

Simulation of Thomas Youngs' Double-Slit Experiment

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Abstract

The purpose of this empirical modelling study is to simulate the Thomas Young's Double-Slit experiment. It will firstly describe background of modelling technology. And then introduce what principle followed to modelling the whole system. Furthermore we will discuss the advantages and problems occur in the modelling and give possible improvement to the modelling environment which could develop empirical modelling in the future. Finally we will conclude the whole article.

1 Introduction

After nearly half a century's development, Empirical Modelling has become an important subject impacting the progress of computer science development. Empirical Modelling is not constrained in certain cutting-edge area, but grew as a general used technology widely spread.

Modelling technology researchers always focus on expanding the modelling technology to other applications, and at the same time, achievements from other fields also stimulate researcher's enthusiasm and continuously promote modelling development to a new point of view. Over half a century of development, modelling technology has become a synthesizing technology that combines similar theories, model theories, systems technologies, and information technologies.

In this article, we are going to show a case about how the concept of agency and dependencies can be used in modelling physical properties of various artefacts seeks to demonstrate the potentials of empirical modelling in the field of physics systems modelling.

2 Modelling Development

2.1 Introduction to the Model

In quantum mechanics, the Thomas Young double-slit experiment demonstrates the inseparability of the wave and particle natures of light and other quantum particles. A coherent light source illuminates a thin plate with two parallel slits cut in it, and the light passing through the slits strikes a screen behind them. The wave nature of light causes the light waves passing through both slits to interfere, creating an interference pattern of bright and

dark bands on the screen. However, at the screen, the light is always found to be absorbed as though it were made of discrete particles, called photons.

If the light travels from the source to the screen as particles, then on the basis of a classical reasoning the number that strikes any particular point on the screen is expected to be equal to the sum of those that go through the left slit and those that go through the right slit. In other words, according to classical particle physics the brightness at any point should be the sum of the brightness when the right slit is blocked and the brightness when the left slit is blocked. However, it is found that unblocking both slits makes some points on the screen brighter and other points darker. This can only be explained by the alternately additive and subtractive interference of waves, not the exclusively additive nature of particles, so we know that light must have some particle-wave duality.

The double slit experiment can also be performed (using different apparatus) with physical particles of matter such as electrons with the same results, demonstrating that they also show particle-wave duality.

2.2 Importance to Physics and Philosophy

The double-slit experiment, and its variations, then became a classic thought experiment for its clarity in expressing the central puzzles of quantum mechanics.

It was shown experimentally in 1972 that in a Young slit system where only one slit was open at any time, interference was nonetheless observed provided the path difference was such that the detected photon could have come from either slit. The experimental conditions were such that the photon density in the system was much less than unity.

A Young double slit experiment was not performed with anything other than light until 1961, when Clauss Jönsson of the University of Tübingen performed it with electrons, and not until 1974 in the form of "one electron at a time", in a laboratory at the University of Milan, by researchers led by Pier Giorgio Merli, of LAMEL-CNR Bologna.

The double-slit experiment has been of great interest to philosophers, because the quantum mechanical behaviour it reveals has forced them to re-evaluate their ideas about classical concepts such as "particles", "waves", "location", and "movement from one place to another".

3 Observables, Agency and Dependencies

For some physics system, we do not necessarily to consider about the detailed physical characteristics and structures. With the help of EM, it is possible for computer to effectively simulate the whole system. Such models can successfully include and indicate the operation of the system without having to imitate the underlying driving mechanisms.

By using this kind of modeling method, model progress becomes much simpler and it frees programmer from devoting too much time designing complex relationships between parameters to focus on more important aspect of the simulation, which may have many interaction with model. Empirical Modelling involves tools and techniques which enable the construction of computer based artifacts that embody what is directly experienced.

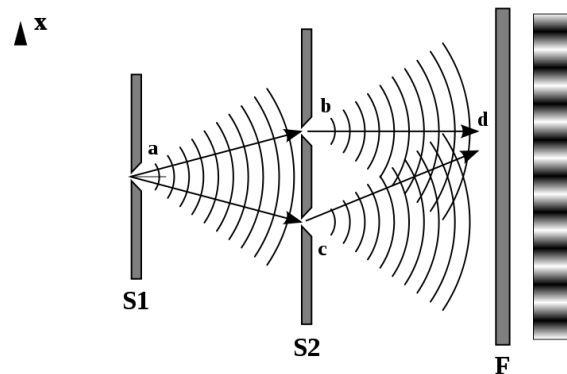
Agents can be identified as a first step within a system along with the various observables which they are able to respond to. Agent is the main attribute of EM, it is considered to be almost the most important concept in modeling, which is also regarded as the source of dependency. If these are capable of changing the state of an environment then it must be clear what an agent is capable of observing and what is capable of changing. When we want to develop a parallel system, there is something we must pay attention to. For instance, we should set an external observer who is responsible for identifying the agencies, observables, dependencies between them and what actions are possible within the constructed environment.

3.1 Observables and Dependency

Thomas Young's sketch of double-slit interference is based on his observations of water waves.

The bright bands observed on the screen happen when the light has interfered constructively—

where a crest of a wave meets a crest from another wave. The dark regions show destructive interference—a crest meets a trough. Constructive interference occurs when



$$\frac{n\lambda}{d} = \frac{x}{L} \Leftrightarrow n\lambda = \frac{xd}{L},$$

where

λ is the wavelength of the light,

d is the separation of the slits, the distance between A and B in the diagram to the right

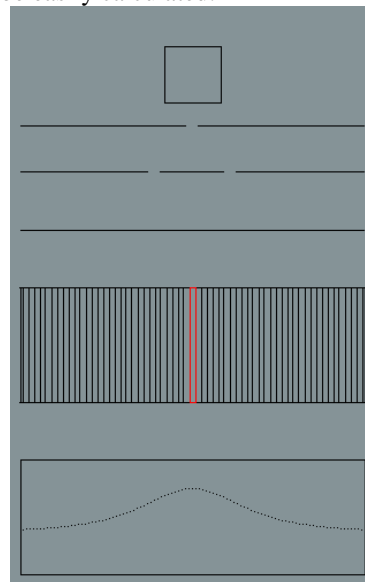
n is the order of maximum observed (central maximum is $n = 0$),

x is the distance between the bands of light and the central maximum (also called fringe distance), and

L is the distance from the slits to the screen midpoint.

This is only an approximation and depends on certain conditions.

It is possible to work out the wavelength of light using this equation and the above apparatus. If d and L are known and x is observed, then λ can be easily calculated.



A detailed treatment of the mathematics of double-slit interference in the context of quantum mechanics is given in the article on Englert-Greenberger duality.

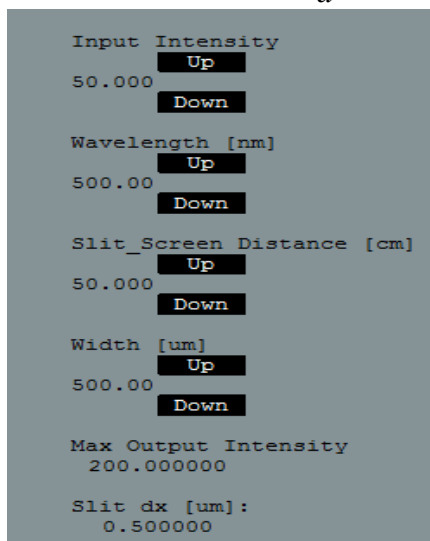
The behavior of output of the interferometer is specified by underlying laws of physics: The intensity of output light (I_x) is given by:

$$I_x = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos 2\pi \frac{\Delta r}{\lambda}$$

I_1 and I_2 refer to the intensity of lights comes out of double slits.

Δr refers to the difference between the distances from slits to position on screen. The distance between bands of light is given by above equations, and there is very little difference between the distance for bright bands and dark bands. So we usually consider that:

$$\Delta x_{\text{bright}} = \Delta x_{\text{dark}} = \frac{\lambda D}{d}$$



4 Advantages and Problems in describing modelling

4.1 Advantages in Modelling

Using Empirical Modelling for some applications has many advantages. By now, some of the EM tools are still not mature, but the dependency feature is absolutely a very strong feature. Dependency functionality would be useful in all programming languages.

As an example above, imagine changing different wavelength value, and the system will update distance between bands of lights automatically without restart the whole system, which means the dependencies would generate new data through the system automatically.

In addition above, inconsistency between the

EDEN, Scout and Donald language is also an advantage. These languages are very different in their construction, although accessing variables from one to another is verbose - we add “!” or “_” to identify different variables, it makes the whole program progress more clear. For instance, if we want to invoke a variable from Donald to access EDEN, “_” indicate clearly the variable is defined in Donald.

EDEN, Scout and Donald are almost C like language, which makes it very easy to get used to it statement and methods. Besides easy to learn, their size are really small compared with C or C++.

4.2 Problems in Modelling

Things always have two sides. Inevitably, EM still has some problems when modelling. In this section, we are going to talk about several problems met in modelling this case.

The most important, although EDEN features three different extensions for handling graphics, there are very few GUI *widgets* such as slider bars and radio buttons. Instead the user must create them. This is something that goes against EM’s usefulness at prototyping — usually the user will not be concerned with specifying these parts of the model as they are using EM as a tool.

The coordinates in Scout and Donald are different. Zero-crossing point in Scout is from left-down corner, while Donald’s counting is from top-left corner. What’s more, coordinates scale vary from Scout to Donald, pixels scale in Donald is times than that in Scout. And aspect ratio of a graph in Donald will adapt to that in Scout, so the graph will change the original shape.

When using Scout and Donald to draw a graph, if we forget to assign value to any of observables, the Scout screen will slip through without any error indication, so it is not very convenient to locate the unassigned observable.

5 Conclusions

This article has briefly introduced the practical usage of Empirical Modelling on experimental physics. It has shown how EM approach can enable the programmer to design and review the abstract behavior of a system and enhanced the benefits that EM can offer to the other subject of different fields. According to this case, although there have been some criticisms of EM and the tools, EM is still considered to be a convenient tool for physics or engineer jobs, and with its help, we can simulate more complex situations.

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