What is Modeling and Simulation and Software Engineering?

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Definitions

Model:

A system of postulates, data and interfaces presented as a mathematical description of an entity or proceedings or state of affair. (Development of equations, constraints and logic rules.)

Simulation:

Exercising the model and obtaining results. (Implementation of the model)

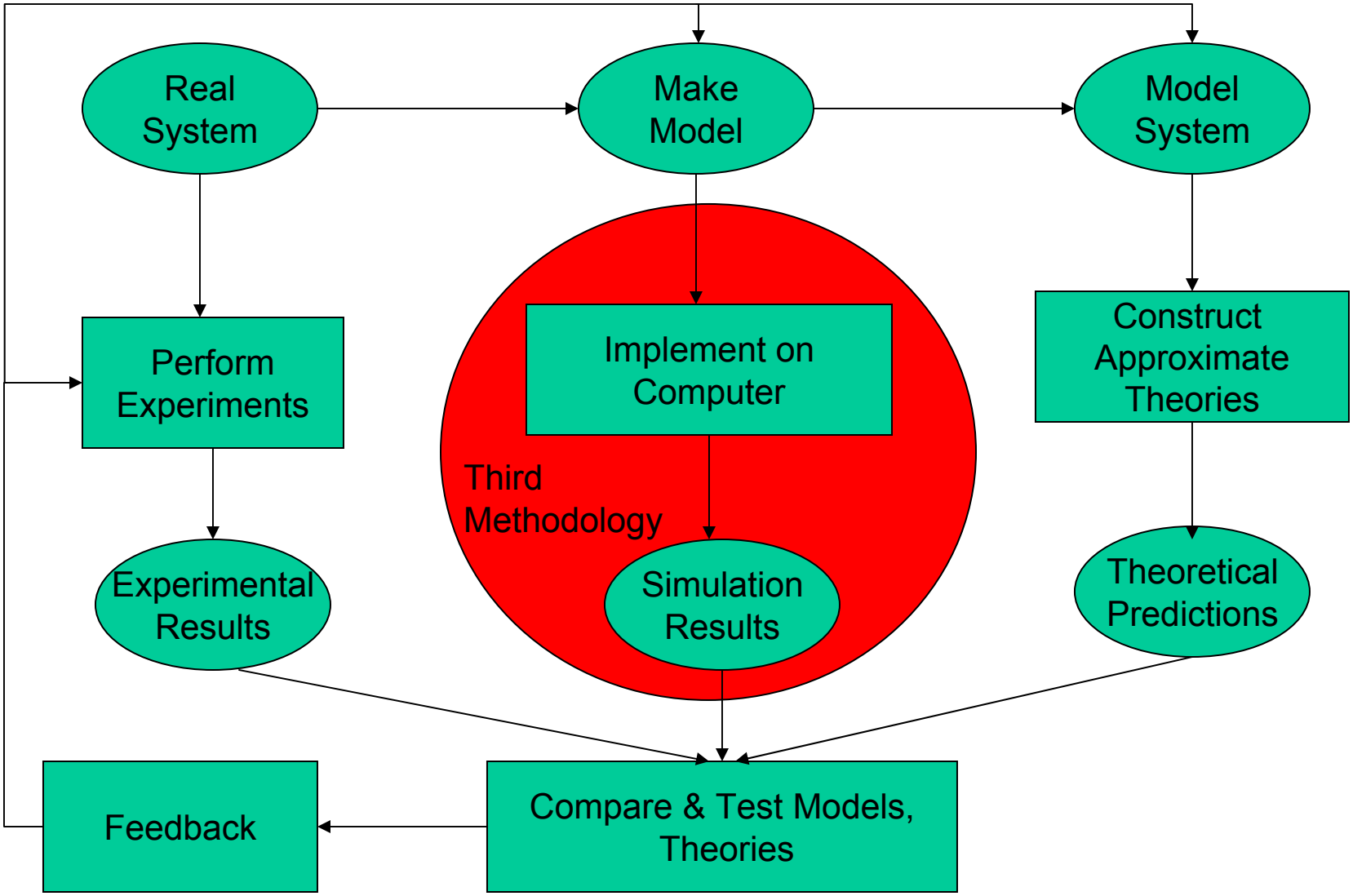
Classification of Models

- Deterministic — Stochastic
- Continuous variable — Discrete variable
- Dynamic — Static
- Time varying — Steady state
- Linear — Non-linear
- Real-time — Batch

Third Methodology

Simulation has emerged as the **Third methodology** of exploring the truth. It would complement the theory and experimental methodology. Simulation will never replace them.

Complementary Approach



Source: Allen and Tildesley

Why Simulations?

Simulations are applicable in the following situations:

1. When operating conditions change e.g. temperature., pressure, etc
2. When non-controllable factors change e.g. weather, earthquake
3. Dependence of variation of critical factors e.g. fatigue, resonance may be destructive.
4. How sensitive is one factor to the changes in another?
5. Other benefits:
   a) Useful in design
   b) Study effects of constraints
   c) Increase understanding
6. Pitfalls: An assumption, which the owner can't model or verbalise; so when two independent models clash, contradictory results arise

Tangible Benefits

- Saves manpower, material
- Useful even if not possible by other means
- Saves money with fast, consistent answers
- Could be used for education after establishing

Intangible Benefits

- Increased flexibility, accuracy, range of operation
- New results not available before
- Improved results due to standardisation
- Increased understanding
- Explicitly stated assumptions and constraints

Major Investments

- Computer
- Skill/Expertise
- Time for implementation

Pitfalls of Simulations

- Modelling errors at different levels
  - Scientific model of reality
  - Mathematical model
  - Discrete numerical model
  - Application program model
  - Computational model
- Input errors: Out of range inputs can give spurious results
- Precision errors: Limits in the precision

Phases of Development

- Real system to mathematical model
- Algorithm to solve mathematical model
- Implementation on a computer
- Validation
  - User with I/O
  - Model
  - Evaluations
- Simulations

Reliability tests

- Fermi solutions: Approximate results what the simulations would give. Fermi a Physicist was very good at making quick estimates of the expected output
- Sensitivity studies: Changes in outputs due to changes in inputs
- Comparing empirical results: Compare with experimental or other computational results
- Comparing with analytical results: Lower dimensional analytical results
- Checking conservation laws: Mass, energy, momentum
- Comparing with alternative numerical methods: Compare with the results from different algorithms
- Parameter studies: Look for any anomaly
- Peer review: Several people arriving at similar results

Software Engineering

- Computer Implementation & Validation
  - Requirements and Analysis
    - List of major functions to come up with software architecture
  - Design
    - Two levels of design up to individual functions
  - Construction
    - Coding
  - Testing
    - Validation and Verification

  ← Development cycle

  - Maintenance (may involve several development cycles)
    - Enhancements and perfection until the software is alive