On Preventing Telephony Feature Interactions which are Shared-Control Mode Confusions

Jan Bredereke

University of Bremen

Overview

1. mode confusions
2. many FI are mode confusions
3. how the notion of mode confusion helps against FI

1. Mode Confusions

Example: Airbus A320 Crash near Strasbourg, 1992

- pilots confused “flight path angle” and “vertical speed” modes of decent
  - 3.3: 3.3° $\sim$ 1,000 feet per minute
  - 3.3: 3,300 feet per minute
- 87 killed

Example: Credit-Card Calling & Voice Mail

- credit-card calling:
  - 1st call: dial company's number + access code + callee's number
  - 2nd call: dial # + callee's number
- access your Aspen voice mail messages:
  1. dial Aspen's number
  2. listen to prompt or go to 3.
  3. dial # + mailbox number + passcode
- check voice mail via credit card

Modes in Example: Credit-Card Calling & Voice Mail

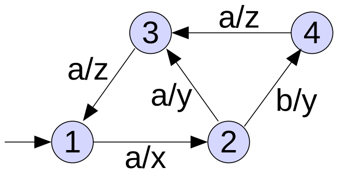
- credit card mode: # = next call
- voice mail mode: # = check mail

- user tries to shortcut voice mail's intro prompt
- surprise: call is terminated
  - new mode guaranteed only when prompt actually started

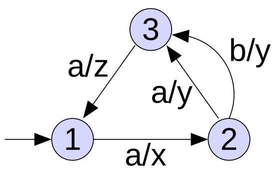
Mode Confusion

- a kind of automation surprise
- in shared-control systems
  - aircraft, automobiles, . . .
- humans use a mental model of the technical system
  - can get out of sync
- many research results

technical system



mental model

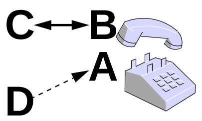


Causes of the Mode Confusion: Credit-Card Calling & Voice Mail

- incorrect abstraction
  - while planning the voice mail shortcut, user created abstraction with relevant parts
  - mistake: abstraction dropped the (latently still active) credit card feature
- incorrect knowledge
  - "implicit mode change"
    - ▷ user cannot observe actual mode change until start of prompt
  - user makes wrong assumption about actual timing

Another Example: Call Waiting & Personal Communication Services

- call waiting:
  - user is busy and 2nd call arrives
  - user gets call-waiting tone
- personal communication services (PCS):
  - user registers for current line
  - user gets all subscribed-to features there, maybe including Call Waiting
- Alice: PCS + Call Waiting Bob: PCS
- Alice, Bob registered for same line
- Bob already talks to Cindy; Dick calls Alice

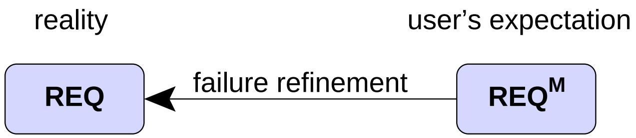


Causes of the Mode Confusion: Call Waiting & Personal Commun. Services

- system has alerting mode because of Alice, mental model of Bob has not
  - if alert, Bob is annoyed and doesn't know how to stop it
  - if no alert, Alice's Call Waiting is ignored
- incorrect knowledge of Bob
  - Bob needs to know all other PCS users' features

Definition of Mode Confusion (1)

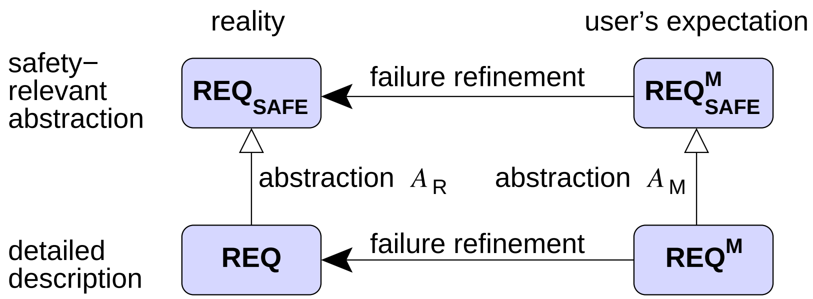
- "The user must not be surprised"
- mental model: specification
  reality: implementation



- failure refinement in CSP (Communicating Sequential Processes)
- REQ: system requirements
- $\mathrm{REQ}^{\mathrm{M}}$: user's mental model of REQ

Definition of Mode Confusion (2)

- "The user must not be surprised" (with respect to safety)
- mental model: specification
  reality: implementation
- a refinement relationship in an abstracted description

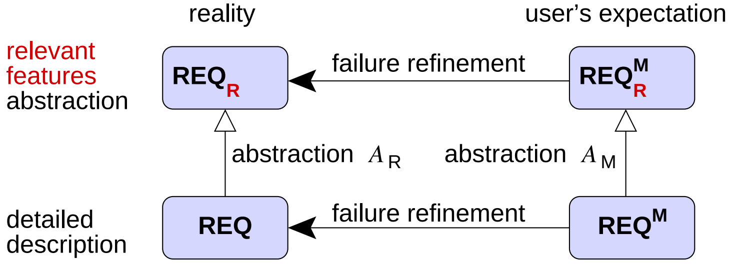


Definition of Mode Confusion (3)

- complete rigorous definition in:
  (Bredereke and Lankenau, 2002)
- formalism: CSP (Communicating Sequential Processes)
- also need to distinguish:
  reality – perceived reality
  - not so relevant for telephony

Adapt the Definition to Telephone Switching

- user does not abstract to safety-relevant aspects, but to the set of features relevant currently
- relevant features:
  currently active or can become active



2. Many FI are Mode Confusions

Mode Confusions in the FI Benchmark

benchmark example ID	# of mode confusions	benchmark example ID	# of mode confusions
CW&AC	–	OCS&CF/2	–
CW&TWC	2	CW&ACB	–
911&TWC	1	CW&CW	2
TCS&ARC	–	CW&TWC/2	1
OCS&ANC	–	CND&UN	–
Operator&OCS	–	CF&CF	–
CCC&VM	2	ACB&ARC	–
MBS-ED&CENTREX	–	LDC&MRC	1
CF&OCS	–	Hotel	2
CW&PCS	1	Billing	–
OCS&MDNL-DR	–	AIN&POTS	–

Summary of Mode Confusions in the FI Benchmark

8/22 benchmark examples with mode confusions

12 mode confusion problems total

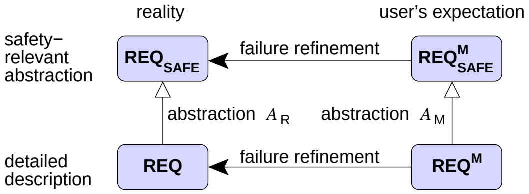
3. How the Notion of Mode Confusion Helps Against FI

Classification of Mode Confusion Causes

(Bredereke and Lankenau, 2002)

1. incorrect abstraction
2. incorrect knowledge
3. incorrect observation
4. incorrect processing

(3. and 4.:) less relevant in telephony



Designing Against Mode Confusions

- help user to avoid:
  - incorrect abstraction
  - incorrect knowledge

Incorrect Abstraction

- complexity of system makes correct abstraction difficult
- complexity factors (see FI benchmark):
  - non-determinism
  - long duration of feature activation
- resulting design rules:
  - give feedback on internal choices
  - terminate feature's activity at end of call, if possible
  - or give feedback on set of active features

Incorrect Knowledge

- feature's behaviour must be learnable
  - intuitive
  - complete training material
- resulting design rule:
  - redesign feature if not learnable
    - ▷ example: Call Waiting & Personal Communication Services

How to Check for Good Design

- (Vakil and Hansman, Jr., 2002):
  "operator directed design process"
  - write user training material before software specification
  - redesign immediately, if too difficult
- (Rushby, 2001), (Buth 2001),
  (Bredereke and Lankenau, 2002):
  model-check for mode confusions:
  system $\leftrightarrow$ mental model
  - extract mental model from user training material

Case Study on Model-Checking for Mode Confusions

- (Bredereke and Lankenau, 2002)
- shared-control service robot: autonomous wheelchair

- extracted mental model through user interview
- four mode confusion problems found
- mathematical proof that no further problems exist

Summary

- many FI are shared-control mode confusions
- Human Factors approach in design can help:
  - design rules derived from definition of mode confusion
  - design processes and tools derived to check for good design

4. References

Some References

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5. Material For Questions

Getting an Explicit Mental Model

according to (Rushby, 2001):

- from training material
- from user interviews
- by user observation

Example: Call Waiting & Call Waiting

- Call Waiting:
  - Alice gets call-waiting tone
  - Alice puts other party Bob on hold
- Call Waiting & Call Waiting:
  - Bob gets call-waiting tone, too
  - Bob puts Alice on hold, too
  - Alice finally returns to call with Bob
  - Alice hears nothing and is surprised

Causes of the Mode Confusion: Call Waiting & Call Waiting

- system has a mode where Alice is on hold when returning from Call Waiting
- Alice's mental model doesn't have this mode

- incorrect knowledge of Alice

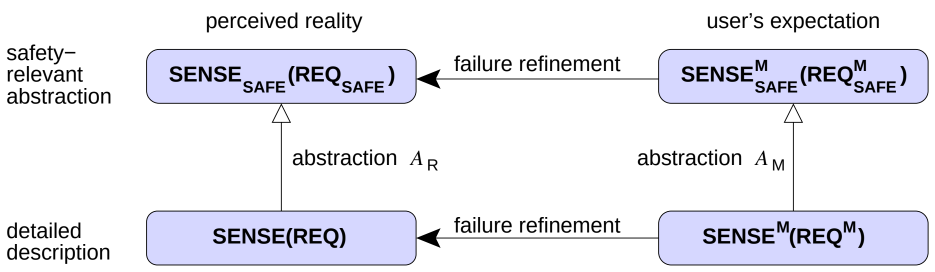
Example: Calling from Hotel Rooms

- hotel cannot determine whether call is completed
- hotel uses timer to guess
- user billed for incomplete call that rang a long time

Causes of the Mode Confusion: Calling from Hotel Rooms

- modes: not billing / billing
- incorrect knowledge:
  - user doesn't know about timer at all
- incorrect observation:
  - user does know about timer
  - user measures time not precisely

Complete Refinement and Abstraction Relations



Distribution of Mode Confusion Causes

cause \ ID	CW&TWC	POTS&POTS	911&TWC	CCC&VM	CW&PCS	CW&CW	CW&TWC/2	LDC&MRC	Hotel	Lock&Vol
incorrect observation									•	••
incorrect knowledge				•	•	••	•	•	•	
incorrect abstraction	•	•	•	•						
incorrect processing										•

Help User to Abstract His/Her Mental Model

- difficult for user: abstraction to relevant features
- enhance feedback
- is it obvious whether the feature is active?
- have simple features
- have few features active

Online Mode Confusion Detection and Resolution

- "intelligent" interface component
  - run-time detection of mode-confusion potential
    - ▷ model-checking of currently active feature set
  - resolution by specific, additional feedback
  - research just started

What Remains to Be Done?

- practical experience in telephony
- more feature design rules that
  help user to abstract to active set of features
  - "minimal safe mental model"
    in shared-control systems
  - how can user have a smaller mental model
    without a mode confusion?