0	0	0	0
	EVT	0	1	0	0	0	0	0	0	0	0	1