Chapter 2 – first half.
A Constructive Approach to Models

in Self-Modifying Systems in Biology and Cognitive Science, George Kampis.

Course: Autonomous Machine Learning

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Contents

Foundations

- What is a model?
  - “small-scale reproduction or representation of something”
  - Ex) Mathematical equations, descriptions of events…
  - Convenient tools / the goals of inquiry themselves
- The role of mathematics
  - Is going to focus on predictive mathematico-logical process models
  - Problem: deductive knowledge is always hypothetical
    - No guarantee that notions of logical truth and empirical validity coincide

Foundations

- (Dynamic) prediction
  - Reduce the apparent complexity of the perceivable world
  - How predictions can be made
    - Empirical regularity: ex) Ohm's law
      no reason other than belief to claim that it will work
    - Deductive theoretical hypothesis: ex) relativity theory
      still hypothetical; grounded in an explanatory theory
    - Dynamical prediction: ex) planetary motion
      not hypothetical as long as valid equation of motion is given
      has an explicit temporal element; what should be pursued

Models and Constructivism

- Mathematical certainty was being threatened
  - Cantorian set theory and notion of infinity
  - D.Hilbert: concentrated on formal methods of mathematical proof; led to the formalist programme of Russel and Whitehead
  - Constructivism (L. Kronecker, J. Brouwer, H. Weyl)
    - Considered infinite sets as ill-defined
    - Rejected many results of modern analysis and set theory
    - Later converged with formalism in the work of Goedel who invalidated both
- Indirect proof
  - "… an infinity must exist, otherwise we run into a logical contradiction"
  - Provides no knowledge: speaking about the 'existence' of mathematical objects which nobody has seen
  - Idea of indirect proof makes no sense for finite objects

Models and Constructivism

- Constructivists' argument
  - Non-constructive specification of a set contains implicit 'excess information'
    - Example of an iceberg
    - No external point of reference outside it
- Mathematical objects applied outside mathematics
  - Computer
    - able to perform only constructively specified operations
    - represent mathematical objects by means of physical states
  - Constructive principle should be followed in order to represent physical objects
  - Reverse the way time functions work: X -> x(t)
    - Construct X with the aid of x(t), as does nature

Causality and Determinism

- Causality
  - A process is causal if reproducible
  - All phenomena have causes that are responsible for why they happen
  - Relationship between things / natural domain
- Determinism
  - It is always determined how things happen
  - Computational procedure / formal domain
- Debates: conflicting views
  - No cause, only determinism
    - B. Russel, M. Bunge, G. Polya, etc.
    - Problem of manipulating objects
  - Causality expressed in determinism
    - ‘why’ is a valid question, while answered by ‘how’ of things
    - Dynamical equations are deterministic expressions of an underlying causality
      ex) Newtonian science – motions expressed with initial positions plus forces

Entities

- Empirical information provided by measurement
  - Specification of a measurement includes descriptions of
    - The subject of measurement
    - The method of measurement
  - Entity: subject of measurement
    - Constancy
      - higher animals perceive objects , not incidental patterns
      - Not a logical necessity, but convenient and widespread
- Three types of entities
  - Natural entities
    - Reproducible definitions of actual things
  - Abstract entities
    - Conceptualized mental images of natural entities
  - Formal entities
    - Variables of mathematical relations

Entities

- Essentialism / atomism
  - Units
    - Well-chosen, relevant entities. Ex) atom
  - Entities enter their interactions with their properties unchanged
- Procedural / declarative knowledge
  - Procedural knowledge
    - Set of rules by which manipulation is done / mathematical model
  - Declarative knowledge
    - Set of statements that can be manipulated / abstract entity
- Observational / functional units
  - Natural boundaries of systems are not necessarily where we draw them
  - Units sharply distinguished in biological systems

Time and Information

- Concept of time
  - Questions of irreversibility
    - Is time factually reversible? (time of observations)
    - Can time be encoded in a model that trajectories become invariant? (time of models)
  - Kampis: no to the first question
  - Even reversible physical processes are parametrized by the irreversible time of observations
- Limited accessibility of information
  - Set-theoretic definition makes past and future coexistent by treating them as ‘data’
  - Effect of time constraint with examples of card games
    - Abbott’s ‘Eleusis’
    - The prisoner’s paradox
  - Modelling cannot be based on complete sets of information

Observables

- Qualities
  - Discretly classified and separately representable aspects of reality, obtained by observations
- Observable
  - Association of a symbolic quantity with a definite procedure
  - Empirical statements are established by observables
- Measuring device
  - In which the measurement procedure is usually embodied
  - Equivalence of devices at different time instances is ensured by transformation

Observables

- Dynamic / static observables
  - What is never experienced yet cannot be measured
    ex) idea of elephants
- Transitory qualities
  - Only temporarily available / observable
  - Dynamic observables contain temporal elements
- Permanent qualities
  - Static observables: time-invariant method for evaluating qualities
  - Different states of a system mean different conditions
- Snapshots
  - Elementary empirical units of modelling provided by dynamic observables

Discussion

- Is neural network always a dynamic model?
  - Gradient descent
  - Curriculum learning
  - Recurrent neural networks
- Minimising human-designed aspects of model
  - How much is neural network constructive, compared to natural selection of organisms?
- Is time factually irreversible?
  - How can one ensure that time is irreversible in the real world, relying on one's observation?
  - Is it ever possible to logically conclude the reversibility of time in the real world?