

Introduction to uncertainty

Davide Ciucci

Outline

1. Daily uncertainties

- Example of how uncertainty is ubiquitous

2. More formally

- Different kind of uncertainty
- More detailed example: three-valued logics

1. Daily uncertainties

April 2020

Il virus dell'incertezza

Francesco Guala

Today's Market | Market Outlook

Market Update: Finding Positives Amid Covid-19 Uncertainty

Mar. 14, 2020 9:31 AM ET | 2 Likes | Includes: ACWF, ACWI, AIQ, BAPR, BAUG, BIBL, BJUL, BJUN, BOCT, CHG...

5 Steps to Living with Uncertainty During Coronavirus

A guide for responding to anxiety and lack of contr

Posted Mar 11, 2020

Home > Politics > Legislators Narrowing Priorities Amid COVID-19 Uncertainty

Politics

Legislators Narrowing Priorities Amid COVID-19 Uncertainty

By Danielle E. Gaines | Bruce DePuyt | Hannah Gaskill - March 14, 2020

Ciò che genera disagio è l'incertezza, Eva Alcara dalla Spagna

Giuseppe Criseo Categoria principale: SOCIETA' SALUTE E BENESSERE 15 Marzo 2020 15 Marzo 2020 🔥 Visite: 13

Ratings ☆☆☆☆☆ (0)



Gli psicologi affermano che ciò che genera uno stato mentale peggiore non sono le incertezze su ciò che accadrà.

Coronavirus / 12 Marzo, 2020

Sport e la grande incertezza

TICINO, GRIGIONI E INSUBRIA

Sospesi nell'incertezza

Il Ticino vive la prima domenica della storia senza messe.
#Distantimavicini anche ai funerali

April 2021

Israel's secrecy on vaccines is causing supply uncertainty, says state adviser

EMERGENZA CORONAVIRUS

Vaccini Toscana, incertezza sulle forniture di Moderna. Aprile a rischio per 45 mila fragili

Caso AstraZeneca, i settantenni che avevano appuntamento oggi sono stati rinviati al 7 aprile. Giani: «Confermati quelli di domani»

Vaccini, Giani, 20mila giorno a over 80, incertezza per fragili

'In dubbio per arrivo dosi Moderna, se oggi o domani'

Vaccini, si viaggia nell'incertezza: in arrivo dosi di Pfizer e un "assaggio" di Johnson

Di Redazione - 10 Aprile 2021

ECONOMIA

Fed ottimista sui vaccini ma "l'incertezza rimane"

'Everyone here is confused': Europe's see-sawing over AstraZeneca's vaccine is stoking uncertainty

PUBLISHED THU, APR 1 2021 4:36 AM EDT | UPDATED THU, APR 1 2021 7:24 AM EDT

The long shot: delays, uncertainty and confusion in Australia's vaccine rollout

March 2022

**UCRAINA, BRI: SANZIONI ALLA RUSSIA
ACCENTUANO L'INCERTEZZA, SITUAZIONE PIÙ
DIFFICILE PER BANCHE CENTRALI**

teleborsa 

Week Ahead – Enormous Uncertainty

By MarketPulse (Craig Erlam) | [Market Overview](#) | 21 hours ago (Mar 04, 2022 03:06PM ET)

Opinion [War in Ukraine](#)

The crisis in Ukraine adds a further dose of uncertainty to markets

Investors have ridden out previous geopolitical tremors, but this one
might be different

**GAS, IL PREZZO CONTINUA A CORRERE.
INCERTEZZA SU FORNITURE**

**Covid-19 impact on mortality rate 'drives uncertainty'
for schemes over the medium term**

Uncertainty permeates reality

- `The most harrowing contemporary fears are born of existential uncertainty'' [Z. Bauman, 2007]
- ``Uncertain is the natural state of things'' [S. Parsons, 2001]
- To represent and manage knowledge, we have to recognize and manage **uncertainties** (different kinds of uncertainty)
- Let's see some examples

Text interpretation

- “Swish un blunt, a swishland/Bling Blaow come i Beatles/Blessing, Tic Tac, le prendo dal mattino”
- Understand irony

Spinoza LIVE @LiveSpinoza · 13 mar
L'Ucraina offre un milione di dollari ai piloti russi disposti a consegnare il proprio aereo. Due, se hanno fatto il pieno.

Evaluate a purchase

Do we have enough information to spend 1355€?



oroa.com, 1355€



amazon.com, 9.39€

Risk assessment

- Order by decreasing probability
 1. Being struck by lightning in 80 years
 2. Dying in a plane crash
 3. Winning at the lottery (superenalotto)
 4. Guessing the code of an ATM card

Decision making

- Which ice-cream flavor to choose
 - Positive side of uncertainty (there does not exist only the flavor “*KitKat al té verde Macha*”!)
 - P. Vidali, F. Neresini, “Il valore dell’incertezza”, Mimesis Edizioni, 2015
- A physician has to make a diagnosis
 - Evaluation of symptoms and exams
 - Image analysis (x-rays, tomography scan,...)

Uncertainty Representation and Machine Learning

How most algorithms need data

Patient	Mitral rigurgitation	Acute dyspnea	Bicuspid aortic valve	EKG stress test
P1	No	Heart failure	Yes	Positive
P2	No	COPD	No	Negative
P3	Yes	Pneumonia	No	Positive
P4	Yes	Heart failure	Yes	Negative
P5	yes	Heart failure	No	Negative
P6	yes	COPD	No	Positive
P7	yes	pneumonia	No	Positive

"Data is not a perfect representation of reality: It's a fundamentally human construct, and therefore subject to biases, limitations, and other meaningful and consequential imperfections." Andrea Jones-Rooy, NYU

Uncertainty representation and Machine Learning

How data are

Patient	Mitral rigurgitation	Acute dyspnea	Bicuspid aortic valve	EKG stress test
P1	No	Heart failure (highly confident)	Yes (sure)	Positive (highly confident)
P2	Mild	COPD (highly confident)	No (confident)	Negative (highly confident)
P3	Moderate	Pneumonia (highly confident)	No (confident)	Not performed
P4	Severe	Heart failure (highly confident) or pneumonia (low confident)	Yes (highly confident)	Negative (confident)
P5	Moderate or Severe	Heart failure (highly confident) or pneumonia (highly confident)	Undetermined	Undetermined
P6	Mild or Moderate	COPD or pulmonary embolism or pneumonia	Not applicable	Not available
P7	Undetermined	Heart failure and pneumonia	Not applicable	Positive (confident)

Uncertainty Representation and Communication

2020

Regione	AGGIORNAMENTO 31/03/2020 ORE 17.00							
	POSITIVI AL nCoV				DIMESSI/ GUARITI	DECEDUTI	CASI TOTALI	TAMPONI
	Ricoverati con sintomi	Terapia intensiva	Isolamento domiciliare	Totale attualmente positivi				
Lombardia	11.883	1.324	11.917	25.124	10.885	7.199	43.208	114.640
Emilia Romagna	3.765	353	6.835	10.953	1.477	1.644	14.074	54.532
Veneto	1.680	356	5.814	7.850	828	477	9.155	106.238
Piemonte	3.174	452	4.456	8.082	365	854	9.301	27.658
Toscana	1.120	293	2.813	4.226	138	244	4.608	33.165
Marche	946	169	2.237	3.352	21	452	3.825	11.724
Liguria	1.153	179	1.176	2.508	480	428	3.416	10.376
Lazio	1.127	173	1.342	2.642	291	162	3.095	34.677
Campania	501	133	1.237	1.871	88	133	2.092	14.403
Trento	354	80	955	1.389	193	164	1.746	6.973
Puglia	609	105	940	1.654	39	110	1.803	14.073
Friuli V.G.	215	60	885	1.160	320	113	1.593	14.899
Sicilia	503	72	917	1.492	74	81	1.647	15.634
Abruzzo	335	73	783	1.191	95	115	1.401	8.758
Bolzano	249	62	831	1.142	153	76	1.371	11.275
Umbria	176	43	632	851	190	37	1.078	8.685
Sardegna	113	28	516	657	34	31	722	5.257
Calabria	132	17	457	606	17	36	659	9.327
Valle d'Aosta	91	26	435	552	20	56	628	1.582
Basilicata	37	17	162	216	3	7	226	2.043
Molise	29	8	80	117	18	9	144	1.049
TOTALE	28.192	4.023	45.420	77.635	15.729	12.428	105.792	506.968

ATTUALMENTE POSITIVI	77.635
TOTALE GUARITI	15.729
TOTALE DECEDUTI	12.428
CASI TOTALI	105.792

- (Different kind of) missing data
- non uniform in time and space
- selection bias

- <https://www.francescocosta.net/2020/03/19/dati-ufficiali-illusione-ottica/>
- <https://www.ilpost.it/2020/03/27/tamponi-lombardia-fontana-coronavirus/>
- <https://www.statnews.com/2020/03/17/a-fiasco-in-the-making-as-the-coronavirus-pandemic-takes-hold-we-are-making-decisions-without-reliable-data/>

Uncertainty Representation and Communication

2021

- Anche in questo caso, i vaccini
- <https://www.valigiablu.it/sospensione-vaccino-comunicazione-scientifica/>
 - “**cosa** viene comunicato, cioè l'oggetto dell'incertezza e la sua fonte”
 - “il **livello** e la **magnitudine** di questa incertezza”
 - “**come** comunicare l'incertezza, cioè in quale forma e con quali espressioni”
 - “**perché** comunichiamo l'incertezza, cioè a quale scopo e quali possono essere gli effetti di questa comunicazione”

Risk assessment - solution

1. Being struck by lightning in 80 years: $1/10.000$
2. Guessing the code of an ATM card: $1/90.000$
3. Dying in a plane crash: $1/11.000.000$
4. Winning at the lottery (superenalotto): 1 su 622.614.630

2. A bit more formally

Definition of uncertain (Merriam-Webster)

1. **Not** known beyond doubt, **not** having **certain** knowledge, **not** clearly identified or defined
2. **Not** constant, variable
3. **Indefinite**, **indeterminate**
4. **Not** certain to occur
5. **Not** reliable, untrustworthy

Definition by negation, however, not always has a negative role

Different forms of uncertainty - examples

- Uncertainty meant as an imperfection in information due to different causes
- **Objects, Agents, Properties**: an agent has an opinion on the properties of the objects
 - Example: objects=cars, properties={color, years}
- Different tools to handle uncertainty —> Beyond probability

Incomplete Information

- **Missing values**
 - I want to decide if "That car is yellow" is true/false and... I do not know the color of the car
- **Imprecise values:** "the car is between 10 and 15 years old"
- **Missing properties**, the existing properties are not enough to describe some objects
 - Example: objects = patients, properties=symptoms
 - Symptoms are not enough to understand if x has illness y
 - I know the extension of the set (the objects/patients) and not the intension, i.e., the description (the properties/symptoms)

Randomness and vagueness

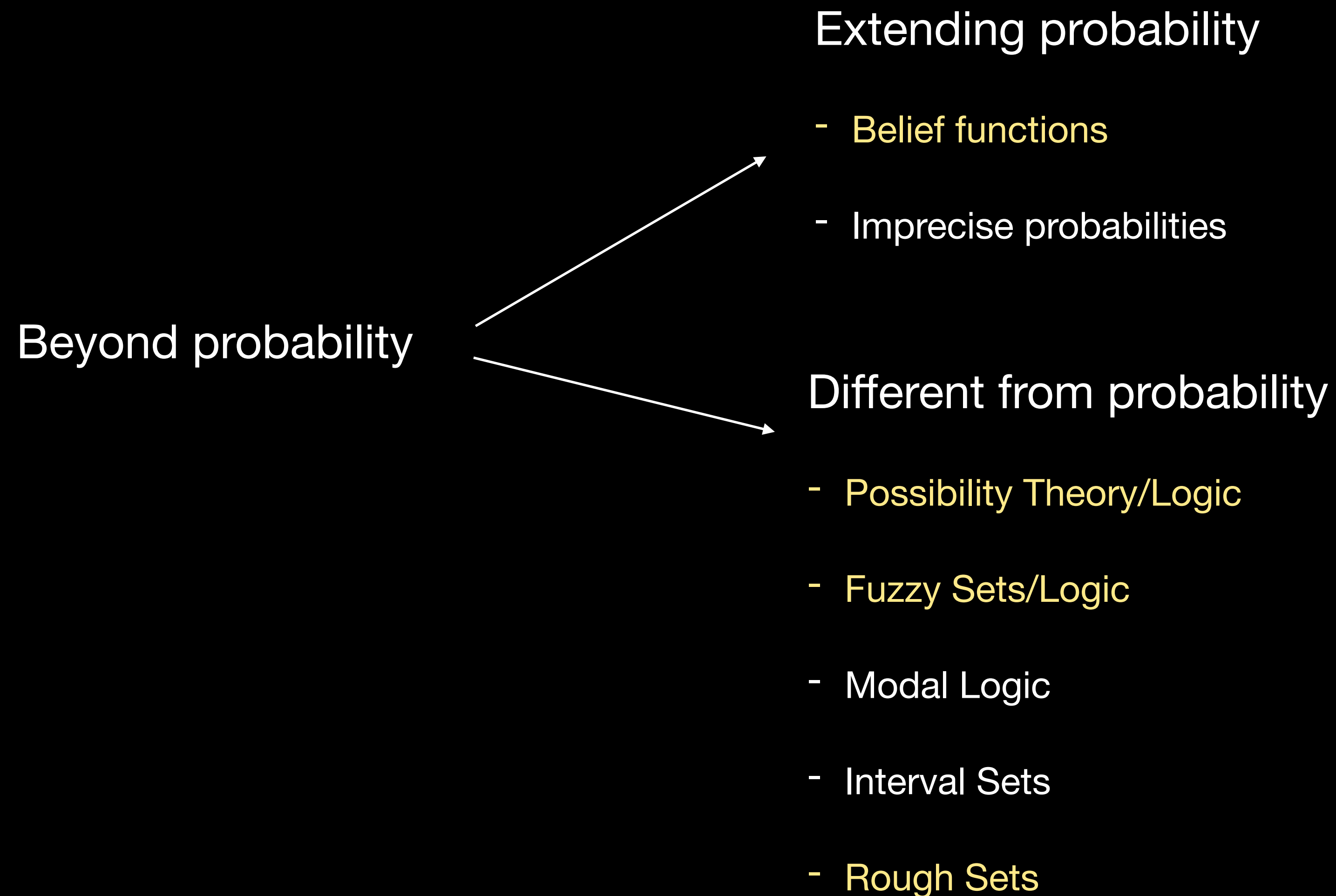
- Impossibility to establish the truth (**randomness**)
 - “Tomorrow it will rain”
- **Vagueness/graduality**
 - “That car is fast”
 - What does it mean *fast*?
 - It is a gradual information (we could assign a degree of speed)
 - Context dependence: 1916 \neq 2016, formula 1 \neq compact car

Not reliable information

- **Conflicting information**
 - Different agents with different opinions. Example:
Agent A "I have seen D. Ciucci in Milano on 23 March 2022 at 12"
Agent B "I have seen D. Ciucci in Rome on 23 March 2022 at 12"
 - Pros/cons
 - Example/counterexamples
- **Not complete trust:** we do not have a complete trust in our data
 - Example: "Giulia's car is red or black, surely not blue", "I have low confidence that Marco's leg is broken"

Beyond probability

Different tools to handle uncertainty —> Beyond probability



The uncertainty of uncertainty classification

- There exists several forms of uncertainty
- Several proposals to classify them, usually in the form of a taxonomy
- These classifications differs in term of
 - **Scope**: the wideness of the field embraced by that classification
 - **Criteria**: source of uncertainty, entailed problems, way to handle, ...

Scope: **general taxonomy**

- A taxonomy with the scope of being universal, that is to capture all kinds of uncertainty and not specific to a particular field
- Taxonomies in the next slide are taken from
 - Simon Parsons “Qualitative Reasoning Under Uncertainty”, MIT Press, 2001

Scope: general taxonomy

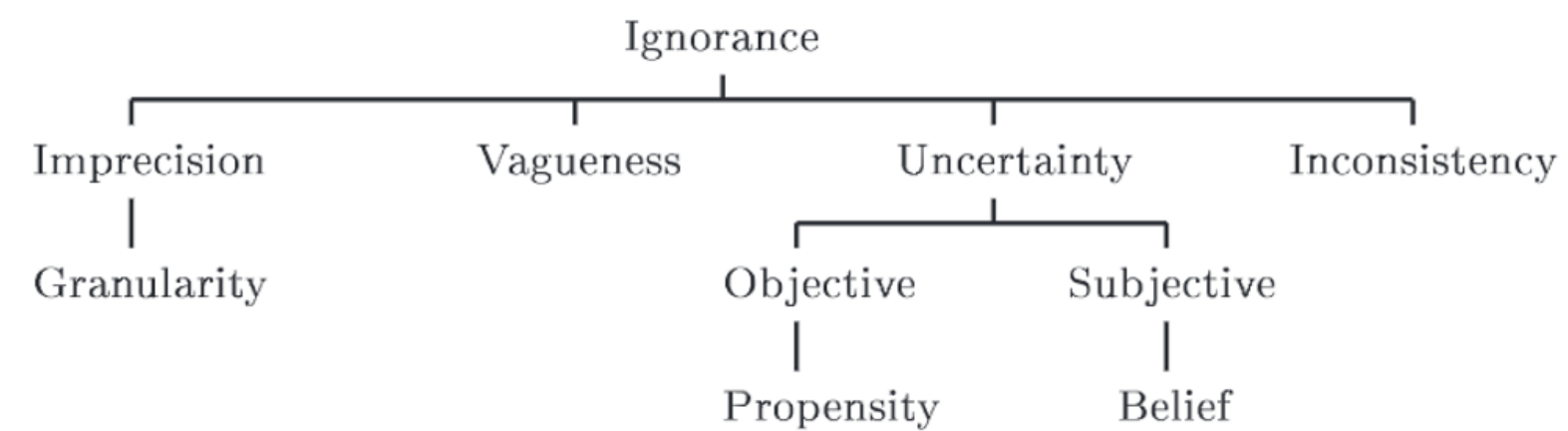


Figure 2.4
Bosc and Prade's taxonomy

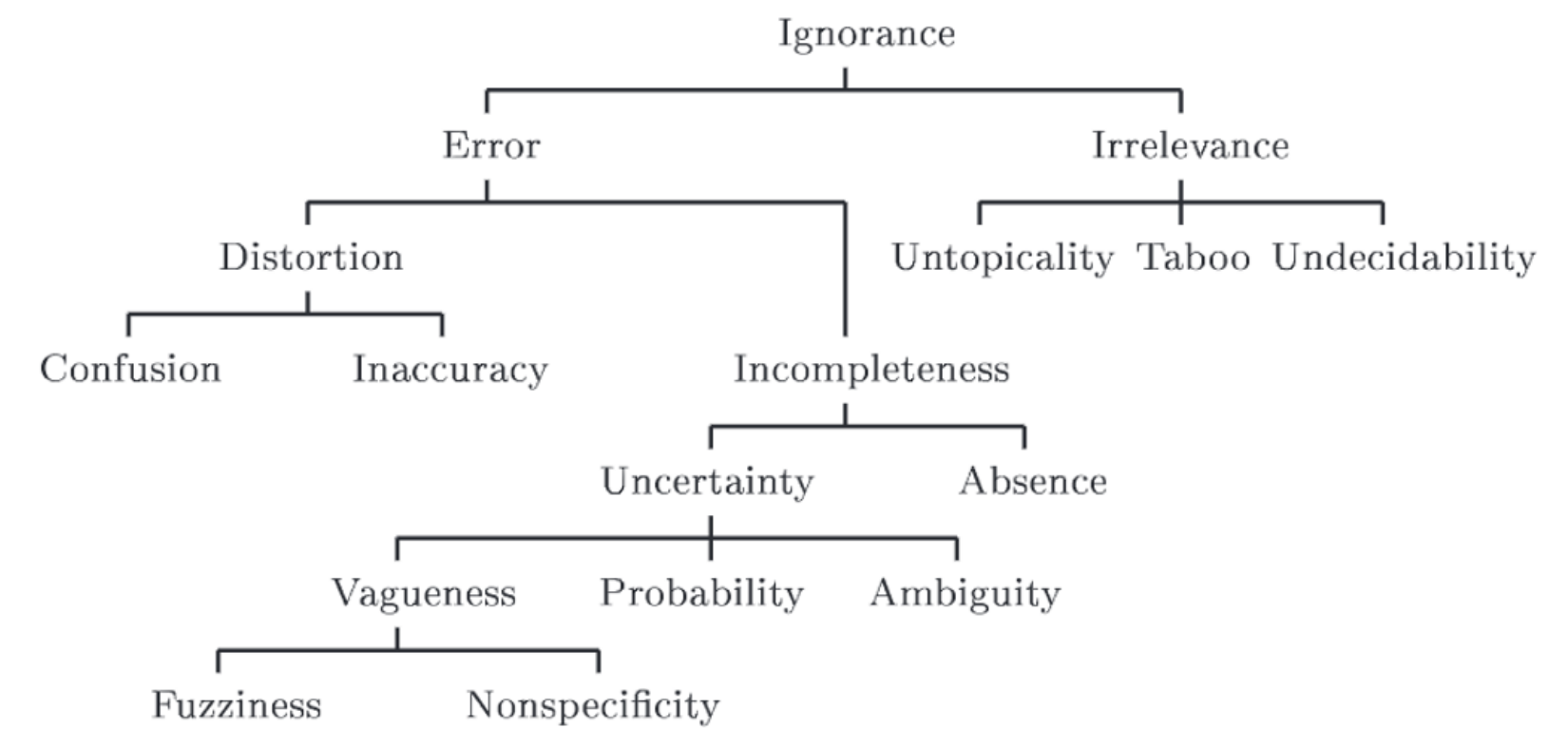


Figure 2.1
Smithson's taxonomy

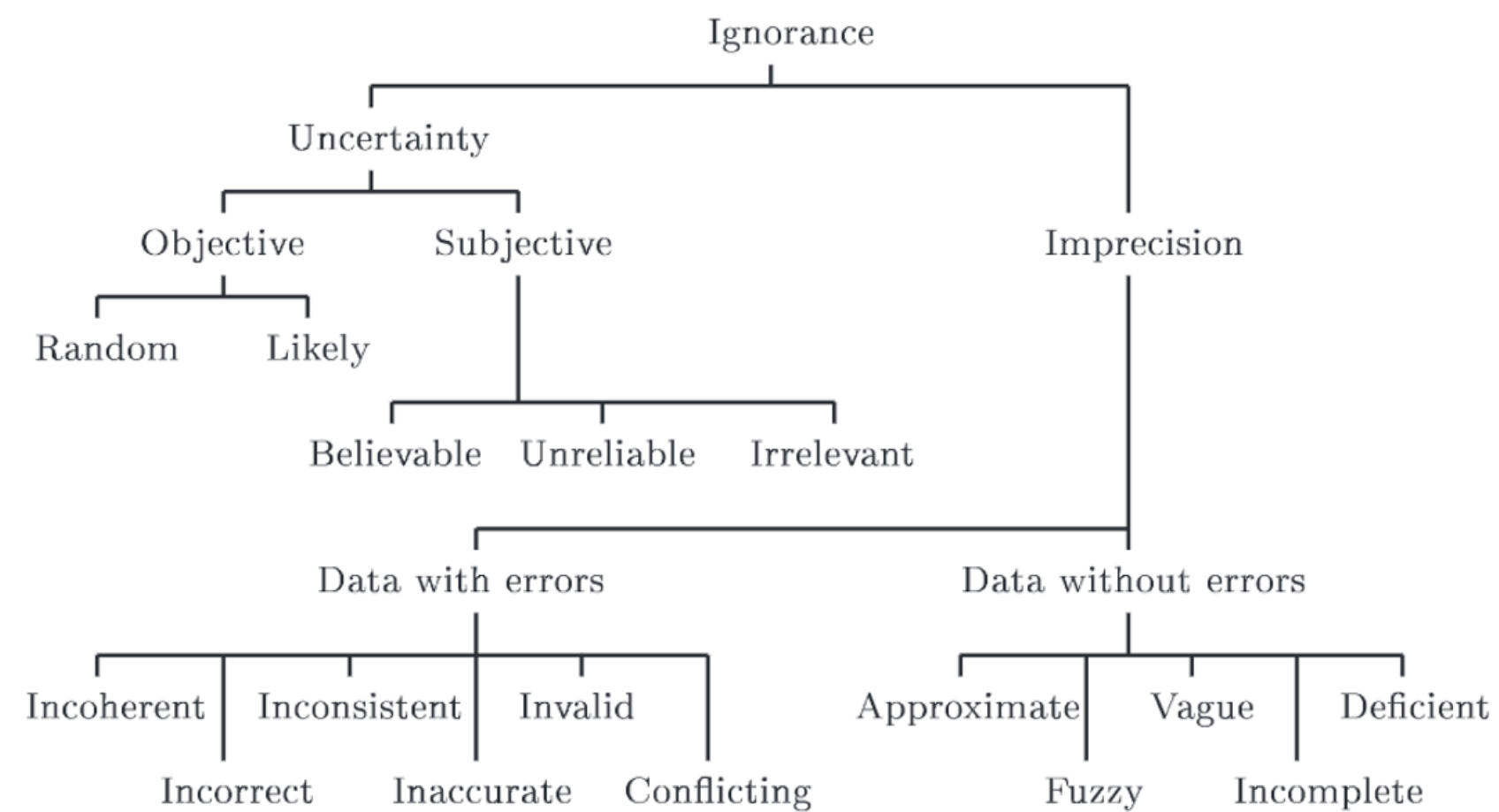


Figure 2.2
Smets' taxonomy

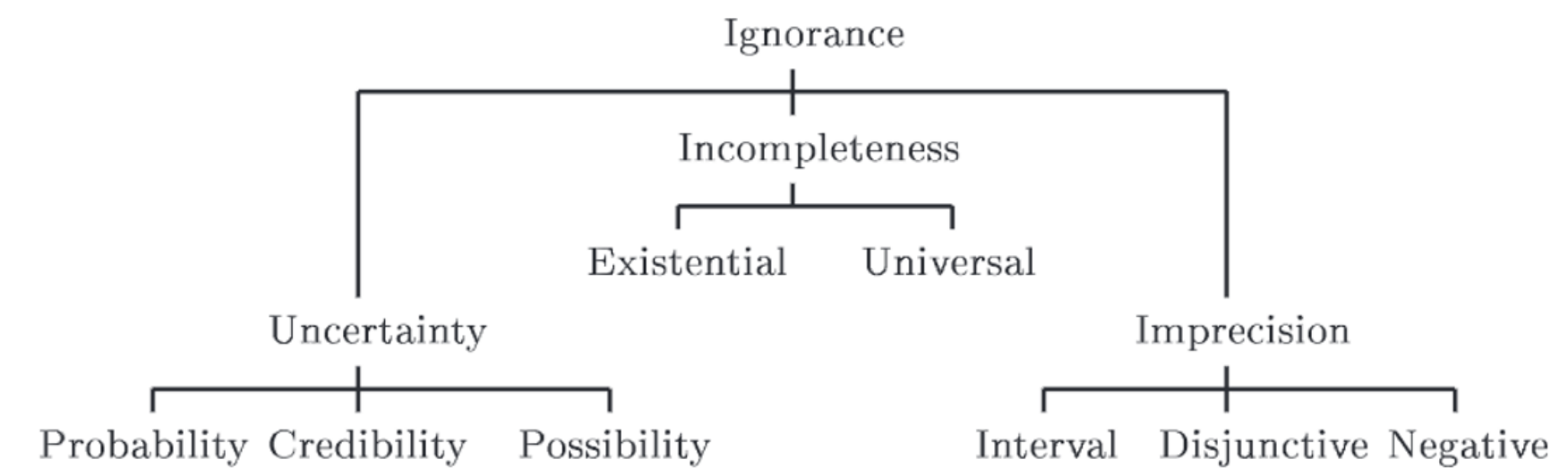


Figure 2.3
Bonissone and Tong's taxonomy

General taxonomy: some comments

- The root is always *ignorance*
- No term occurs in all the taxonomies
- Some appear in 3 out of 4, but not always in the same “position” (e.g. vagueness)
- Different terms may refer to the same problem
 - Ambiguity/inconsistency: impossibility to distinguish between alternatives
- More or less detailed classification (in the examples, from 9 to 23 types)

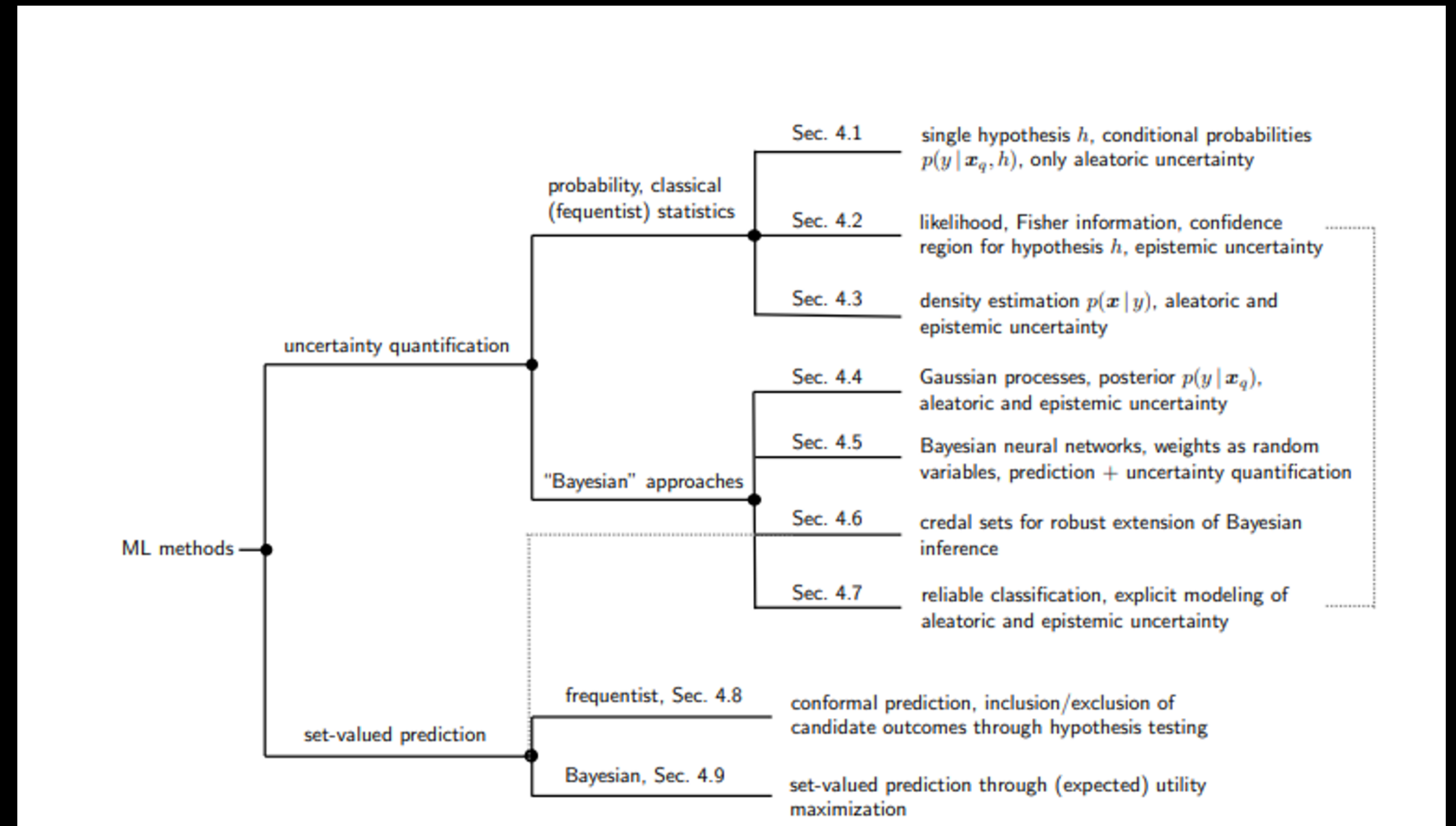
General taxonomy: some comments (Parsons)

1. “A complete and consistent analysis of all the many varieties of uncertainty involved in human thinking and revealed in human language is a philosophical goal that we should not expect to achieve soon (Elkan, 1994)”
2. These taxonomies “draw attention to the fact that there are a large number of different types of ignorance and uncertainty” (Parsons, 2001)
3. “Comparing all the different types of uncertainty suggested in the different classifications, it is possible to extract some common concepts” (Parsons, 2001)

Scope: disciplinary taxonomy

we restrict to a specific field, e.g. ecology or machine learning

Source of uncertainty
Epistemic uncertainty
Measurement error
Systematic error
Natural variation
Inherent randomness
Model uncertainty
Subjective judgment
Linguistic uncertainty
Numerical vagueness
Nonnumerical vagueness
Context dependence
Ambiguity
Indeterminacy in theoretical terms
Underspecificity



Scope: domain taxonomy

the area of interest is more specific such as volunteered-geographic information (VGI) or dynamical adaptive systems

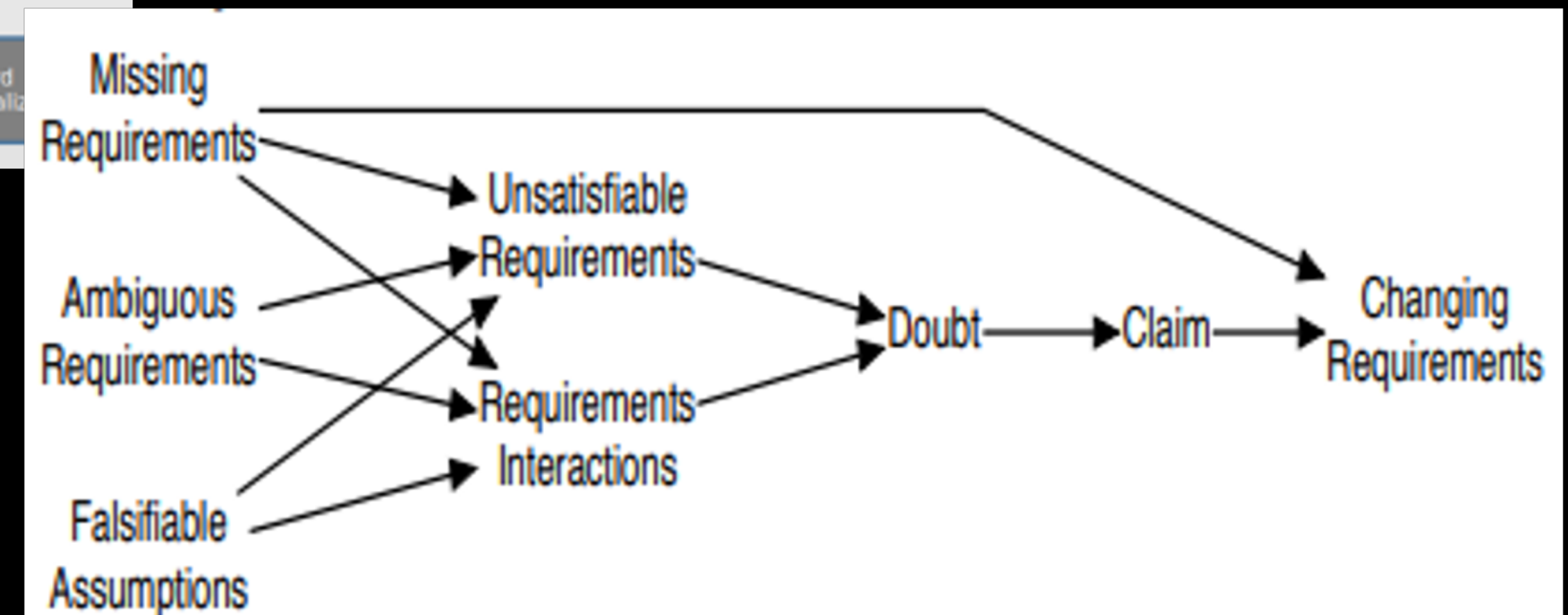
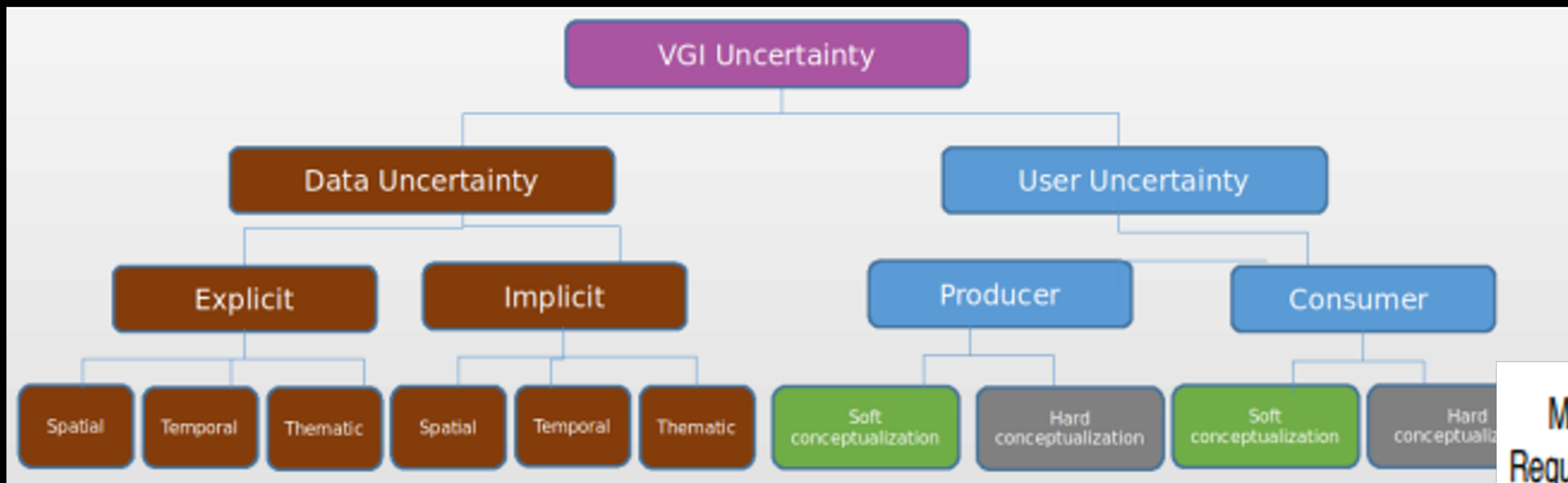


Figure 2. Taxonomy of Uncertainty at the Requirements Level.

Domain taxonomy: some comments

- The more narrow the domain, the more specific the classification and terminology
- Domain ontology can be useful in understanding where uncertainty is and then where to act to manage it
- When building a domain classification, the general picture of uncertainties should be clear

Criteria of the classification

- **Source**: the main criterion, but can have different meanings also depending on the domain
 - Data Uncertainty or User Uncertainty [VGI]
 - Spatial/temporal/linguistic uncertainties [Digital Humanities]
 - Requirement/project/runtime uncertainties [Dynamically Adaptive Systems]
- **Concrete manifestation**: where you can see the effect of uncertainty
 - Psychological and social consequences, effect on diagnosis, prognosis or therapy, etc. [clinical genome sequencing]
- **Who is carrying the uncertainty**
 - Patient, family, paziente, physician [clinical genome sequencing]

Not only taxonomies: Multiple perspectives

Box 2 Clinician perspective

I. Source

- A. Probability: Mark's genomic variant confers some risk of drug-induced myopathy
- B. Ambiguity: the strength of the scientific evidence linking Mark's genomic variant with drug-induced myopathy is not clear

2. Methodological

- c. Unmeasured factors: associations with additional biological variables that may play a causal role have not been established

C. Complexity

3. Effect modification

- a. Gene-environment interactions: Mark's exercise program and other environmental and behavioral factors may moderate the risk of drug-induced myopathy

II. Issue

A. Scientific

1. Diagnostic

- a. Phenotype-disease association: whether Mark's hypercholesterolemia will result in cardiovascular disease; whether Mark's genomic variant will result in drug-induced myopathy

3. Prognostic

- b. Individual: whether Mark will develop myopathy and, if so, how severe it will be

4. Therapeutic

- a. Prevention: what interventions can be undertaken to avert drug-induced myopathy or cardiovascular disease
- b. Treatment: whether statin therapy should be prescribed and, if so, which statin at what dose

Box 3 Patient perspective

I. Source

- A. Probability: Mark's genomic variant confers some risk of drug-induced myopathy
- C. Complexity: information about Mark's genomic variant is unfamiliar and multifaceted and thus difficult for him to understand

II. Issue

A. Scientific

- 1. Diagnostic: the meaning of Mark's genomic variant is unclear to him

3. Prognostic

- b. Individual: whether Mark will develop myopathy and, if so, how severe it will be

4. Therapeutic

- a. Prevention: what interventions can be undertaken to avert drug-induced myopathy or cardiovascular disease
- b. Treatment: whether statin therapy should be prescribed and, if so, which statin at what dose

B. Personal

- 1. Psychological: whether and to what extent Mark will experience adverse effects of knowledge of the genomic variant on his psychological well-being

- 2. Social: whether discontinuing running with Mark's social group will have adverse effects on his social well-being

- C. Practical: what actions Mark needs to undertake, both now and in the future, to access the care he needs is unclear

Not only taxonomies: multiple dimensions

Table 2. Classes and sources of spatial, temporal and linguistic dimensions of uncertainties.

	Uncertainties				
	Intrinsic		Extrinsic		
	Ontological	Epistemic	User Input	Data Conversion	Data Record
Dimensions	(lack of capacity to know what really exists)	(imprecision/ignorance/incompleteness)	(errors/misinterpretations/entropy/information truncation)	(uncertainties introduced by changing technologies)	(ambiguities/undecidibilities/data conversion errors/users' introduced errors)
Spatial	- Places that ceased to exist	- Unknown places - Exact place vs approximate/region			- Homographs (places) - Difference in details among records
Temporal	- Events with fiat limits [67] - Punctual events vs processes over time	- Events for which it is impossible to know the exact start, beginning and/or duration	- Typos - Abbreviations - Changing transcription guidelines - Assumptions on certain orthographies - Lack of precision on creating data records - Guessing - Prejudice and biases	- Language codification errors - Errors in the conversion of formats and databases - Heterogeneity of data sources	- Differences in data formats - Differences in data standards (e.g., Roman numbers) - Differences in details among records
Linguistic	- Dialects that ceased to exist	- Lack of standard orthographies for a certain lemma			- Homographs (lemmas) - Difference in details among records - Different standards for representing (e.g., IPA vs. TUSTEP)

The uncertainty of uncertainty classification

- An example in a deeper way: three-valued logics
 - How a simple change (wrt classical logic) can generate a great variety of problems and solutions

Three-valued logics

Interpretations of the third value

Three-valued logics

- A third value besides true/1 and false/0
- No agreement on the interpretation of the third value
 - **Ontological**: uncertainty is a matter of fact
 - **Epistemic**: uncertainty is a flaw in our knowledge
- Several connectives/logics are possible according to the interpretation

Ontological interpretation

- **Half-true:** The intuition is that for some propositions, truth is a matter of degree. This is typical of fuzzy logic.
 - Example A man whose height is 1.80 m is tall, a man with height 1.60m is not tall. A man whose height is 1.70 m is *half tall*
 - Example **typical vs borderline case**



Ontological interpretation

- **Undefined (Kleene)**: the undefined state corresponds to the choice of the argument of a (Boolean) function outside its definition domain
- Example “The book in the image has more than 200 pages”



Ontological interpretation

- **Irrelevant:** the idea is that in some possible worlds, propositions are not applicable
 - Example “All ravens are black”



Epistemic interpretation

- **Unknown (Kleene)**: a proposition is unknown if its (Boolean) truth-value cannot be computed for some reason
 - Example In a database about houses, the surface of a house is not known (but it exists!)
- **Inconsistent**: the third value stands for a proposition which is both true and false → paraconsistent logics
 - **Example** We have a witness which says I was in Como at 10am on the 18 March 2022 and a witness which says I was in Milan.

Thus, not enough vs too much information



Epistemic interpretation

- **Possible (Łukasiewicz)**: a proposition is Possible if its truth-value will be only known in the future
 - Example The 13 Aprile 2022 it will rain in Milano

A (partial) list of three-valued logics

- Lukasiewicz
- Godel
- Kleene
- Bochvar
- Priest
- Sette
- Sobocinski
- Nelson