

# Discuss at least two similarities and at least two differences in the way a scientist and an engineer would approach a simulation project

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## 1 Introduction

Engineers and scientists would not be able to exist without each other. While scientists might call engineering ‘Applied Science’, an engineer might retort that science is ‘Pure Engineering’. Simulation projects are attempted by both scientists and engineers: there are some differences and some similarities in the approach each group might take. While engineers and scientists have different research goals and applications for their simulations, they develop their simulations and verify / validate them in very similar ways.

## 2 Simulation Projects

Take a system - that is, a group of entities that interact, interrelate or have interdependency with each other. A simulation project is a representation of such a system in a way that captures the fundamentally interesting properties of the system in a realistic way. The purpose for embarking on a simulation project is an important consideration. In general, for engineers, the simulation (as a tool they can use to help with their engineering) itself is the goal of the project whereas, for scientists, evidence (produced by a simulation) supporting, opposing or understanding a scientific theory is the goal.

### 2.1 Scientific Simulation Goals

Scientists will embark on a simulation project because they will want to understand or explore a system and therefore generate scientific theories about such a system. A simulation project may or may not generate a tool for predicting the behaviour of a system; this is not of primary importance. What is important is the fact that the simulation model generated can act as a scientific proof for any theories developed about the system it represents. Bullock et al [4] claim that ‘computer programs are able to function as scientific models for the same reason that verbal arguments and mathematical proofs can do so; they can be made to reflect our theories about the ways in which ... entities behave in reality’ (p11).

Michael Wilkinson's paper on modelling Intestinal Microflora [1] aims to understand the 'ecology of the human intestinal microflora'. Different microflora compete with each other in the intestine. High levels of some microflora can cause illness and he would like to show how using probiotics to stimulate growth of competing microflora can be beneficial over using antibiotics to kill the offending bacteria. Wilkinson notes that the 'need to understand the intestinal microflora lies in the rapid and alarming increase in antibiotics resistance'. He doesn't have complete confidence in his simulation however and tempers any results he might find by stating they are only a basis for further investigation using a physical model.

## 2.2 Engineering Simulation Goals

Engineers will embark on a simulation project because they will generally want to control, change, predict or optimise the way a system behaves. Simulation can also be an important factor in the design of systems. Occasionally, the development of an engineering simulation can provide some scientific results; similar to those a scientist might glean from a simulation. While this is a positive side effect, the engineer's goal will still be to produce a simulation that can be applied to a future problem.

Dr Keith Still's Legion system [2] was used to model crowd dynamics for the XXVII Olympiad in Sydney. The model was able to predict how crowds would react to emergencies - after several tragedies involving crowds at football matches, the way crowds evacuate spaces is of vital importance - and how they form bottlenecks etc. The model was used to improve crowd flow at Wembley stadium so that its 80,000 capacity could be evacuated in less than eight minutes.

## 3 Simulation Development

Scientists and engineers will both approach the development of simulation models in similar ways. Firstly they will need to define the system they need to study and decide on the best way to study it.

There are various ways one might study a system. Clearly the best way is to experiment with the actual system. This is rarely possible due to often practical or moral reasons. The alternative to experimenting with a real system is to experiment with a model of the system. Physical models are often hard to create and suffer from problems of inaccuracies and scale. Analytical mathematical models are very desirable. Newton's model for acceleration of a mass under force ( $\text{force} = \text{mass} \times \text{acceleration}$ ) is simple and reliable. Some systems are too complex to be modelled by analytical mathematical models and thus can only be modelled by using simulation.

By its very nature, a simulation is a simplification of reality. The process of simplification is of vital importance. Too much simplification and the model will not represent the system properly, too little and the model will never work due to computational constraints.

Both scientists and engineers have to make assumptions when generating their simulations. Wilkinson [1] explains his assumptions in his introduction. ‘A reason for eliminating the immune system from the model (apart from its complexity) is that the majority of bacteria in a healthy intestine do not seem to evoke an immune response, thus modelling them without an interaction may well be realistic’.

From an engineering perspective, in ‘Crowd Dynamics’ [2], Still quotes that ‘In defining the Objective [Try to move to a desired or intended end point], Motility [Try to maintain your optimum velocity], Constraint [Try to maintain a minimum distance between yourself and the other objects in the environment] and Assimilation [Delay time taken to read and react to the environment] framework we have reduced the complexity of the system to its basic interactive elements’. People are unpredictable, they may do many different things. Still has assumed that they will only behave in these four ways when moving within a crowd - it is enough to build a model that works in the majority of cases.

## 4 Simulation Verification and Validation

Any simulation development must first be verified then validated. For verification the simulation program must be confirmed to be bug free. On top of the sort of procedures any competent development team might test their programming with, there are several extra tests a simulation programmer should do. Law and Kelton [5] list several which generally involve analysing the output against various inputs or using visualisation techniques.

Validation can involve some similar methods to verification. The data generated by the simulation must be shown to fit any real life data in a reasonable way. This can never be enough though because data can be easily made to fit without the simulation being realistic. Therefore, the conceptual model, or design of the simulation, must be true to reality - or shown to be at least a good approximation. This can be done by checking the assumptions and performing a structured walkthrough.

Playing with the simulation can also be a good way of validating it. By changing the assumptions of the simulation and then watching how the simulation behaves, the assumptions can be shown to be valid and relevant (some assumptions can make no difference). By trying to prove the simulation is false, one can only help to show that it is in fact a good simulation. A visual, animated output of the data is a good idea as well: if the simulation is good then an observer shouldn’t be able to tell the difference between the simulated output and the real model.

It is always a good idea to test the system against any available real data, especially against data generated from a system that was modified on the basis of results from the simulation. It is almost certainly not true that Still crammed 80,000 people into Wembley and set off the fire alarm, but he almost certainly did some tests on subsections of the overall system and checked that his model’s predictions were confirmed.

Wilkinson [1] states that he was not able to completely validate his simulation due to the lack of real data. He notes that ‘The numbers of anaerobes found in the large intestine is in line with what is observed, as is the ratio of anaerobes to aerobes’. He is aware that his simulation is merely only a beginning of an ongoing simulation project which would involve physical experiments as well: the physical experiments helping to validate his original model.

Both scientific and engineering simulation developers need to validate their simulation in similar ways. Only once they are happy that the simulation is a valid model can they move onto its applications.

## 5 Simulation Application

Engineering simulations are mainly applied by using their results to improve a design or modification process. Still used his Legion simulation [3] during the planning stages of the XXVII Olympiad in Sydney: ‘The results of the model (above) were used by Dr. Still during a presentation to Michael Knight and the SOCOG committee during the final planning stages of the 2000 Olympic Games to approve the finance for a \$16 million dollar bridge.’ As is well known, the Olympic Games were a massive success. Simulations often save engineers vast amounts of money, simulated cars crash into simulated walls rather than the expensive real cars.

When applying an engineering model it is always important to remember the assumptions made when generating the model and to ask whether they are still relevant. For example, a crowd dynamics model may assume that the crowd are using a flat concrete path that is not wet. If the model is applied to a scenario with a muddy bank, the crowd will not move as they do on the dry concrete path.

Scientific simulations are applied by testing scientific hypotheses with the simulation. Certain conceptual or parametric changes are made to the simulation and it is re-run. By investigating the way the simulation output has changed, evidence can be collected that supports, opposes or explains the reasons behind the hypothesis being tested. Wilkinson [1] notes that his simulation supports the hypothesis that ‘colonization resistance between individuals may be due to the order in which they were initially colonized by toxin producers or susceptibles’. His research is at its early stages, but some real science has come from his simulation project.

## 6 Conclusion

The two case studies discussed show how engineers and scientists take different approaches. The core simulations actually have more in common than might be obvious at a first glance. They both involve the movement of organisms through pathways. They took similar approaches in the development of their simulations, but their goals and applications were vastly different.

## References

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