Speaker: Matthias Van Hove

Types of uncertainty in simulation models: Categorisation for better identification, accounting and assessment

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A simulation model is a rich and complex structure that maps between the input(s) and the output(s) [1]. It aims to replicate the workings and logic of a real system by using physical and/or statistical descriptions of the activities involved [3]. Consequently, no simulation model can be a perfect representation of the system it aims to emulate [25]. All simulation models inevitably contain uncertainty, which should be addressed and quantified as part of the quality assurance process of the model and as part of inferences.

Uncertainty in modelling can be defined as "any departure from the unachievable ideal of complete deterministic knowledge of the system" (Walker *et al.*, 2003). As the systems, being modelled, increase in scale and complexity, it is expected that the uncertainty in the model also increases (Langevin J., 2020). Though, a fair amount of simulation model outputs are expressed as a single value (Cerezo, 2017), which may yield misleading impressions about the certainty of model insights when used for inferences and/or policy making (Langevin J., 2020).

In the literature, several different authors have addressed sources of uncertainty in simulation models in wording and/or schemes (Booth et al., 2012 [6]; Walker et al., 2003 [8]; Coakley et al., 2014 [9]; Oberkampf et al., 2002 [23]), however a general consensus in terms of uncertainty classification and related terminology does not appear to exist (Refsgaard et al., 2007 [28]). A review of 25 existing uncertainty classification schemes ([5]-[29]) highlighted a broad pattern with types of uncertainty being grouped according to where it occurs in the modelling chain: in the model inputs, the simulation model itself or the model outputs.

In *Figure 1*, the different types of uncertainty in simulation modelling are categorised. In *Table 1*, a concise definition is given.

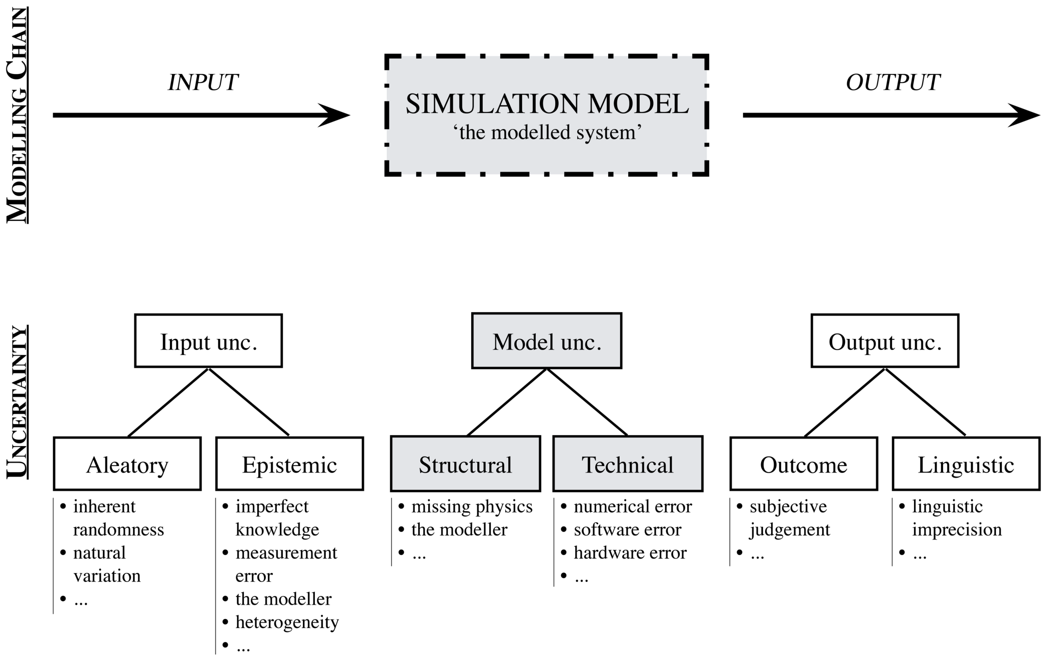

Figure 1 *- Types of uncertainty identified in existing uncertainty classification schemes. Types of uncertainty may be grouped by whether they relate to model inputs, the model itself, or model outputs.*

Definitions

Aleatory uncertainty: Uncertainty due to inherent or natural variation of the system under investigation.
Epistemic uncertainty: Uncertainty resulting from imperfect knowledge; can be quantified and reduced.
Model structural uncertainty: Uncertainty that arises from a lack of sufficient understanding of the system (past, present or future), that is the subject of the policy analysis, including the behaviour of the system and the interrelationships among its elements.
Model technical uncertainty: The uncertainty generated by software or hardware errors.
Model outcome uncertainty: Total uncertainty on the model simulation (so endogenous rather than exogenous as the other categories).
Linguistic uncertainty: Uncertainty arising from language issues; can be quantified and reduced.

Table 1 - *Definition of the types of uncertainty categorised in Figure 1.*

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Types of Uncertainty in Simulation Models:
Categorisation for better Identi⌊cation, Accounting and Assessment

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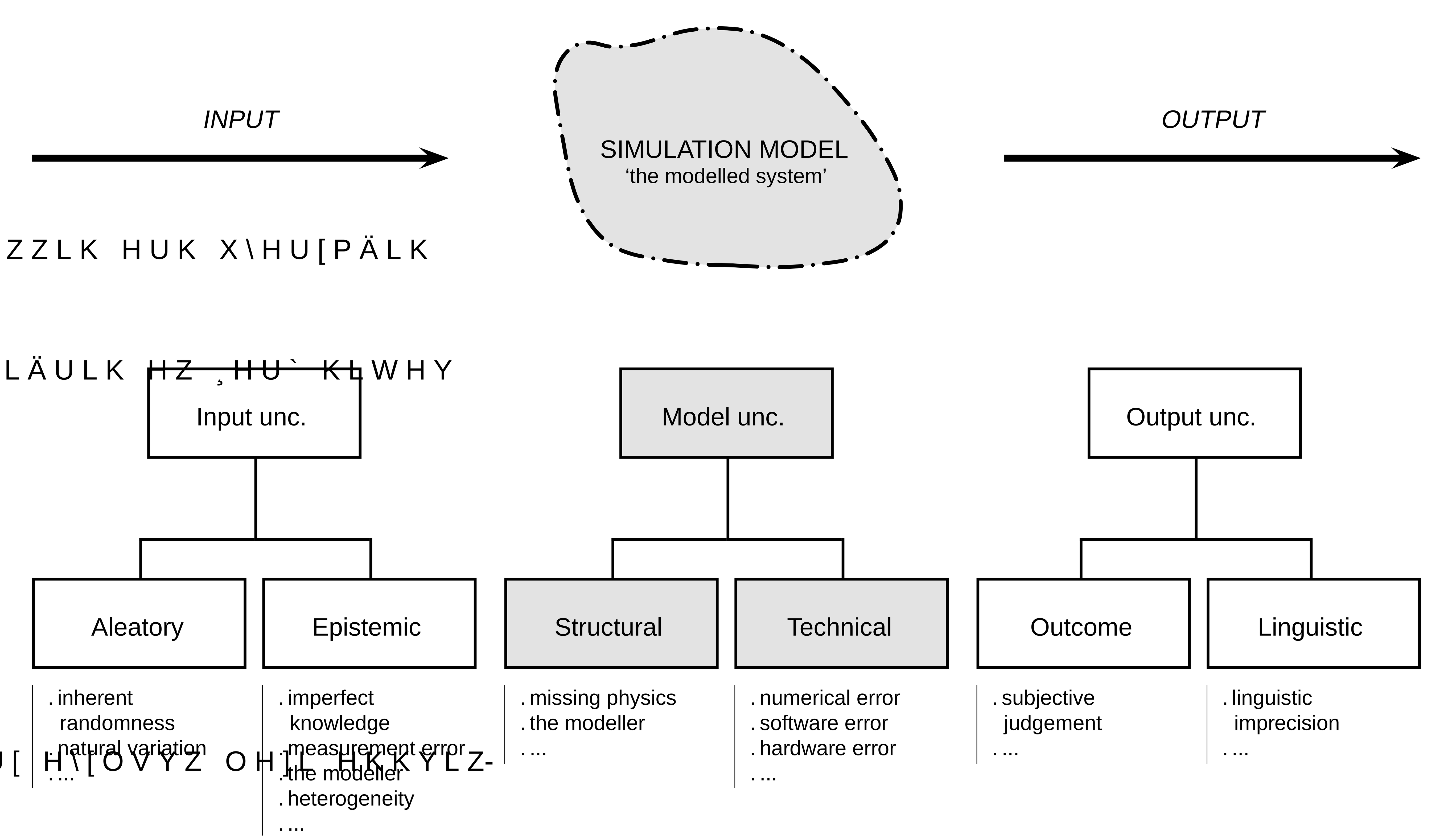
Summary

A simulation model is a rich and complex structure that maps between the input(s) and the output(s) [1]. It aims to replicate the workings and logic of a real system by using physical and/or statistical descriptions of the ac - tivities involved [3]. Consequently, no simulation model can be a perfect representation of the system it aims to emulate [25]. All simulation models inevitably contain \UJLY[HPU[` ^OPJO ZOV\SK IL HKKYLZZLK HUK X\HU[PÄLK as part of the quality assurance process of the model and as part of inferences.

<UJLY[HPU[` PU TVKLSSPUN JHU-IL KLÄULK HZ ¸HU` KLWHY ture from the unachievable ideal of complete determi-nistic knowledge of the system" (Walker et al., 2003). As the systems, being modelled, increase in scale and complexity, it is expected that the uncertainty in the model also increases (Langevin J., 2020). Though, a fair amount of simulation model outputs are expressed as a single value (Cerezo, 2017), which may yield mis-leading impressions about the certainty of model in-sights when used for inferences and/or policy making (Langevin J., 2020).

0U [OL SP[LYH[\YL ZL]LYHS KPHLYLU[H\[OVYZ OH]L HKKYLZ-sed sources of uncertainty in simulation models in wor - ding and/or schemes (Booth et al., 2012 [6]; Walker et al., 2003 [8]; Coakley et al., 2014 [9]; Oberkampf et al., 2002 [23]), however a general consensus in terms of \UJLY[HPU[` JSHZZPÄJH[PVU HUK YLS not appear to exist (Refsgaard et al., 2007 [28]). A re- ]PL^ VM L_PZ[PUN \UJLY[HPU[` JS ([5]-[29]) highlighted a broad pattern with types of un-certainty being grouped according to where it occurs in the modelling chain: in the model inputs, the simula-tion model itself or the model outputs.

Uncertainy Categorisation according to Occurrence in Modelling Chain



Aleatory uncertainty:	Uncertainty due to inherent or natural variation of the system under investigation.
Epistemic uncertainty:	<UJLY[HPU[` YLZ\S[PUN MYVT PTWLYMLJ[RUV^SLKNL" JHU IL X\HU[PÄLK HUK YLK\JLK
Model structural uncertainty:	<UJLY[HPU[` [OH[ HYPZLZ MYVT H SHJR VM Z\IJPLU[ \UKLYZ[HUKPUN VM [OL Z`Z[LT WHZ[WYLZLU[or future), that is the subject of the policy analysis, including the behaviour of the system and the interrelationships among its elements.
Model technical uncertainty:	The uncertainty generated by software or hardware errors.
Model outcome uncertainty:	Total uncertainty on the model simulation (so endogenous rather than exogenous as the other categories).
Linguistic uncertainty:	<UJLY[HPU[` HYPZPUN MYVT SHUN\HNL PZZ\LZ" JHU IL X\HU[PÄLK HUK YLK\JLK

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