Unit 2: Modelling Methods

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1.0 Introduction

Modelling is an essential and inseparable part of all scientific activity, and many scientific disciplines have their own ideas about specific types of modelling. There is little general theory about scientific modelling, offered by the philosophy of science, systems theory, and new fields like knowledge visualization.

We create **models** for representation of the objects within a system together with the rules that govern the interactions of the objects. The representation may be concrete as in the case of the spaceship or flight simulators or abstract as in the case of the computer program that examines the number of checkout stations in service queue.

2.0 Intended Learning Outcomes (ILOs)

At the end of this unit, the student should be able to:

- Define Modelling
- Describe some basic modelling concepts
- Differentiate between Visual and Conceptual models
- Explain the Characteristics of Visual, models

3.0 Main Content

Definitions of Modelling

Modelling is the process of generating abstract, conceptual, graphical and/or mathematical models. Science offers a growing collection of methods, techniques and theory about all kinds of specialized scientific modelling. A scientific model can provide a way to read elements easily which have been broken down to a simpler form.

Model
A scientific model seeks to represent empirical objects, phenomena, and physical processes in a logical and objective way. All models are simplified reflections of reality, but despite their inherent falsity, they are nevertheless extremely useful. Building and disputing models is fundamental to the scientific enterprise. Complete and true representation may be impossible but scientific debate often concerns which is the better model for a given task, such as the most accurate climate model for seasonal forecasting.

For the scientist, a **model** is also a way in which the human thought processes can be amplified. For instance, models that are rendered in software allow scientists to leverage computational power to simulate, visualize, manipulate and gain intuition about the entity, phenomenon or process being represented.

3.1 Basic Modelling Concepts

<u>Modelling as a substitute for direct measurement and experimentation</u>
Models are typically used when it is either impossible or impractical to create experimental conditions in which scientists can directly measure outcomes. Direct measurement of outcomes under controlled conditions will always be more accurate than modelled estimates of outcomes. When predicting outcomes, models use *assumptions*, while measurements do not. As the number of assumptions in a model increases, the accuracy and relevance of the model diminishes.
<u>Modelling language</u>
A *modelling language* is any *artificial language* that can be used to express information or knowledge or systems in a structure that is defined by a consistent set of rules. The rules are used for interpretation of the meaning of components in the structure.
<u>Simulation</u>
A *simulation* is the implementation of a model. A steady state simulation provides information about the system at an instant in time (usually at equilibrium, if it exists). A dynamic simulation provides information over time. A simulation brings a model to life and shows how a particular object or phenomenon will behave. It is useful for testing, analysis or training where real-world systems or concepts can be represented by a model.
<u>Structure</u>
Structure is a fundamental and sometimes intangible notion covering the recognition, observation, nature, and stability of patterns and relationships of entities. From a child's verbal description of a *snow*, to the detailed *scientific analysis* of the properties of magnetic fields, the concept of structure is an essential foundation of nearly every mode of inquiry and discovery in science, philosophy, and art.
<u>Systems</u>
A *system* is a set of interacting or interdependent entities, real or abstract, forming an integrated whole. In general, a system is a construct or collection of different elements that together can produce results not obtainable by the elements alone. The concept of an 'integrated whole' can also be stated in terms of a system embodying a set of relationships which are differentiated from relationships of the set to other elements, and from relationships between an element of the set and elements not a part of the relational regime.

There are two types of systems:

1) Discrete, in which the variables change instantaneously at separate points in time and,
2) Continuous, where the state variables change continuously with respect to time.

3.1.1 The process of generating a model

Modelling refers to the process of generating a model as a conceptual representation of some phenomenon. Typically a model will refer only to some aspects of the phenomenon in question, and two models of the same phenomenon may be essentially different, that is in which the difference is more than just a simple renaming. This may be due to differing requirements of the model's end users or to conceptual or aesthetic differences by the modellers and decisions made during the modelling process. *Aesthetic* considerations that may influence the *structure* of a model might be the modeller's preferences regarding probabilistic models vis-a-vis deterministic ones, discrete vs continuous time etc. For this reason users of a model need to understand the model's original purpose and the assumptions of its validity.

3.1.2 Factors in evaluating a model

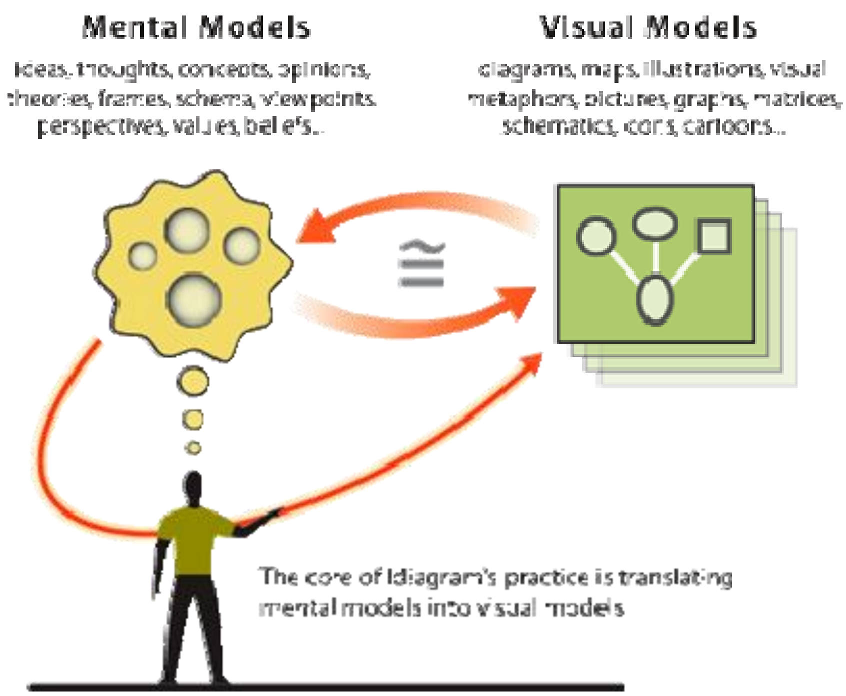
A model is evaluated first and foremost by its consistency to empirical data; any model inconsistent with reproducible observations must be modified or rejected. However, a fit to empirical data alone is not sufficient for a model to be accepted as valid. Other factors important in evaluating a model include:

- Ability to explain past observations
- Ability to predict future observations
- Cost of use, especially in combination with other models
- Refutability, enabling estimation of the degree of confidence in the model
- Simplicity, or even aesthetic appeal

3.2 Visual and Conceptual models

Visualization is any technique for creating images, diagrams, or animations to communicate a message. Visualization through visual imagery has been an effective way to communicate both abstract and concrete ideas since the dawn of man. Examples from history include cave paintings, Egyptian hieroglyphs, Greek geometry, and Leonardo da Vinci's revolutionary methods of technical drawing for engineering and scientific purposes. We should not hold a narrow definition of exactly what a **visual model** should *look like*. We should rather use whatever visual elements or styles such as diagrams, maps, graphs, charts, pictures, cartoons, etc. – that will most effectively represent the problem at hand.

We can however define visual models by what they strive to do, and list some of the important characteristics that distinguish 'visual models' from other kinds of graphic art.



Visual representation of data depends fundamentally on an appropriate **visual** scheme for mapping numbers into graphic patterns (Berlin 1983). One reason for the widespread use of graphical methods for quantitative data is the availability of a natural **visual** mapping: magnitude can be represented by length, as in a bar chart, or by position along a scale, as in dot charts and scatter plots. One reason for the relative paucity of graphical methods for categorical data may be that a natural **visual** mapping for frequency data is not so apparent.

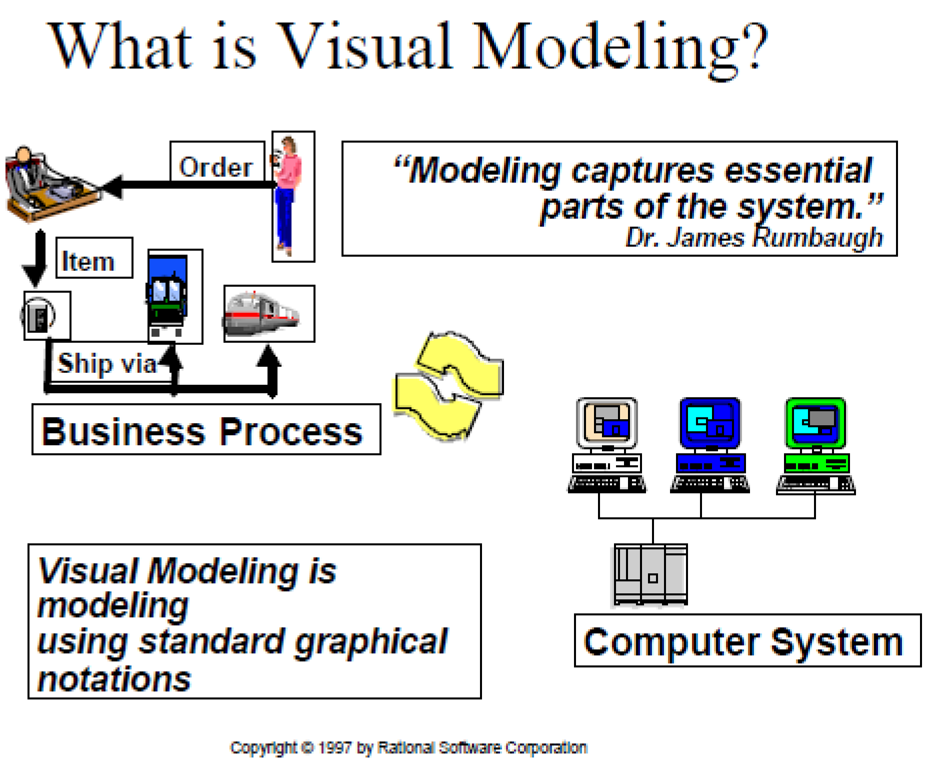
Conceptual model helps you interpret what is shown in a drawing or graph. A good **conceptual** model for a graphical display will have deeper connections with underlying statistical ideas as well.

For quantitative data, position along a scale can be related to mechanical models in which fitting data by least squares or least absolute deviations correspond directly to balancing forces or minimizing potential energy (Farebrother 1987).

The mechanical model for least squares regression, for example, likens each observation to a unit mass connected vertically to a rod by springs of unit modulus. Sall (1991a) shows how this mechanical model neatly describes the effects of sample size on power of a test, the leverage of outlying observations in regression, principal components, and collinearity among others.

Conceptual Modelling

- Is used for abstract (visual) representation of the problem domain
- It serves to enhance understanding of complex problem domains.
- It provides a basis for communication among project team members



3.3 Features of Visual and Conceptual Model

A visual model should:

- Render **conceptual knowledge** as opposed to quantitative data (information visualization) or physical things (technical illustration). We usually express conceptual knowledge with words alone, and yet the meaning behind those words is often *inherently visual*. Visual models seek to render directly the image-schematic (meaning that lies behind our words).
- Be **good models** - the images should accurately reflect the situation in the world and embody the characteristics of a useful model.
- **Integrate** the most salient aspects of the problem into a clear and coherent picture.
- **Fit the visual structure to the problem** – and not force the problem into a predefined visual structure.
- Use a **consistent visual gramma**r.
- Should be **visually and cognitively *tractable***. Visual models exist to support robust qualitative thinking: they're software for 'human-simulation' (as opposed to computer-simulation) of the issue at hand. To serve as effective 'simulation software', visual models must be 'readable' and 'run able' by our visio-cognitive 'hardware' and should positively engage our prodigious visual intelligence.
- Tap into the power of **elegant design**. In other words, they shouldn't be ugly

Conceptual Modelling

- A good conceptual model should NOT reflect a solution bias.
- Should model the problem domain, not the solution domain.
- Initial conceptual model may be rough and general.
- May be refined during incremental development.

3.4 Cognitive Affordances of Visual Models

Due to the limited capacity of our working memory, 7 ± 2 ‘chunks’ of information, we cannot hold in our minds concepts, arguments, or problems that consist of more than 5 to 9 objects or relationships. While this cognitive limitation severely restricts our ability to think about complex things, we can do what we often do: extend our intellectual abilities with external representations or 'models' of the problem.

The particular affordances diagrams – their ability to simultaneously show many objects and relationships – make them an ideal tool for thinking about conceptually-complex problems. Diagrams provide an external mnemonic aid that enables us to see complicated relationships and easily move between various mind-sized groupings of things.

4.0 Self-Assessment Exercise(s)

Answer the following questions:

1. Differentiate between modelling and a model
2. What factors are important in evaluating a model?
3. What are the desirable features of a visual model?

5.0 Conclusion

The essence of constructing a model is to identify a small subset of characteristics or features that are sufficient to describe the behaviour of the system under investigation. Since a model is an abstraction of a real system and not the system itself, there is therefore, a fine line between having too few characteristics to accurately describe the behaviour of the system and more than you need to accurately describe the system. The goal should be to build the simplest model that effectively describes the relevant behaviour of the system.

6.0 Summary

- We defined **modelling** as the process of generating abstract, conceptual, graphical and/or mathematical models. Science offers a growing collection of methods, techniques and theory about all kinds of specialized scientific modelling.
- We Listed and briefly explained some basic modelling concepts
- Differentiating between Visual and Conceptual models
- we discussed the important factors in evaluating a model to include:
    - Ability to explain past observations
    - Ability to predict future observations
    - Cost of use, especially in combination with other models
    - Refutability, enabling estimation of the degree of confidence in the model

- Simplicity, or even aesthetic appeal

- We discussed the features of a good visual model which include:
  - Ability to render conceptual knowledge as opposed to quantitative data (information visualization) or physical things (technical illustration),
  - the images should accurately reflect the situation in the world,
  - the model should Integrate the most salient aspects of the problem into a clear and coherent picture,
  - Fit the visual structure to the problem,
  - It should Use a consistent visual grammar,
  - Should be visually and cognitively tractable.
- We also stated the Characteristics of Conceptual models

7.0 Further Readings

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