

清华大学刘宝碇主讲《不确定理论》课件

Why Uncertainty?

Uncertainty Theory

Uncertain Statistics

Uncertain Programming

Uncertain Risk Analysis

Uncertain Reliability Analysis

Uncertain Set

Uncertain Logic

Uncertain Inference

Uncertain Process

Uncertain Renewal Process

Uncertain Canonical Process

Uncertain Calculus

Uncertain Differential Equation

Uncertainty + Randomness

Frequently Asked Questions

Law of Truth Conservation

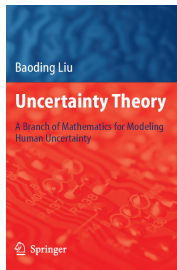
Maximum Uncertainty Principle

Evolution of Measures

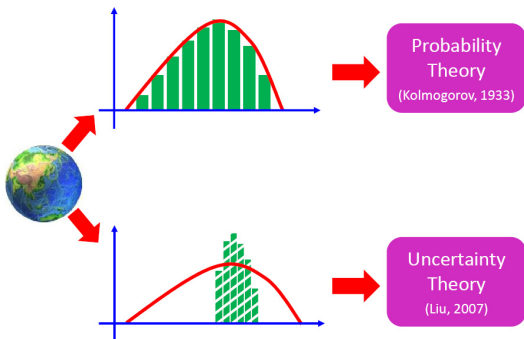
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Matlab Uncertainty Toolbox

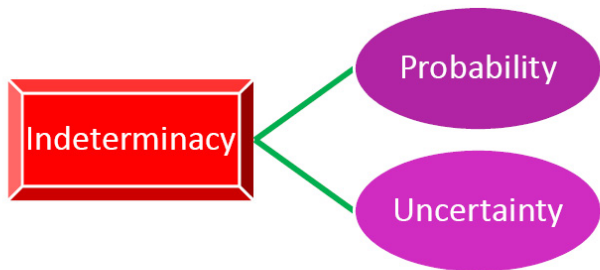


When the sample size is large enough,
the estimated probability (curve) may be close enough to the frequency (histogram)
and probability theory is applicable.



When no sample is available,
some domain experts are invited to evaluate belief degree of each event.
Since human beings usually overweight unlikely events,
belief degree may have much larger variance than the frequency
and then probability theory is no longer valid.
In this situation, we have no choice but to use uncertainty theory.





*In order to deal with the indeterminacy world,
there exist two mathematical systems,
one is probability theory and
the other is uncertainty theory.*



奥卡姆剃刀

第一，理论上自圆其说；

第二，存在一个实际问题，比对手干得好。

Occam's Razor

An acceptable approach is not only theoretically self-consistent but also the best among others for at least one practical problem.



不确定测度解释为信度，
概率测度解释为频率。

Uncertain measure is interpreted as belief degree, while probability measure is interpreted as frequency.



不确定理论和概率论是互补的数学系统。

*Uncertainty theory and probability theory
are complementary mathematical systems.*



Uncertainty Theory

Uncertainty theory is a branch of mathematics for modeling human uncertainty.

Axioms of Uncertainty Theory

Axiom 1. (Normality Axiom) $\mathcal{M}\{\Gamma\} = 1$ for the universal set Γ .

Axiom 2. (Duality Axiom) $\mathcal{M}\{\Lambda\} + \mathcal{M}\{\Lambda^c\} = 1$ for any event Λ .

Axiom 3. (Subadditivity Axiom) $\mathcal{M}\left\{\bigcup_{i=1}^{\infty} \Lambda_i\right\} \leq \sum_{i=1}^{\infty} \mathcal{M}\{\Lambda_i\}$.

Axiom 4. (Product Axiom) $\mathcal{M}\left\{\prod_{k=1}^{\infty} \Lambda_k\right\} = \bigwedge_{k=1}^{\infty} \mathcal{M}_k\{\Lambda_k\}$.

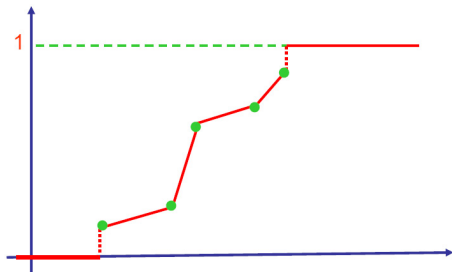


Liu B., *Uncertainty Theory*, 2nd edition, Springer-Verlag, Berlin, 2007



Uncertain Statistics

Uncertain statistics is a methodology for collecting and interpreting expert's experimental data by uncertainty theory.



Liu B, *Uncertainty Theory: A Branch of Mathematics for Modeling Human Uncertainty*, Springer-Verlag, Berlin, 2010.



Uncertain Programming

Uncertain programming is a type of mathematical programming involving uncertain variables.

$$\left\{ \begin{array}{l} \min_{\mathbf{x}} E[f(\mathbf{x}, \xi)] \\ \text{subject to:} \\ \mathcal{M}\{g(\mathbf{x}, \xi) \leq 0\} \geq \alpha \end{array} \right.$$

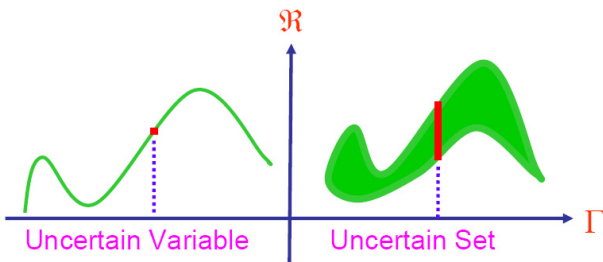


Liu B., *Theory and Practice of Uncertain Programming*, 2nd edition, Springer-Verlag, Berlin, 2009.



Uncertain Set

Uncertain set is a set-valued function on an uncertainty space, and attempts to model “unsharp concepts”.

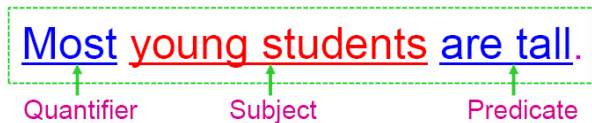


Liu B, Uncertain set theory and uncertain inference rule with application to uncertain control, *Journal of Uncertain Systems*, Vol.4, No.2, 83-98, 2010



Uncertain Logic

Uncertain logic is a methodology for calculating the truth values of uncertain propositions via uncertain set theory.



Liu B, Uncertain logic for modeling human language, *Journal of Uncertain Systems*, Vol.5, No.1, 3-20, 2011.



Uncertain Inference

Uncertain inference is a process of deriving consequences from human knowledge via uncertain set theory.

If \mathbb{X} is ξ , then \mathbb{Y} is η

\mathbb{X} is a constant a

\mathbb{Y} is conditional $\eta^* = \eta|_{a \in \xi}$



Liu B, Uncertain set theory and uncertain inference rule with application to uncertain control, *Journal of Uncertain Systems*, Vol.4, No.2, 83-98, 2010.

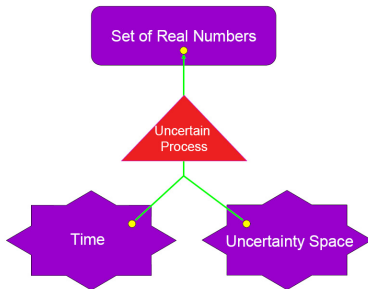


Gao X, Gao Y, and Ralescu DA, On Liu's inference rule for uncertain systems, *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, Vol.18, No.1, 1-11, 2010.



Uncertain Process

Uncertain process is a sequence of uncertain variables indexed by time.



Liu B, Fuzzy process, hybrid process and uncertain process, *Journal of Uncertain Systems*, Vol.2, No.1, 3-16, 2008.



Uncertain Calculus

Uncertain calculus is a branch of mathematics that deals with differentiation and integration of function of uncertain processes.

$$\int_a^b X_t dC_t = \lim_{\Delta \rightarrow 0} \sum_{i=1}^k X_{t_i} \cdot (C_{t_{i+1}} - C_{t_i})$$



Liu B, Fuzzy process, hybrid process and uncertain process, *Journal of Uncertain Systems*, Vol.2, No.1, 3-16, 2008.



Liu B, Some research problems in uncertainty theory, *Journal of Uncertain Systems*, Vol.3, No.1, 3-10, 2009.



Uncertain Differential Equation

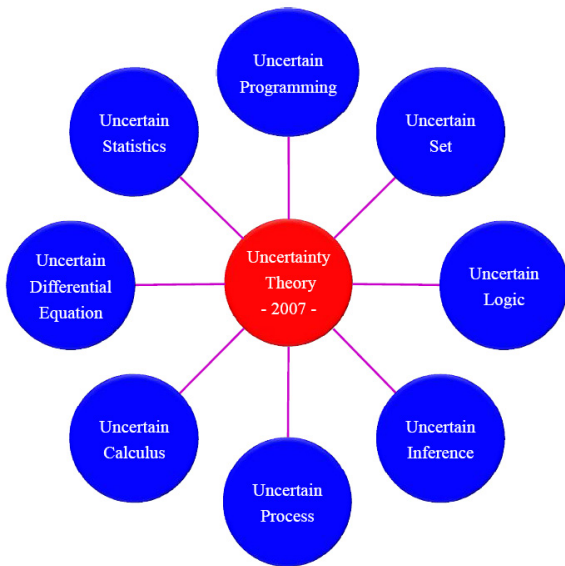
Uncertain differential equation is a type of differential equation driven by canonical process.

$$dX_t = f(t, X_t)dt + g(t, X_t)dC_t$$



Liu B, Fuzzy process, hybrid process and uncertain process, *Journal of Uncertain Systems*, Vol.2, No.1, 3-16, 2008.





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