Diversity:
Directions for research

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Contributors

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Outline

- redundancy, diversity for resilience of ubiquitous systems
- diversity: what we have and what we lack
- some research challenges identified in ReSIST

Laudata sii, Diversita`
delle creature, sirena
del mondo. [...]

D’Annunzio

Praise to you,
O Diversity of creatures,
siren of the world

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NOT our meaning of "diversity"

(but somewhat related)

Premise: Redundancy, diversity, resilience, ..

- interest in "Resilience" stresses dependability *despite imperfect knowledge* of threats and possible failure modes
- important role for redundancy
  - avoiding system failure despite broad ranges of component failures
- redundancy is effective if the chance of redundant parts failing together is small enough: diversity
  - desired: diversity *of failures*
  - pursued via: diversity of *construction* and *exposure*
  - linking means to results is (difficult) area for research
    - + pursued in the computing area over the last 20-30 years

Redundancy, diversity, resilience: the ReSIST angle

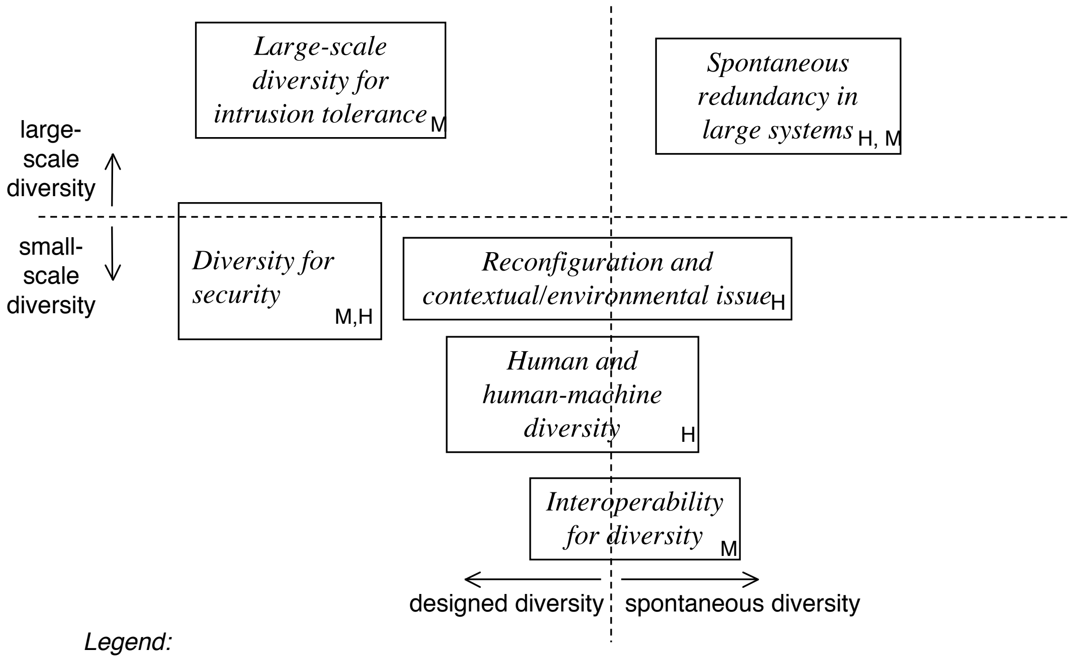
- redundancy to provide resilience... despite imperfect knowledge of threats/failures
- "ubiquitous ICT systems" - ReSIST's topic - provide many sources of *imperfection of knowledge*:
  - openness
  - change
  - enemies
  - multiple owners/managers
- ... as well as potential for redundancy
- *but also* for catastrophic common-mode or propagated failures
- thus new potential and need for *ensuring*, *exploiting, assessing* diversity

Past research about diversity ...

- has produced important results, with a focus on *embedded, small, closed, modular-redundant, safety critical control* systems
- hence necessary directions of expansion of research:

from	*towards*
small-scale diversity	large-scale diversity
dealing with unintended faults	dealing with malice as well
systems made of hardware and software	systems including people
closely controlled ("designed") diversity	more "spontaneous" diversity

The landscape of open problems



Large-scale diversity for intrusion tolerance M

Spontaneous redundancy in large systems H, M

large-scale diversity

small-scale diversity

Diversity for security M,H

Reconfiguration and contextual/environmental issue H

Human and human-machine diversity H

Interoperability for diversity M

designed diversity

spontaneous diversity

Legend:
H: involves consideration of human components
M: considers not only accidental faults, but malicious attacks

Scale of diversity

- current uses of diversity, and thus focus of past research, are "small scale"
  - e.g. safety-critical control systems with
    - + 2 channels, with 2-way diversity
    - + 2+2 channels, with 4-way diversity
    - + 4+1 channels, with 2-way diversity

- "small-scale" diversity is also present in ubiquitous systems, with new problems ...

- but what if we have potential for 10,100,..10^n-way diversity?
  the mathematics change... the experimental difficulties change...

Some challenges in small-scale diversity

- Interoperability for diversity
  - competing off-the-shelf products offer (almost) free diversity
  - but minor incompatibilities frustrate the would-be developer of diverse-redundant solutions
  - needed: extensions to selection methods and wrapping mechanisms, especially for run-time evolving configurations
- Reconfiguration and contextual/environmental issues
  - multiple/multimodal human-machine interfaces used to improve interaction
  - needed: methods for *using towards resilience:* assessing diversity aspects, planning reconfiguration for resilience

Some challenges in small-scale diversity -2

- Diversity for security
  - an attractive idea, some prototypes, e.g. server diversity, limited detailed analysis. Many options, trade-offs, unknowns
  - needed: more formal analysis of goals, effectiveness, trade-offs; more knowledge about efficacy of methods; designs dealing with collusions and multiple attacks
- Human diversity and human-machine diversity
  - integrated socio-technical systems rely on extensive redundancy between human and machine components
  - needed: extending models to account for humans' heterogeneity and changeability; inclusion of more psychological and sociological knowledge

Some challenges in large-scale diversity

- Large-scale diversity for intrusion tolerance
  - scattering techniques tolerate intrusion if intruders cannot break into too many machines at once. Need to diversify vulnerabilities among many servers
  - needed: more automatic diversification techniques, at various architectural levels; methods for evaluating and selecting

- Spontaneous redundancy in large systems
  - multi-node socio-technical networks with *potential* for redundant service delivery, connectivity, monitoring...
  - needed: methods for *discovering* redundancy, *assessing* actual failure diversity, *organising* the exploitation of spontaneous redundancy

Conclusions?

Important challenges:

- items of technical knowledge needed for deploying effective diversity in large socio-technical systems
- requiring extension of current knowledge in multiple directions

... presented here for discussion