THE AREA OF STUDY

Overview

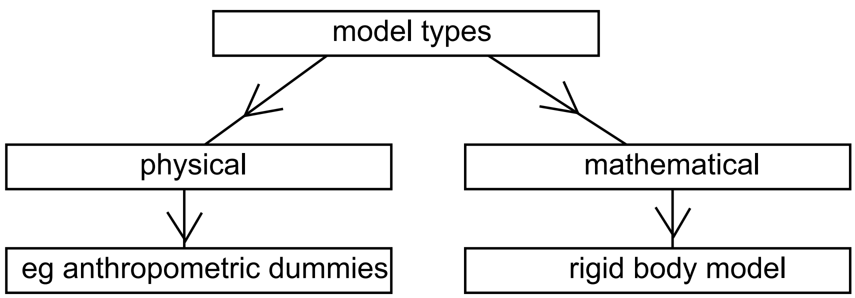
- What is a model?
- Simulation modeling
- Simulation modeling - what applications?
- Types of questions
- Experiments versus simulation modeling
- Phases in model development
- Example
    - Definition of the problem.
    - Statement of assumptions.
    - Formulation of system equations
    - Solution of system.
    - Validation
    - Simulations
- Conclusions

"An intellect knowing at any given instant of time, all forces acting in nature, as well as the momentary positions of all things of which the universe consist, would be able to comprehend the motions of the largest bodies of the world and those of the smallest atoms in one single formula, provided it were sufficiently powerful to subject all the data to analysis."
Pierre Simon Laplace (1749-1827)

WHAT IS A MODEL?

Eykhoff (1974) defined a model as "...a representation of the essential aspects of an existing system (or a system to be constructed) which presents knowledge of that system in a usable form." (page 1)

Eykhoff,P. (1974) ***System Identification-Parameter and State Estimation***. Wiley, New York



SIMULATION MODELING

- Can ask “what if” type questions.

- Generally rely on computers to solve large system of equations.

Advantages

- Safe
- Control
- Time

Disadvantages

- Validation difficult.
- Only an abstraction of reality.
- Reliance on math and computers.

For simulation modeling the normal most usable form is a set of equations which can be programmed on a computer.

SIMULATION MODELING
WHAT APPLICATIONS?

- Weather prediction
- Muscle cross-bridge theory
- Demographics models in geography
- Lichen growth models in biology
- Motor control non-linear dynamics models

TYPES OF QUESTIONS

How come?

For example Alexander (1992) offered an explanation of why long jumpers run-up quicker than high jumpers.

Do it like this?

For example Hatze (1983) could offer advice to a long jumper on how to modify technique.

What if?

Simulations models have been used to examine the effect if as a result of surgery a muscle is re-attached.

EXPERIMENTS VERSUS SIMULATION MODELING

EXPERIMENT	
Poor Control	Perfect Model

SIMULATION	
Excellent Control	Imperfect Model

Experiments and model approaches should not be seen as competing but complementary.

PHASES IN MODEL DEVELOPMENT

1. ***Definition of the problem***. - what is it you are trying to investigate.

2. ***Statement of assumptions***. - for example segments are rigid bodies acting about friction-less joints.

3. ***Formulation of system equations***. - for example $\mathbf{F}=m\mathbf{a}$ etc.

4. ***Solution of system***. - yield output parameters given input parameters.

5. ***Validation***. - correlation of model predictions with experimental results. This stage may suggest model refinements and therefore a return to stage 2 or 3.

6. ***Simulations***. - examine the behavior of modeled system under varying conditions.

Note - Stages 3 and 4 normally require computerization.

EXAMPLE I
STAGE1.

Definition of the Problem.
What effect do velocity, angle, and height of release have on how far a shot will travel?

Questions
- Is there a question being phrased which can be answered?
- Is it suitable for modeling?

EXAMPLE I
STAGE 2.

Statement of Assumptions.
- Ignore air resistance
- Ignore athlete

Questions
- Are assumptions reasonable?

- Will model once formulated indicate which assumptions should not have been ignored?

- Could assumptions be incorporated into model if necessary?

- Have others made the same assumption?

EXAMPLE I
STAGE 3.

Formulation of System Equations

$$R = \frac{V^2}{g}.\cos\theta.\left[\sin\theta + \left(\sin^2\theta + \frac{2.g.h}{V^2}\right)^{\frac{1}{2}}\right]$$

Where

R - distance of throw
V - projectile velocity
θ - angle of release
h - height of release
g - acceleration due to gravity

EXAMPLE I
STAGE 3.

Formulation of System Equations

$$R = \frac{V^2}{g}.\cos\theta.\left[\sin\theta + \left(\sin^2\theta + \frac{2.g.h}{V^2}\right)^{1/2}\right]$$

Questions

- Are the equations correct?
- Could they be formulated in a more compact form?
- Are the equations in a form readily programmed on a computer?

EXAMPLE I
STAGE 4

Solution of System.
Write computer program which given input parameters and variables will yield required output. In this case

Input	projectile velocity angle of release height of release
Output	distance of throw

Questions

- Is program coded correctly?
- Can input parameters be determined?

EXAMPLE I
STAGE 5

Validation
Video some throws from which you can measure projectile velocity, angle of release, height of release, and distance of throw

Questions
- What would be suitable prediction accuracy?
- Are predictions of model sufficiently accurate?
- What extrapolations from model are realistic?

➢ If the model **is not valid** then go back to stage 2 and re-examine assumptions.

➢ If the model **is valid** then it is possible to perform simulations with the model

EXAMPLE I
STAGE 6

Simulations
For example fix some values (velocity and angle), and systematically vary some others (height of release) and look at effect on distance thrown.

Questions
- What extrapolations beyond validation are realistic?

CONCLUSIONS

Why model?

- Permits total control
- Forces recognition of essential elements of system
- Complementary to experimental approach

Safety measures

- Fit model to task
- Model must be validated