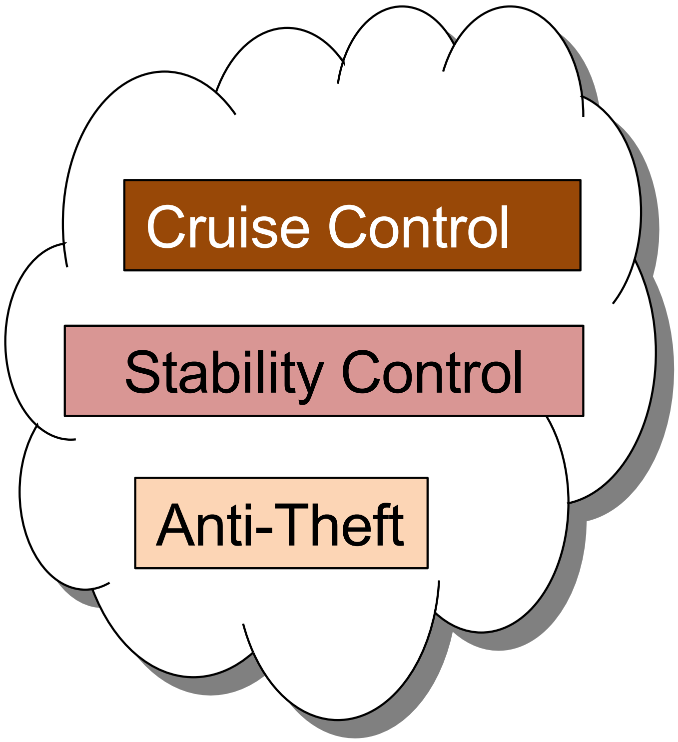
Feature Modularity

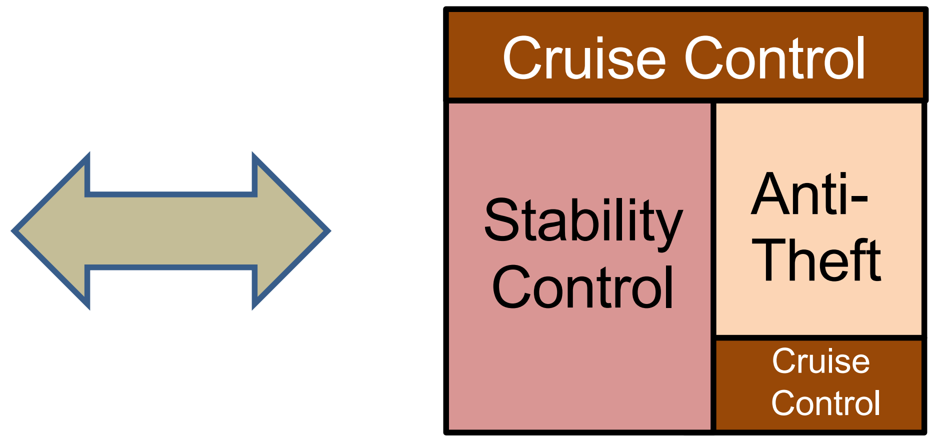
Jo Atlee • Modularity • March 2015

WATFORM
David R. Cheriton School of Computer Science
University of Waterloo

necsis

feature-oriented software development





stakeholders' mental model of system

feature-oriented software system

what is a feature?

"unit of functionality" [Hall,2000]
- additive / incremental
- optional

"a modification of or an addition to a service, and does not stand on its own" [Bellcore1992]

"a tariffable unit" [Bellcore1992]

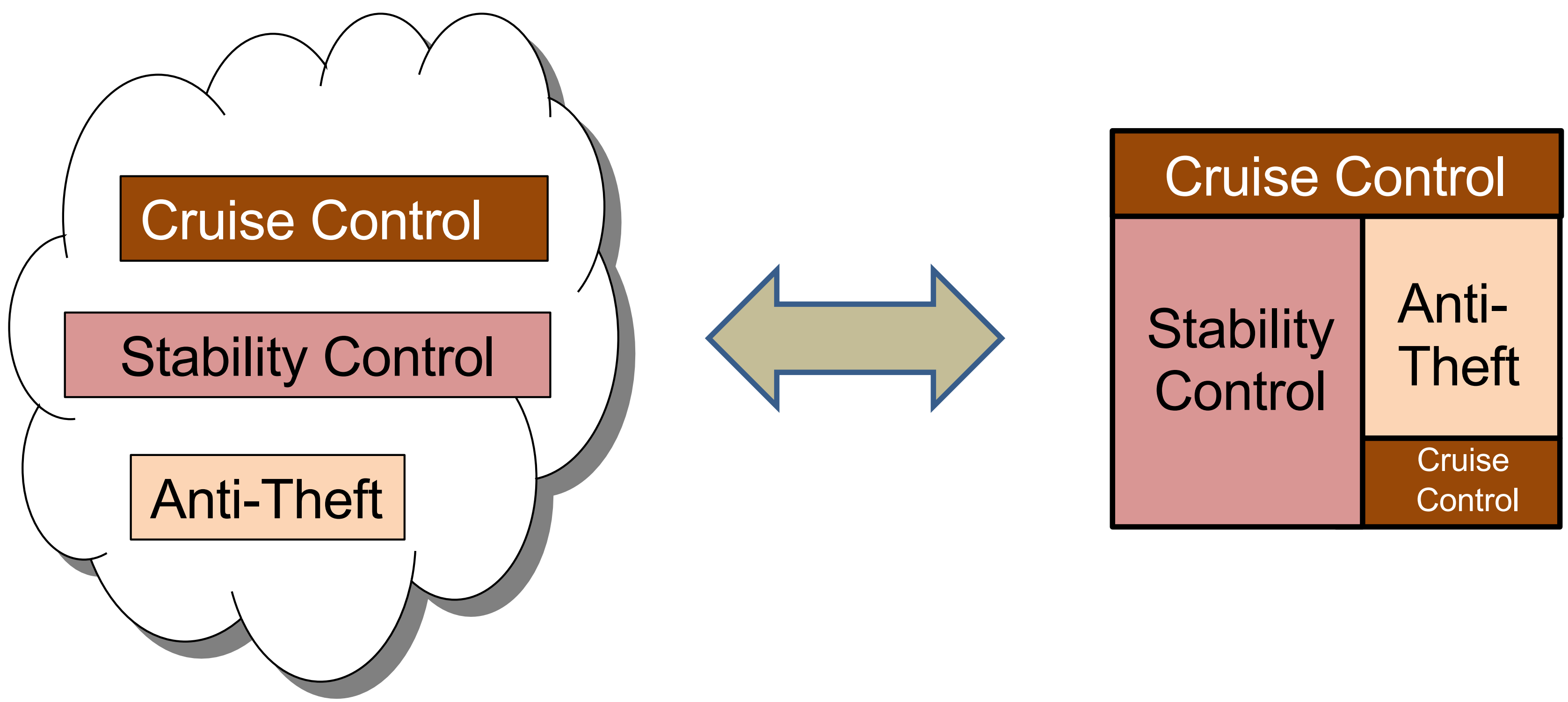
"a unit of variability"

"a requirement" [Zave2015]

"a characteristic / property / quality / aspect / profile / concern of the system"

feature-oriented software development

feature : a requirement



stakeholders' mental model of system

feature-oriented software system

feature interactions

feature interaction: a feature *behaves differently* in the presence of another feature than it behaves in isolation

- nondeterministic
- conflicting actions
- violate global correctness property
- emergent behaviours

hybrid brakes ⊕ anti-lock breaking

2010 Toyota Prius

hybrid brake system

- (normal) hydraulic brake system
- regenerative braking system
  - converts loss of vehicle momentum into electrical energy
  - stored in on-board batteries

anti-lock brake system (ABS)

- maintains stability, steerability during panic braking

interaction

- braking force after ABS actuation reduced
- vehicle stopping distance is increased
- 62 reported crashes, 12 injuries

cruise control ⊕ traction control

cruise control
- vehicle set to maintain driver-specified speed

traction control
- brake fluid applied when wheels slip

interaction
- engine power is increased (to maintain speed)
- driver senses “sudden acceleration”
  - vehicle becomes difficult to control

resolution
- advise drivers not to use cruise control on slippery roads

not all interactions are bad!

intended interactions

- advanced cruise-control variants override basic cruise control
- prohibit navigation overrides navigation
- prohibit-navigation override overrides prohibit-navigation

unintended but harmless interactions

- call screening prevents activation of caller id

(planned) resolutions to conflicts

- brake override overrides (acceleration ⊕ braking)

all interactions require work

- verify *intended* interactions
- detect un*expected* interactions
- analyze them for un*desired* interactions
- fix undesired interactions
  - faulty feature
  - disallow feature combination
  - resolve interaction using exceptions / new features
- test the fixes

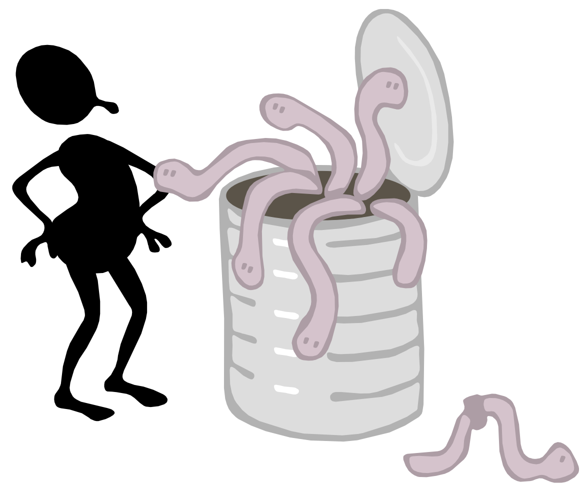
feature modularity vs. interactions

FOSD emphasizes features

de-emphasizes interactions

but still must detect, analyze, fix, test interactions

this is exactly the chore that feature-orientation was meant to avoid!



what this talk is about

history of feature modularity

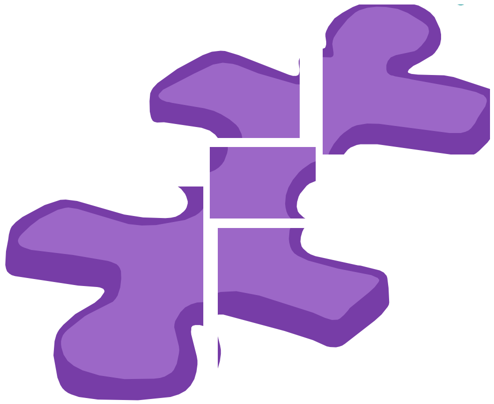
- representing features as isolated modules
- (some) information hiding

addressing feature interactions

- scalable to large numbers of features
- supports third-party development

approach #1:

feature module =
co-location of feature's code



interactions resolved using exceptions

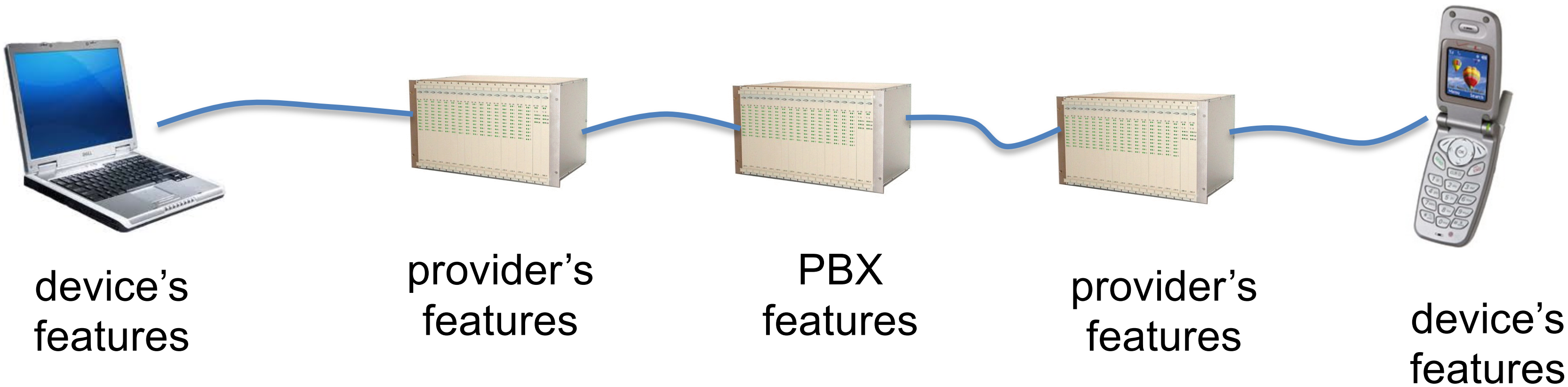
$$F_{\mathbf{1}} = f_1 + e_{f_2} + e_{f_3} + \ldots + e_{f_n}$$

$$+ e_{f_2 f_3} + e_{f_3 f_4} + \ldots$$

$$+ e_{f_2 f_3 \ldots f_n}$$

lots of features

e.g., telephony has 1000+ features per system

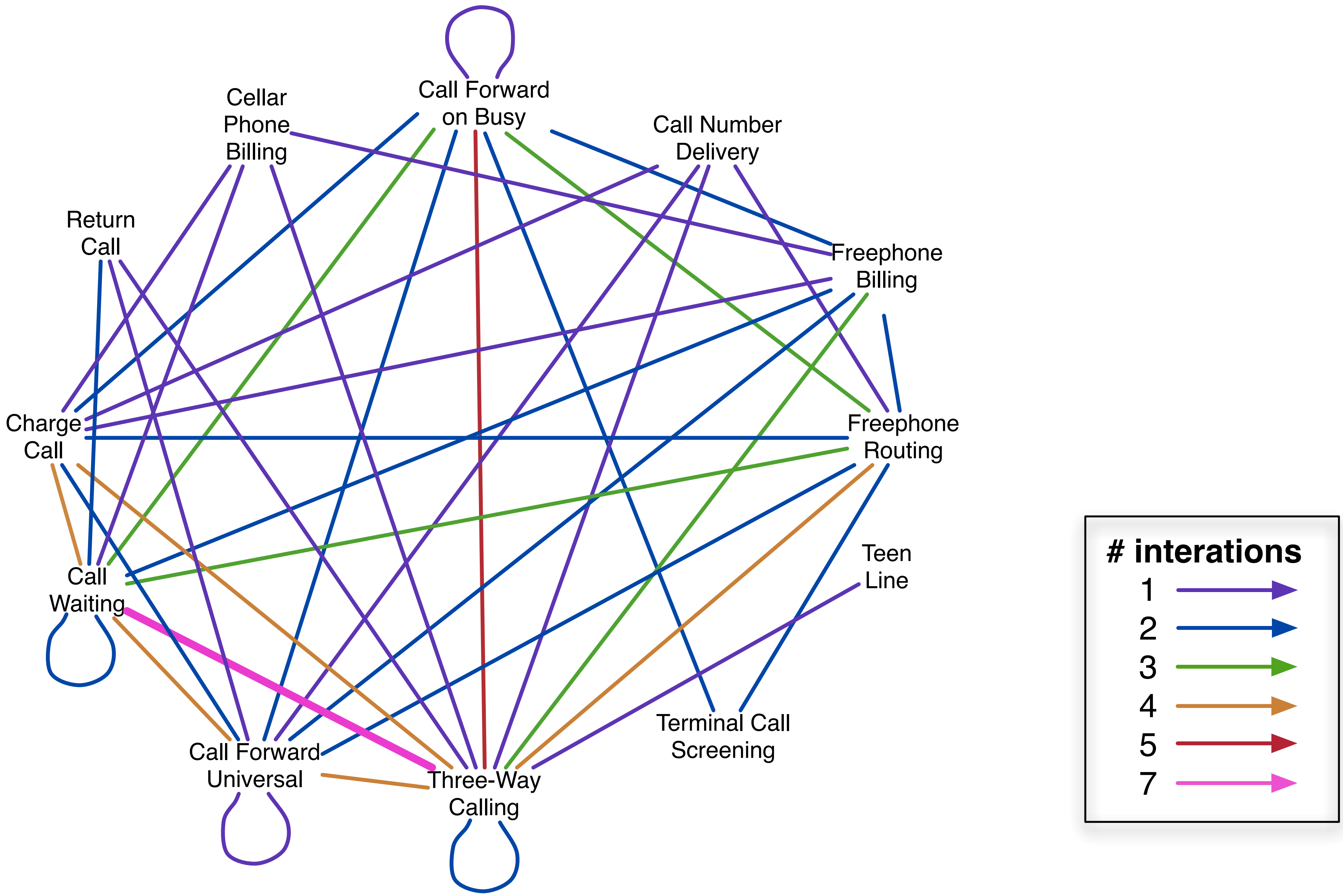


a system of feature-rich systems

- features from multiple providers
- multiple active versions of the same feature

lots of interactions

results of the second feature interaction contest



lots of types of interactions

control-flow
one feature affects the flow of control in another feature

data-flow
one feature affects (deletes, alters) a message destined for another feature

data modification
shared data read by one feature is modified by another feature

data conflict
two features modify the same data

control conflicts
two features issue conflicting actions

assertion violation
one feature violates another feature's assertions or invariants

resource contention
the supply of resources is inadequate, given the set of competing features

introduced in several phases

Bowen, SETSS'89

[req] understanding / specifying how features ought to interact

[req] the number of interactions (and resolutions) to consider grows exponentially with the number of features

[design] more interactions introduced during design due to sharing of resources, I/O devices, protocol signals, etc.

[imp] near-commonalities among features leads to questions about how to effectively reuse software components

[test] the sheer number of interactions and resolutions to be tested lengthens the testing phase

feature interaction problem

death by exceptions [Zave]

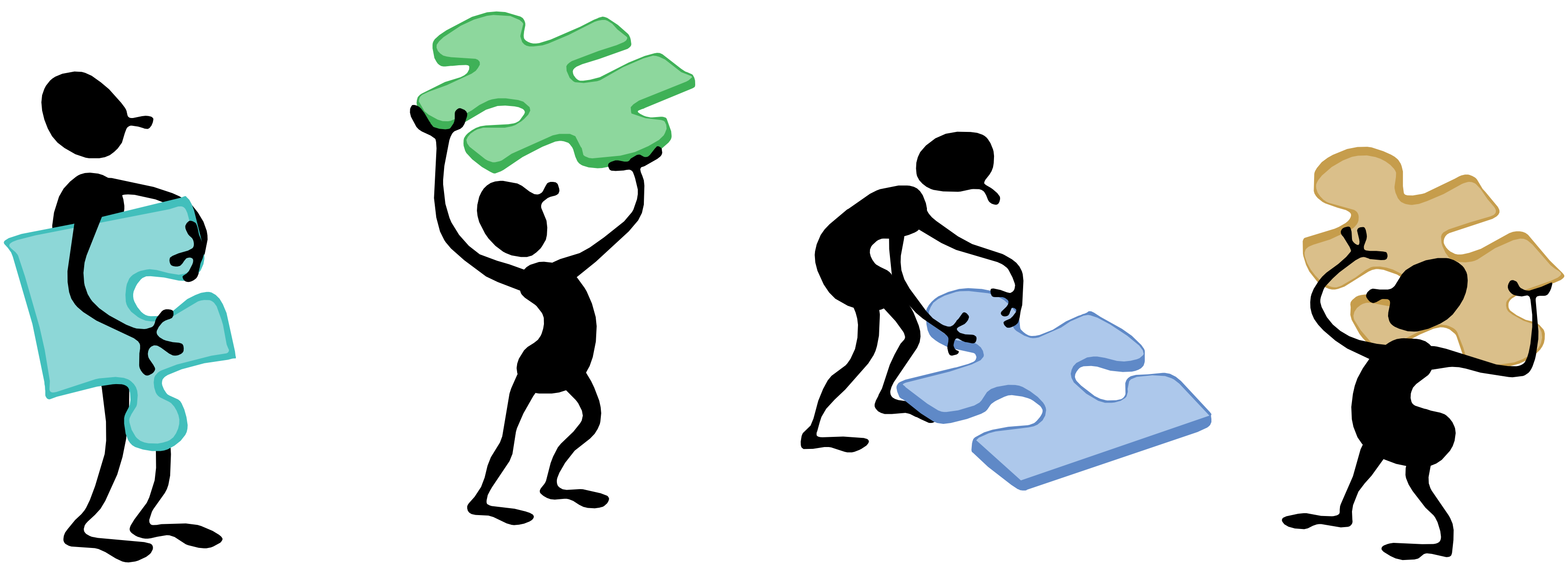
$$F_{\mathbf{1}} = f_1 + e_{f_2} + e_{f_3} + e_{f_4} + e_{f_5} + e_{f_6} + e_{f_7}$$
$$+ e_{f_8} + e_{f_9} + e_{f_{10}} + e_{f_{11}} + e_{f_{12}}$$
$$+ e_{f_{13}} + e_{f_{14}} + e_{f_{15}} + e_{f_{16}} + \ldots + e_{f_n}$$

interactions

- dominate feature development
- complicate third-party feature development

approach #2:

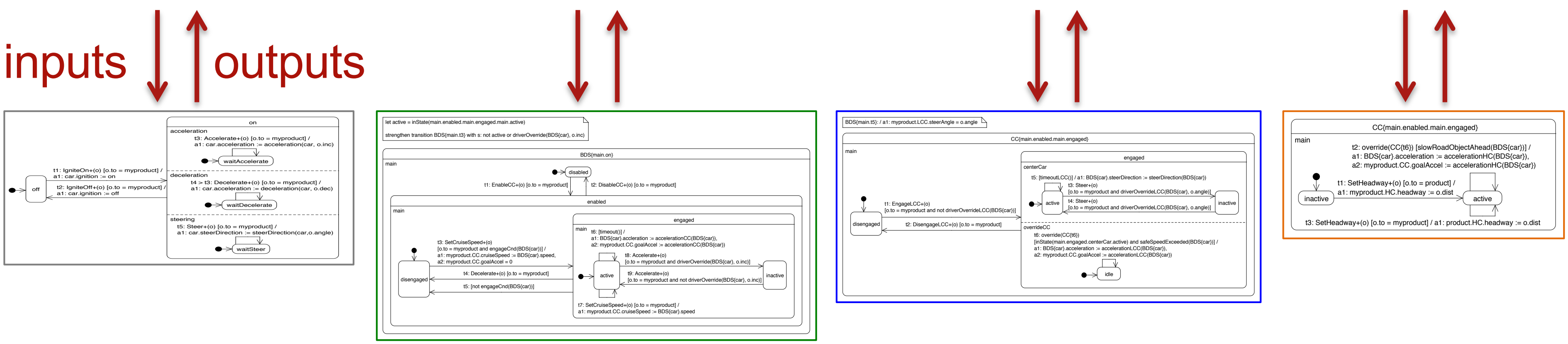
feature module = black box



feature modules

features are independent entities that are oblivious to the presence of other features

- each module's interface is simply its inputs and outputs to a shared environment



- enables third-party feature development
- simplifies detection of interactions

detecting feature interactions

feature

requirements of feature (property)

$$F_1 \models \Phi_1$$
$$F_2 \models \Phi_2$$
$$\vdots$$
$$F_n \models \Phi_n$$

$$\underbrace{F_1 \oplus F_2 \oplus \cdots \oplus F_n}_{\text{feature composition}} \not\models \Phi_1 \wedge \Phi_2 \wedge \cdots \wedge \Phi_n$$

call forward vs. voice mail

CFNA $\models$ call is forwarded to new directory number

VM $\models$ message is from the caller is recorded

$$\text{CFNA} \oplus \text{VM} \overset{?}{\models} \text{forward call} \land \text{record message}$$

nonmonotonic resolutions
(Veldhuijsen'95)

adding a new feature can change the requirements of existing features:

- nonmonotonic extensions
  - e.g., Freephone changes billed party
- changes to definitions of terms
  - e.g., refinement of the notion of being *busy*
  - e.g., evolution of a *call*
  - e.g., *evolution of directory numbers; of private numbers*
- violation of invariants / assumptions
  - *"I have not been able to think of a* ***single*** *interesting assertion that would be true of a system incorporating all [features of the public switched telephone network]."* [Zave'01]

feature interaction problem

death by "interaction features"

$$F_1 + F_2 + F_3 + \ldots + F_n$$

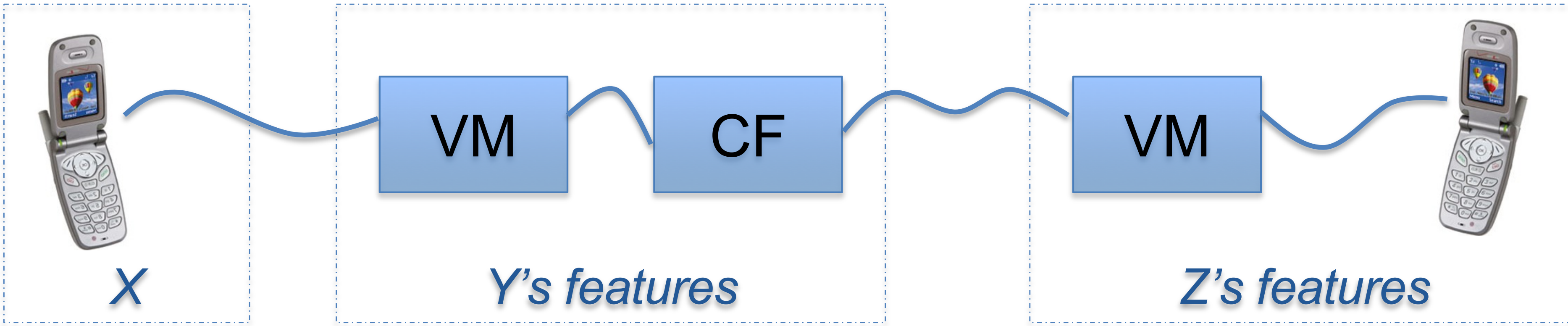
$$+ F_1\#F_2 + F_1\#F_3 + \ \ldots \ F_{n-1}\#F_n$$

$$+ F_1\#F_2\#F_3 + F_1\#F_2\#F_4 +$$

$$+ F_1\#F_2\#F_3\#\ldots\#F_n$$

aiming for perfect resolution of interactions doesn't scale

best resolution not always obvious



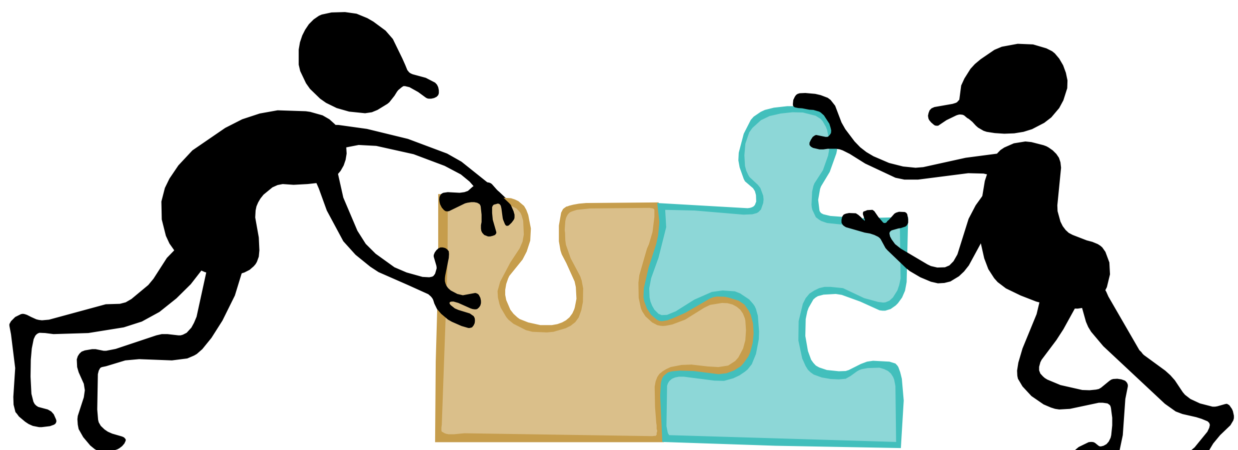
X calls Y, which forwards the call to Z, and the call attempt fails.

whose VM should react?

- what if Y is a sales group and Z is a sales representative?
- what if Y is on a long leave of absence?

approach #3:

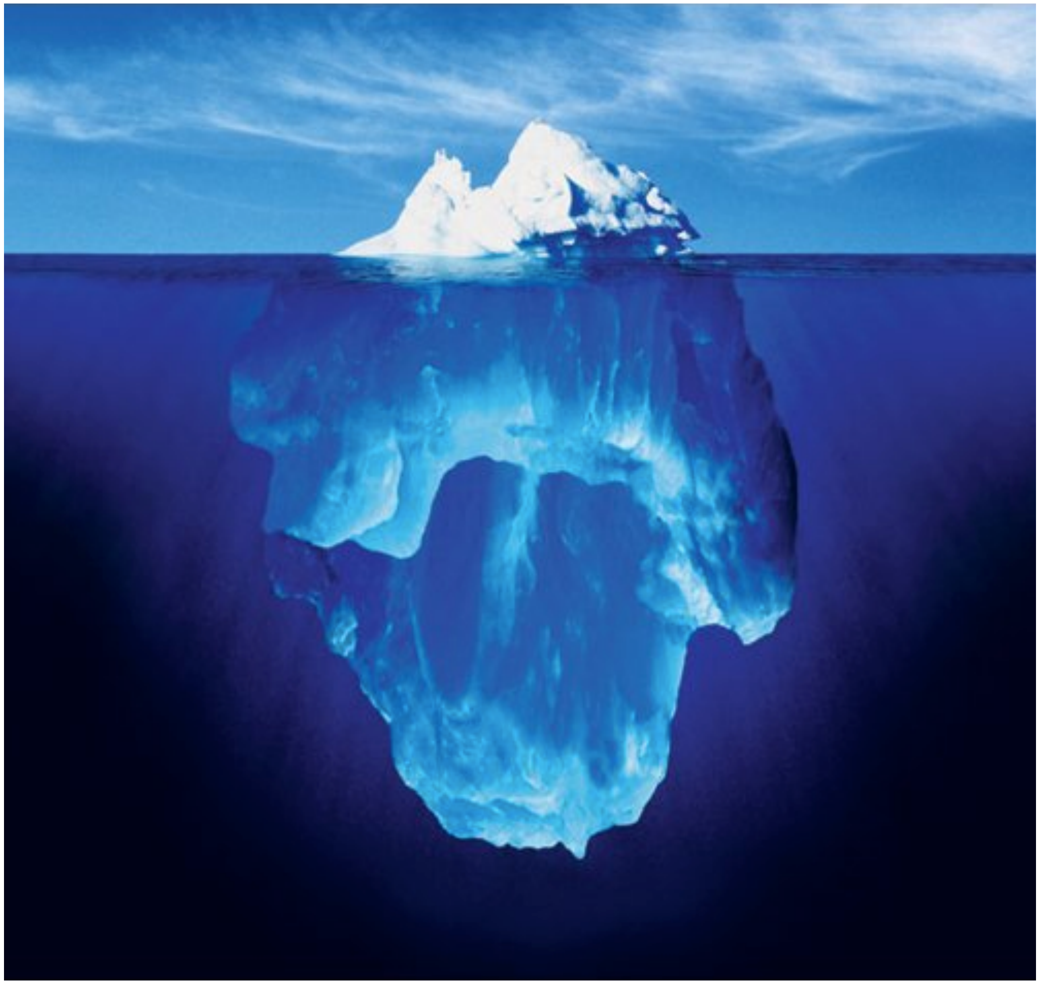
feature modules with interfaces



interfaces and information hiding

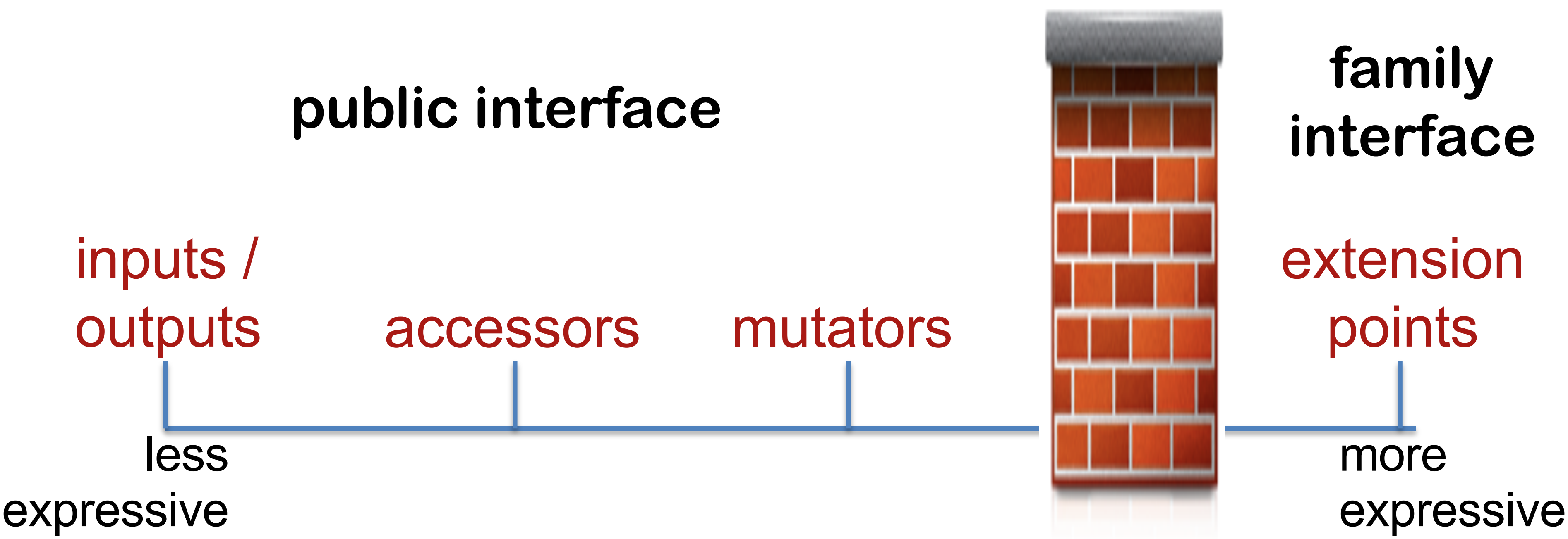
interface advertises what services a module provides to the rest of the system, and how they can be accessed

information hiding encapsulates a design decision inside a module, whose interface reveals only externally visible properties [Parnas'72]

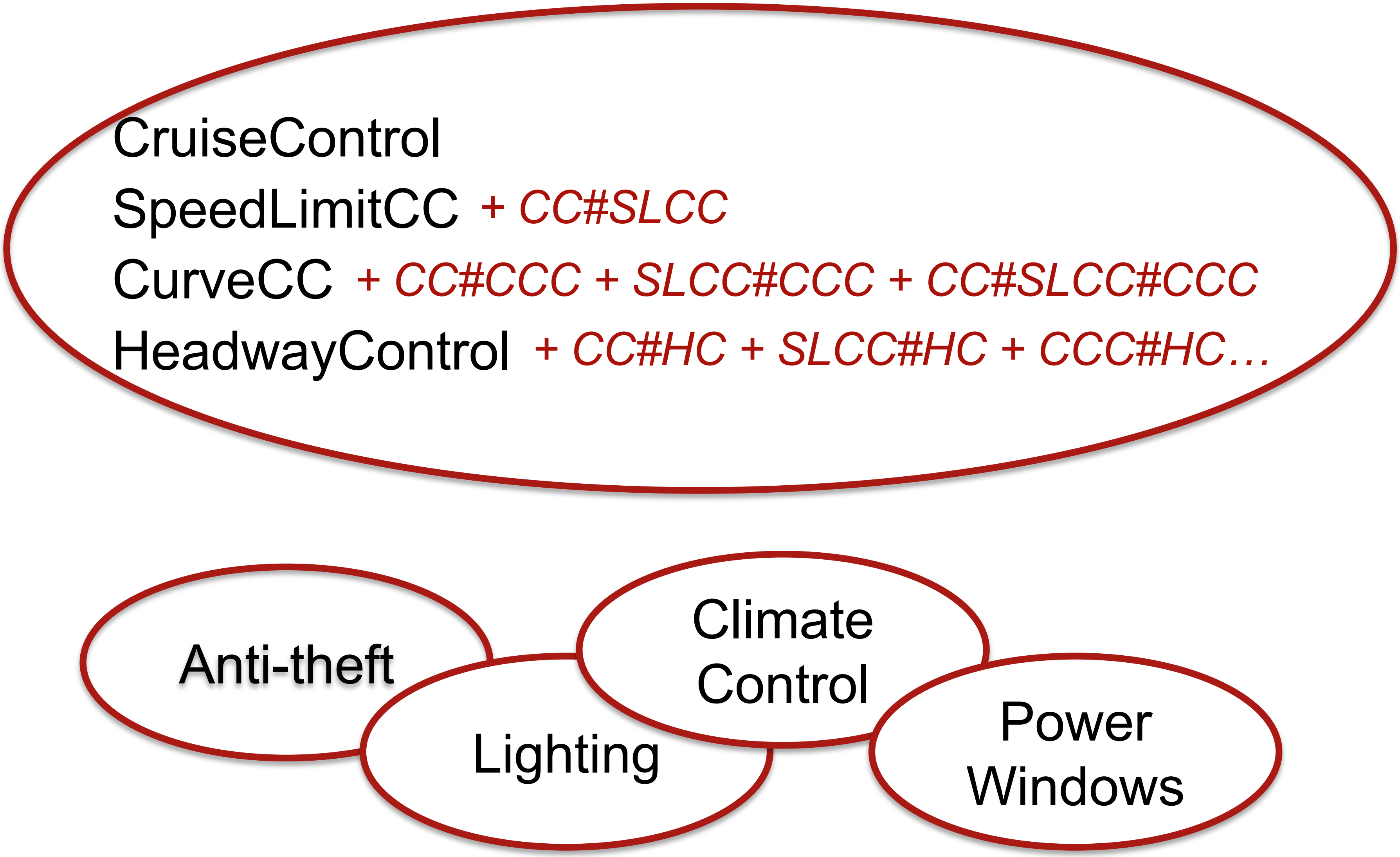


interfaces

feature interface defines what services a feature provides to the rest of the system and how other features can access those services



feature families



minimal public interface

most inter-feature references are to high-level common modes of operation

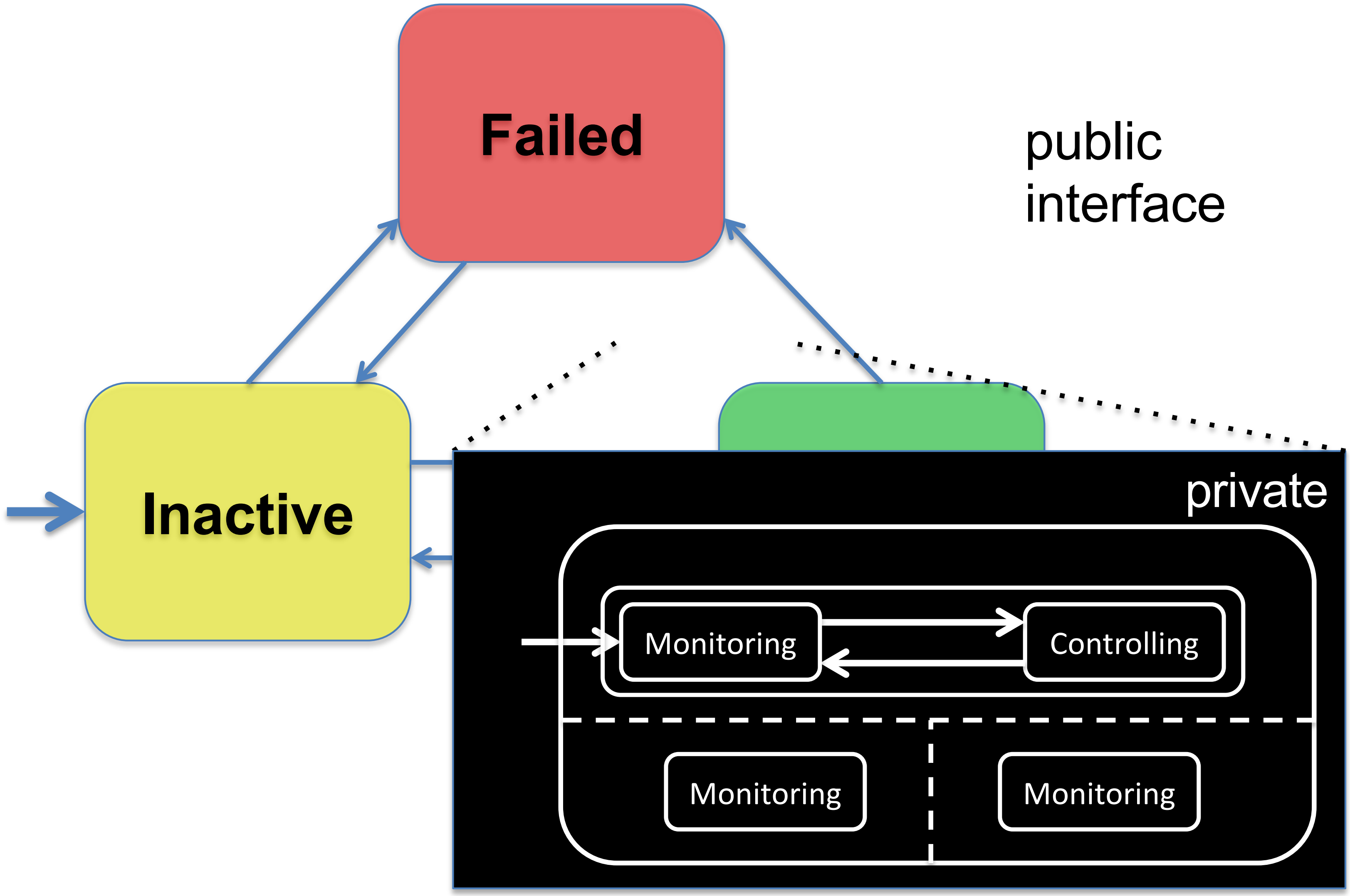
examples

FeatureX_Fail flag is set to true when FeatureY is in fail state

FeatureQ is enabled only if FeatureP is enabled

minimal public interface

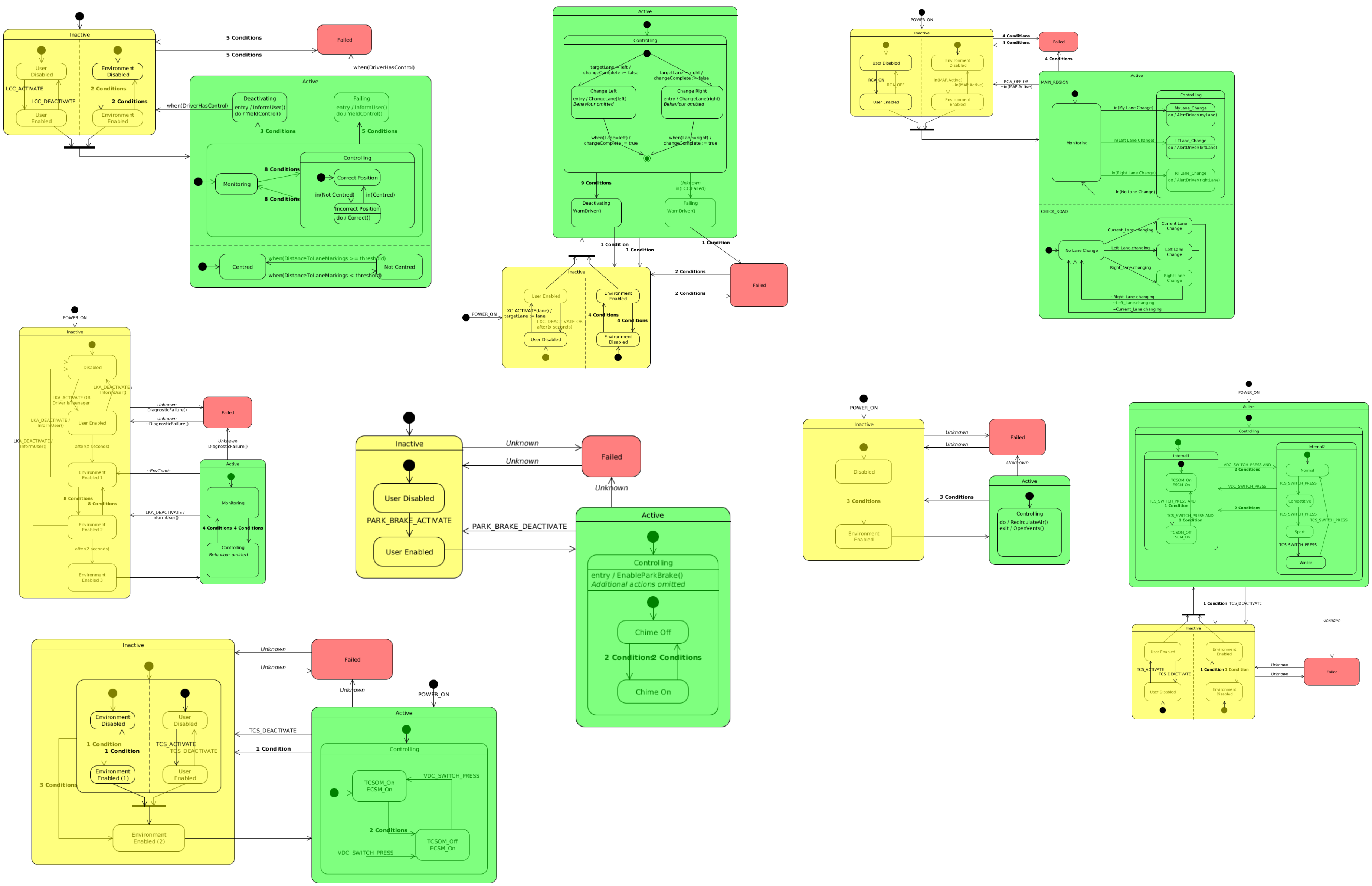
most inter-feature references are to high-level common modes of operation



generic public interface

modes of operation can serve as criterion for structuring feature modules

generic public interface (2)



2 strategies for resolving interactions

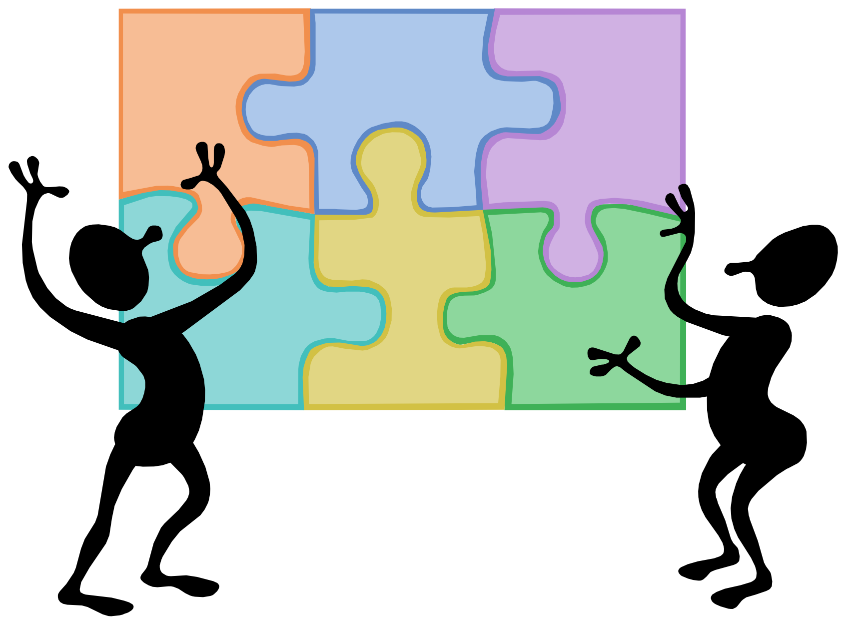
feature families

resolve interactions within a feature family *perfectly* (e.g., new “interaction” features)

unrelated features

handle unexpected interactions between unrelated features using default resolution strategies

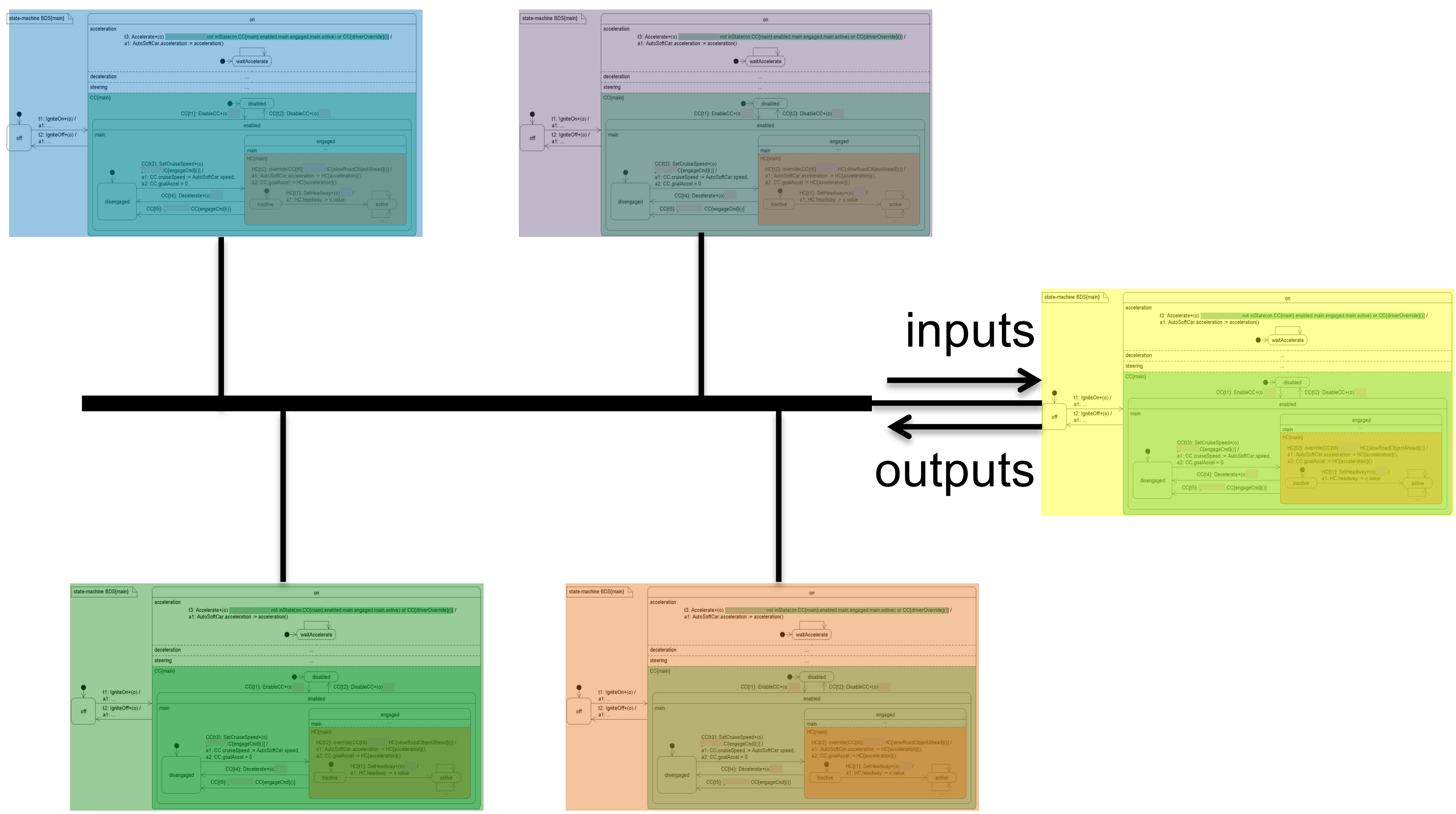
resolving interactions between unrelated features



feature coordination

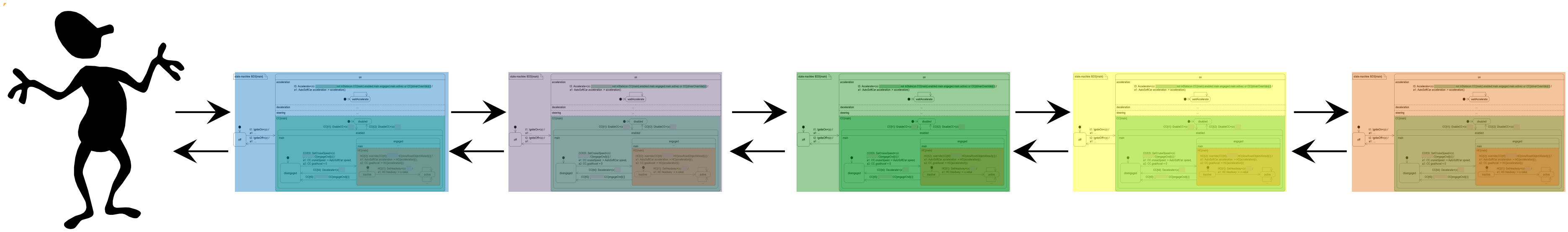
given a collection of feature families, each with a minimal public interface…

… want to coordinate the features' executions such that entire classes of interactions are resolved by default



serializing features

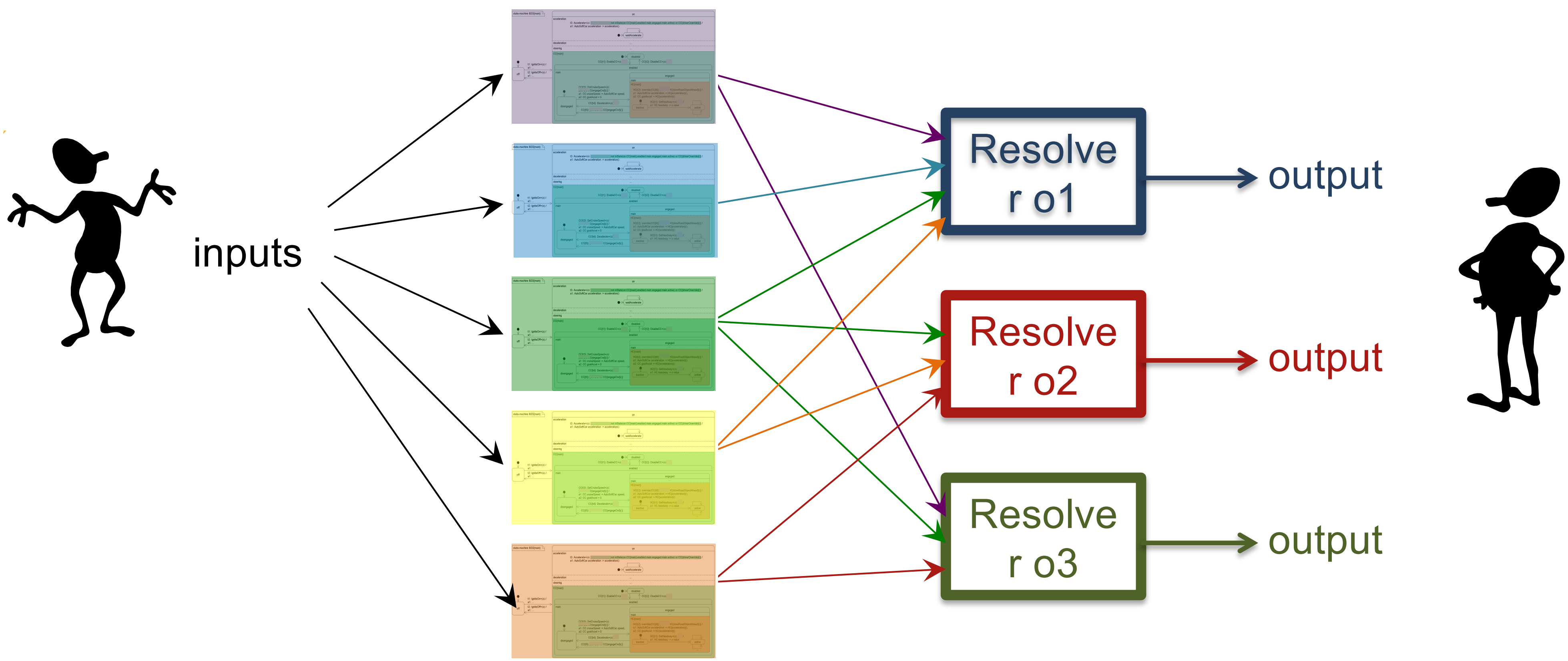
Distributed Feature Composition [Jackson, Zave, TSE'98]



pipeline architecture

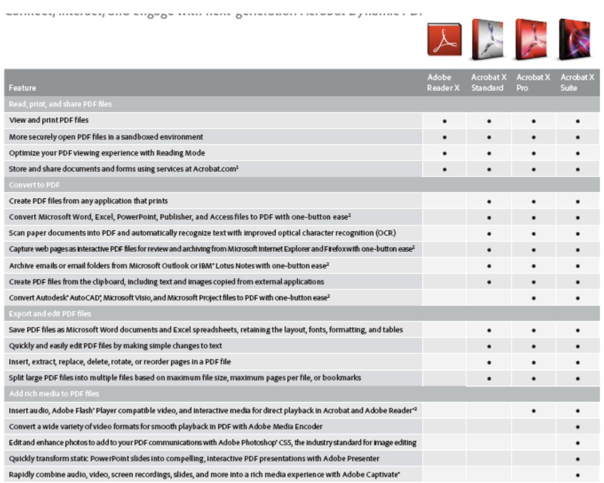
+ features make no assumptions about other features
+ avoids simultaneous reactions to the same event
+ conflicts are resolved through serialization
+ feature ordering realizes a priority scheme
− resolution is implicit

parallel execution (resolution modules)



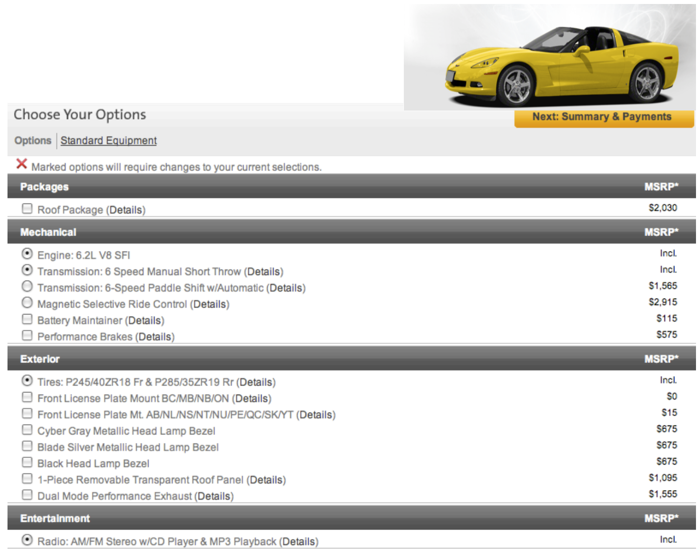
+ features make no assumptions about other features
+ conflicting actions are resolved by resolution modules
+ all actions are considered in resolution
+ resolution strategies can be variable-specific

feature coordination



Feature	Adobe Reader X	Acrobat X Standard	Acrobat X Pro	Acrobat X Suite
Read, print, and share PDF files				
View and print PDF files	•	•	•	•
More securely open PDF files in a sandboxed environment	•	•	•	•
Optimize your PDF viewing experience with Reading Mode	•	•	•	•
Store and share documents and forms using services at Acrobat.com[1]	•	•	•	•
Convert to PDF				
Create PDF files from any application that prints		•	•	•
Convert Microsoft Word, Excel, PowerPoint, Publisher, and Access files to PDF with one-button ease[2]		•	•	•
Scan paper documents into PDF and automatically recognize text with improved optical character recognition (OCR)		•	•	•
Capture web pages as interactive PDF files for review and archiving from Microsoft Internet Explorer and Firefox with one-button ease[2]		•	•	•
Archive emails or email folders from Microsoft Outlook or IBM® Lotus Notes with one-button ease[2]		•	•	•
Create PDF files from the clipboard, including text and images copied from external applications		•	•	•
Convert Autodesk® AutoCAD®, Microsoft Visio, and Microsoft Project files to PDF with one-button ease[2]			•	•
Export and edit PDF files				
Save PDF files as Microsoft Word documents and Excel spreadsheets, retaining the layout, fonts, formatting, and tables		•	•	•
Quickly and easily edit PDF files by making simple changes to text		•	•	•
Insert, extract, replace, delete, rotate, or reorder pages in a PDF file		•	•	•
Split large PDF files into multiple files based on maximum file size, maximum pages per file, or bookmarks		•	•	•
Add rich media to PDF files				
Insert audio, Adobe Flash® Player compatible video, and interactive media for direct playback in Acrobat and Adobe Reader®[2]			•	•
Convert a wide variety of video formats for smooth playback in PDF with Adobe Media Encoder				•
Edit and enhance photos to add to your PDF communications with Adobe Photoshop® CS5, the industry standard for image editing				•
Quickly transform static PowerPoint slides into compelling, interactive PDF presentations with Adobe Presenter				•
Rapidly combine audio, video, screen recordings, slides, and more into a rich media experience with Adobe Captivate®				•

- fixed set of features
- pre-determined selection of features
- static integration
- perfect coordination possible



Choose Your Options

Next: Summary & Payments

Options | Standard Equipment

Marked options will require changes to your current selections.

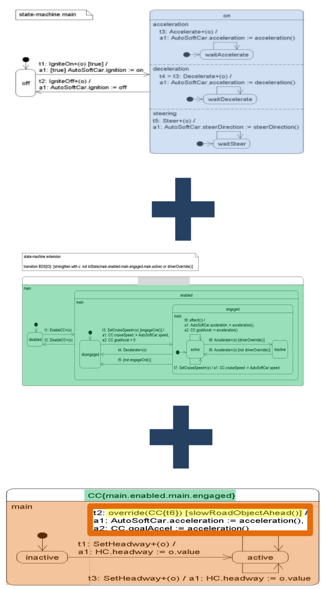
Packages	MSRP*
Roof Package (Details)	$2,030
Mechanical	**MSRP***
Engine: 6.2L V8 SFI	Incl.
Transmission: 6 Speed Manual Short Throw (Details)	Incl.
Transmission: 6-Speed Paddle Shift w/Automatic (Details)	$1,565
Magnetic Selective Ride Control (Details)	$2,915
Battery Maintainer (Details)	$115
Performance Brakes (Details)	$575
Exterior	**MSRP***
Tires: P245/40ZR18 Fr & P285/35ZR19 Rr (Details)	Incl.
Front License Plate Mount BC/MB/NB/ON (Details)	$0
Front License Plate Mt. AB/NL/NS/NT/NU/PE/QC/SK/YT (Details)	$15
Cyber Gray Metallic Head Lamp Bezel	$675
Blade Silver Metallic Head Lamp Bezel	$675
Black Head Lamp Bezel	$675
1-Piece Removable Transparent Roof Panel (Details)	$1,095
Dual Mode Performance Exhaust (Details)	$1,555
Entertainment	**MSRP***
Radio: AM/FM Stereo w/CD Player & MP3 Playback (Details)	Incl.

- fixed set of features
- semi-configurable selection of features
- set of static integrations
- perfect coordination possible, but impractical

- unlimited features
- user-defined selection of features
- dynamic integration
- loose coordination

summary

modular features



tight integration of feature families

- no interfaces
- perfect resolution

(looser) coordination of unrelated features

- feature interfaces
- default resolution
- relax “correctness”