Calculation and Communication

A Climate Change Controversy

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A tale of woe

An episode from a workshop organized at PIK in 2006. Participants from two communities: climate change and development studies. Former talk about “vulnerability to climate change”, latter about “vulnerability to poverty”.

Problem: Should it be “vulnerability to <deleterious effect>” or “vulnerability to <cause of said effect>”?

“Holy seems the quarrel” AW III.i.4.2
Don’t you wish . . .


Quo facto, quando orientur controversiae, non magis disputatio opus erit inter duos philosophos, quam inter duos Computistas. Sufficiet enim calamos in manus sumere sedereque ad abacos, et sibi mutuo (accito si placet amico) dicere: calculemus.

“Ay me, for pity! What a dream was here!” MND II.ii.153
Why all the fuss?

...The complexity of the climate, ecological, social and economic systems that researchers are modelling means that the validity of scenario results will inevitably be subject to ongoing criticism.

...What this criticism does, however, is emphasize the need for a strong foundation upon which scenarios (i.e., modelling) can be applied, a foundation that provides a basis for managing risk despite uncertainties associated with future climate changes.

_This foundation lies in the concept of vulnerability._

(from “Climate Change Impacts and Adaptation”, 2004)

“of great import indeed, too” LLL V.i.95
Definitions of vulnerability

“...a human condition or process resulting from physical, social and environmental factors which determine the likelihood and damage from the impact of a given hazard” (UNDP Annual Report, 2004)

“Vulnerability [...] is a way of conceptualizing what may happen to an identifiable population under conditions of particular risk and hazards.” (Cannon et al. 2004)

“vulnerability: the extent to which climate change may damage or harm a system.” (The Intergovernmental Panel on Climate Change, 1995)

“Define, define, well-educated infant.” LLL I.ii.90
The latest IPCC definition

**vulnerability:** the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

(The Intergovernmental Panel on Climate Change, 2007)

“...authority, though it err like others, / Hath yet a kind of medicine in itself” MM II.ii.134-5
vulnerable (adj.):

1. exposed to the possibility of being attacked or harmed, either physically or emotionally: *we were in a vulnerable position* | *small fish are vulnerable to predators*

2. Bridge (of a partnership) liable to higher penalties, either by convention or through having won one game towards a rubber.

(Oxford English Dictionary, 2005)

“…things acquainted and familiar to us” 2H4 V.ii.139
The practice of vulnerability assessment

1. run model a number of times under various scenarios
2. collect "indicators" of "badness" along the different trajectories (e.g. GDP loss, average temperature increase, lost lives . . . )
3. aggregate the collected data (in most cases by some sort of weighted average) into a vulnerability measure

"... no words, but deeds ..." 1H6 III.ii.49
The “logical form” of vulnerability

\[ \text{possible} :: \text{Functor } F \Rightarrow \text{State} \rightarrow F \ [\text{State}] \]
The “logical form” of vulnerability

\[
possible :: \text{Functor } F \Rightarrow \text{State} \rightarrow F [\text{State}]
\]

\[
harm :: \text{Preorder } V \Rightarrow [\text{State}] \rightarrow V
\]
The “logical form” of vulnerability

\[ \text{possible} :: \text{Functor } F \Rightarrow \text{State} \rightarrow F [\text{State}] \]

\[ \text{harm} :: \text{Preorder } V \Rightarrow [\text{State}] \rightarrow V \]

\[ \text{measure} :: \text{Functor } F, \text{Preorder } V, \text{Preorder } W \Rightarrow F V \rightarrow W \]
The “logical form” of vulnerability

possible :: Functor $F$ ⇒ $State$ → $F[State]$

harm :: Preorder $V$ ⇒ $[State]$ → $V$

measure :: Functor $F$, Preorder $V$, Preorder $W$ ⇒ $F V$ → $W$

vulnerability :: Preorder $W$ ⇒ $State$ → $W$
The “logical form” of vulnerability

possible :: Functor $F \Rightarrow \text{State} \rightarrow F \left[ \text{State} \right]

harm :: \text{Preorder } V \Rightarrow \left[ \text{State} \right] \rightarrow V

measure :: \text{Functor } F, \text{Preorder } V, \text{Preorder } W \Rightarrow F \left[ V \right] \rightarrow W

vulnerability :: \text{Preorder } W \Rightarrow \text{State} \rightarrow W

vulnerability = measure \circ \text{fmap harm} \circ \text{possible}

“...formal ostentation” Ham IV.v.215
The OED example revisited

“Small fish are vulnerable to predators”

\[ \text{predators} :: [\text{State}] \rightarrow \text{Bool} \]
\[ \text{wounded} :: [\text{State}] \rightarrow \text{Bool} \]

\[ \text{harm} :: [\text{State}] \rightarrow \text{Bool} \]
\[ \text{harm} = \text{wounded} \land \text{predators} \]

“expound the meaning or moral of his signs and tokens.” TS IV.iv.77
A difference of emphasis

General pattern: the computation of harm results from assessing the some impacts along those evolutions which are influenced by some factors of interest (such as climate change or predators).

In development studies, researchers are interested more in the evolutions which end up with a population subject to poverty (no matter what the cause might be).

In the climate change community, the focus is on those evolutions influenced by anthropogenic global warming (no matter what the impacts might be).

“Henceforth I charge you [...] / Quite to forget this quarrel” 1H6 IV.i.136
The latest IPCC definition

**vulnerability**: the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

(The Intergovernmental Panel on Climate Change, 2007)

“Must I remember?” Ham l.ii.143
Sensitivity

*sensitivity*: the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

(The Intergovernmental Panel on Climate Change, 2007).

“What must we understand by this?” AYL IV.iii.95
Sensitivity, ctd.

“the degree to which a system is affected [...] by climate change”

$sensitivity :: [State] \rightarrow V1$
Sensitivity, ctd.

“the degree to which a system is affected […] by climate change”

\[ sensitivity :: [State] \rightarrow V1 \]

“adverse effects”

\[ impacts :: [State] \rightarrow V2 \]
Sensitivity, ctd.

“the degree to which a system is affected […] by climate change”

\[ \text{sensitivity} :: [\text{State}] \to V1 \]

“adverse effects”

\[ \text{impacts} :: [\text{State}] \to V2 \]

\[ \text{harm} :: [\text{State}] \to V \]
\[ \text{harm} = \text{combine} \circ \text{pair} \left( \text{impacts}, \text{sensitivity} \right) \]

“A pair of cursed hell-hounds …” Tit V.ii.144
Adaptive Capacity

*adaptive capacity*: the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

(The Intergovernmental Panel on Climate Change, 2007).

“You must translate. ’Tis fit we understand them.” Ham IV.i.2
Adaptive Capacity, ctd

“the ability of a system to adjust . . . , take advantage . . . , cope . . .”

\[ available\text{Actions} :: \text{State} \rightarrow [\text{Action}] \]
Adaptive Capacity, ctd

“the ability of a system to adjust . . ., take advantage . . ., cope . . .”

\[ availableActions :: State \rightarrow [Action] \]

the evolutions of a system that does not react

\[ standard :: State \rightarrow F [State] \]
Adaptive Capacity, ctd

“the ability of a system to adjust . . . , take advantage . . . , cope . . .”

\[\text{availableActions} :: \text{State} \rightarrow [\text{Action}]\]

the evolutions of a system that does not react

\[\text{standard} :: \text{State} \rightarrow F [\text{State}]\]

\[\text{possible } s = (\text{standard } s) \oplus (\text{availableActions } s)\]

“Is able with the change to kill and cure.” 2H6 V.i.101
Adaptive Capacity, ctd

Example

\[ F = [] \]
\[ f :: State \to Action \to [State] \]
\[ ss \oplus as = [f s a | s \leftarrow ss, a \leftarrow as] \]

\[
possible s_0 = [f s a | s \leftarrow standard s_0, a \leftarrow availableActions s_0] \\
= (standard s_0) \oplus (availableActions s_0)
\]

“And on all sides th’ authority allowed.” H8 II.iv.4
Adaptive Capacity, ctd

vulnerability s
Adaptive Capacity, ctd

\[
vulnerability \ s = \ \{ \text{Definition of vulnerability} \}\ 
\]

\[
measure (fmap \ harm (possible \ s))
\]
Adaptive Capacity, ctd

\[ \text{vulnerability } s \]

\[ = \{ \text{Definition of vulnerability} \} \]

\[ \text{measure } (fmap \text{ harm } (\text{possible } s)) \]

\[ = \{ \text{Express possible evolutions in terms of standard ones} \} \]

\[ \text{measure } (fmap \text{ harm } ((\text{standard } s) \oplus (\text{availableActions } s))) \]
Adaptive Capacity, ctd

\[ vulnerability \ s \]

\[ = \{\text{Definition of vulnerability}\} \]

\[ measure \ (fmap \ harm \ (possible \ s)) \]

\[ = \{\text{Express possible evolutions in terms of standard ones}\} \]

\[ measure \ (fmap \ harm \ ((standard \ s) \oplus (availableActions \ s))) \]

\[ = \{\text{introduce } \otimes \text{ explained below}\} \]

\[ (measure \ (fmap \ harm \ (standard \ s))) \otimes ((availableActions \ s)) \]
Adaptive Capacity, ctd

\[ \text{vulnerability } s \]

\[ = \{ \text{Definition of vulnerability} \} \]

\[ \text{measure } (fmap \text{ harm } (\text{possible } s)) \]

\[ = \{ \text{Express possible evolutions in terms of standard ones} \} \]

\[ \text{measure } (fmap \text{ harm } ((\text{standard } s) \oplus (\text{availableActions } s))) \]

\[ = \{ \text{introduce } \otimes \text{ explained below } \} \]

\[ ((\text{measure } (fmap \text{ harm } (\text{standard } s))) \otimes ((\text{availableActions } s))) \]

\[ = \{ \text{introducing stdVulnerability and adaptiveCapacity} \} \]

\[ (\text{stdVulnerability } s) \otimes (\text{adaptiveCapacity } s) \]

"it were pity you should get your living by reck’ning, sir.”  LLL  V.ii.496-7
Adaptive Capacity, ctd

The condition required for the calculation to hold is a sort of distributivity: for all \(ss : [State], as : Actions\)

\[
\text{measure } (fmap \text{ harm } (ss \oplus as)) = \\
(\text{measure } (fmap \text{ harm } ss)) \otimes as
\]

In some studies, it is easy to see that this condition holds.

“But so it must be” R3 l.iii.16
Conclusions

Win some:

1. three PhD thesis directly from this work, one greatly influenced, another one funded by it
2. about five publications in peer reviewed journals, many technical reports, talks, deliverables
3. sparkled similar activities in and around PIK (resilience), spread a different idea of mathematics (not just about numbers)

Lose some:

1. poor follow-through

“winner and loser?” Ham IV.v.145
Some lessons learned

1. formalization can be effective in communication
2. a lot of scope for applying computer science formalisms outside computer science (e.g. $\pi$-calculus to systems biology)
3. many scientists were interested in calculational proofs
4. ... but not when it came to scientific programming

“Before I came, marry, thus much I have learned” LLL II.i.84