An Artist's Impression of Richardson's Fantastic Forecast Factory

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Dedicated to Oliver M. Ashford, Hon FRMetS, on the occasion of his 100th birthday.

In 1922 Lewis Fry Richardson published a remarkable book, *Weather Prediction by Numerical Process*, describing his attempt to forecast changes in the weather by numerical means. In his Preface, Richardson wrote “This investigation grew out of a study of finite differences and first took shape in 1911 as the fantasy which is now relegated to Ch. 11/2.”

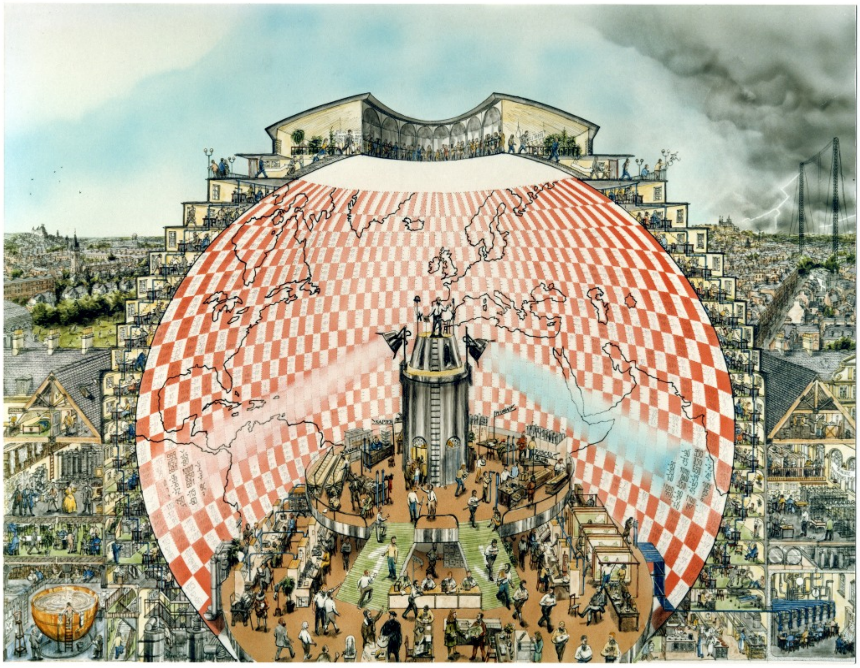


FIGURE 1: “Weather Forecasting Factory” by Stephen Conlin, 1986. Based on the description in *Weather Prediction by Numerical Process,* by L.F. Richardson, Cambridge University Press, 1922, and on advice from Prof. John Byrne, Trinity College Dublin. Image: ink and water colour, c. 50 x 38.5 cm. © Stephen Conlin 1986. All Rights Reserved. For a very high resolution version (38 MBytes) click HERE [LINK TO FOLLOW].

Weather Prediction by Numerical Process

Richardson devised a method of solving the mathematical equations that describe atmospheric flow by dividing the globe into cells and specifying the dynamical variables at the centre of each cell. Fig. 2 shows the frontispiece of his book. His caption began “An arrangement of meteorological stations designed to fit with the chief mechanical properties of the atmosphere”. Pressure was to be observed at the centre of each shaded chequer and wind velocity at the centre of each white one. This staggered grid was designed to harmonise with the structure of the dynamical equations.

Chapter 11 of Richardson's book is entitled “Some Remaining Problems”. The running header on page 219 is “A Forecast Factory” and §11/2 on that page is headed “The Speed and Organization of Computing”. Here Richardson presents what he calls his 'fantasy', describing in detail his remarkable vision of an enormous building, similar in some respects to the Royal Albert Hall in London. Richardson did not state the source of his inspiration, but he must have been familiar with the large assembly of (human) computers at University College London organized by the renowned statistician Karl Pearson. Richardson was a mathematical assistant to Pearson in 1907 (Ashford, 1985).

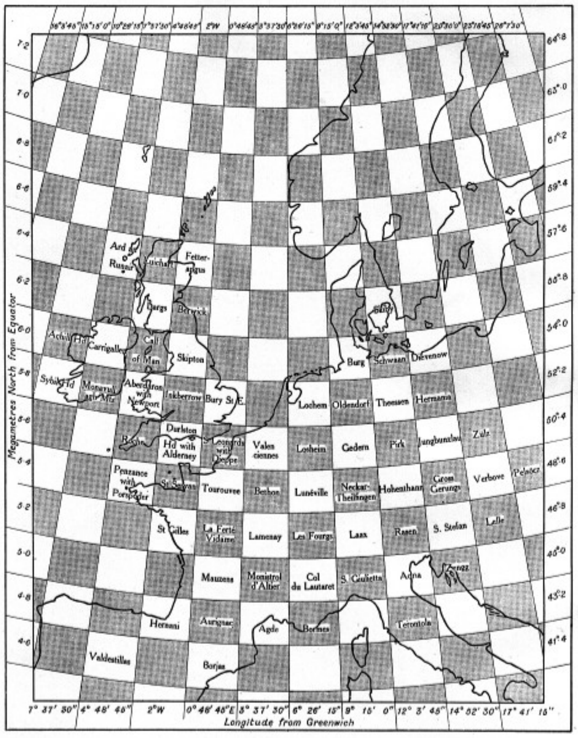


FIGURE 2: Frontispiece of Richardson's *Weather Prediction by Numerical Process*.

Several artists have created images of the forecast factory. One particular image, which has recently come to light, is described in this note. The painting in Figure 1, in ink and water colours, was made by Stephen Conlin in 1986, on the commission of Prof. John Byrne, then Head of the Department of Computer Science in Trinity College, Dublin, who provided both Richardson's text and suggestions regarding the inclusion of important figures from the history of mathematics and computation.

During the annual IFIP Congress (International Federation for Information Processing) in September, 1986 the painting was part of an exhibition in the Long Room in Trinity College, *Computing through the Ages*. The painting, which has been displayed in an obscure location within the Department, and has gone unnoticed for many years, is a remarkable work, rich in detail and replete with hidden gems.

Richardson's Fantasy.

Richardson showed remarkable foresight when he penned his famous fantasy. Let us take the words he wrote on page 219 of *Weather Prediction by Numerical Process*, and relate them to Conlin's illustration:

“After so much hard reasoning, may one play with a fantasy? Imagine a large hall like a theatre, except that the circles and galleries go right round through the space usually occupied by the stage. The walls of this chamber are painted to form a map of the globe. The ceiling represents the north polar regions, England is in the gallery, the tropics in the upper circle, Australia on the dress circle and the antarctic in the pit.”

Conlin's image (Fig. 1) depicts a huge building, some twenty storeys high, with a vast central chamber, spherical in form. On the wall of this chamber is a map with roughly half the globe visible, divided into red and white chequers, like Richardson's grid (Fig. 2). The numbers in the red cells represent pressure at the model levels (Richardson's model had five layers) and those in the white cells are momenta or winds.

Richardson's description continues:

“A myriad computers are at work upon the weather of the part of the map where each sits, but each computer attends only to one equation or part of an equation. The work of each region is coordinated by an official of higher rank. Numerous little “night signs” display the instantaneous values so that neighbouring computers can read them. Each number is thus displayed in three adjacent zones so as to maintain communication to the North and South on the map.”

Note that Richardson's “computers” are human. The image divides the globe into about twenty zones, corresponding to an average grid-step of nine degrees latitude. Fig. 3 shows the computers working on a region around Hudson Bay in Canada (left) and a section of the computational grid near India (right); the blue hue indicates that the computations here are falling behind.

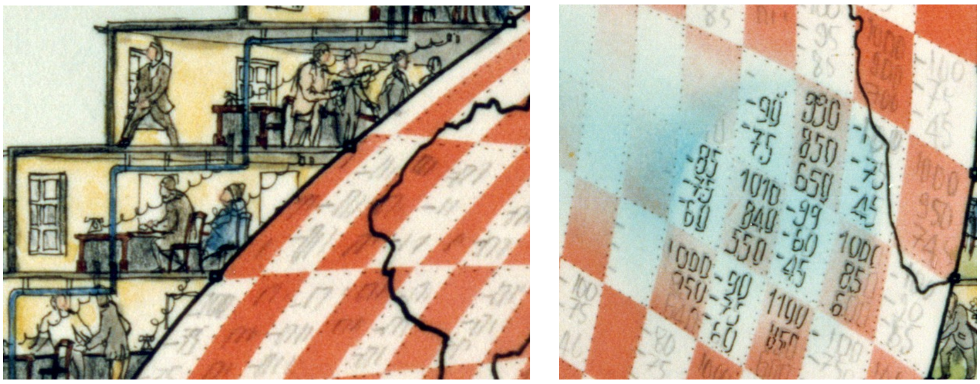
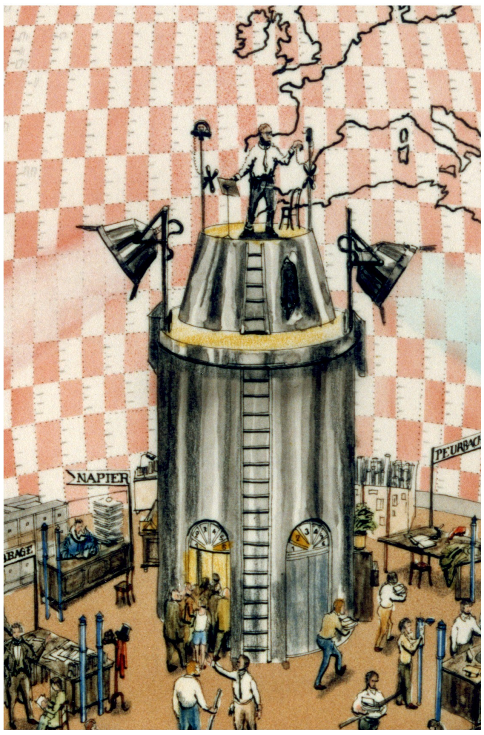


FIGURE 3. Left: Computers working on the region around Hudson Bay. Right: A section of the computational grid.

“From the floor of the pit a tall pillar rises to half the height of the hall. It carries a large pulpit on its top. In this sits the man in charge of the whole theatre; he is surrounded by several assistants and messengers. One of his duties is to maintain a uniform speed of progress in all parts of the globe. In this respect he is like the conductor of an orchestra in which the instruments are slide-rules and calculating machines. But instead of waving a baton he turns a beam of rosy light upon any region that is running ahead of the rest, and a beam of blue light upon those who are behindhand.”

FIGURE 4: Director of Operations standing on central tower. The figure of the director represents Lewis F. Richardson.



The Director of Operations stands on a dais atop the tower. He coordinates the computations, signalling by spotlight to those who are racing ahead or lagging behind. There are striking similarities between Richardson's forecast factory and a modern massively parallel processor (MPP). Richardson envisaged a large number of processors – his estimate was 64,000 – working in synchronous fashion on different sub-tasks. In fact, 64,000 was a substantial under-estimate (see Lynch, 2006, Appendix 4).

The forecasting job was sub-divided, or parallelized, using domain decomposition, a technique often used in MPPs today. Richardson's *night signs* provided nearest-neighbour communication, analogous to message-passing techniques in MPPs. The director in the pulpit (Lewis F. Richardson in Fig. 4) with his blue and rosy beams, acted as a synchronisation and control unit.

"Four senior clerks in the central pulpit are collecting the future weather as fast as it is being computed, and despatching it by pneumatic carrier to a quiet room. There it will be coded and telephoned to the radio transmitting station. Messengers carry piles of used computing forms down to a storehouse in the cellar."

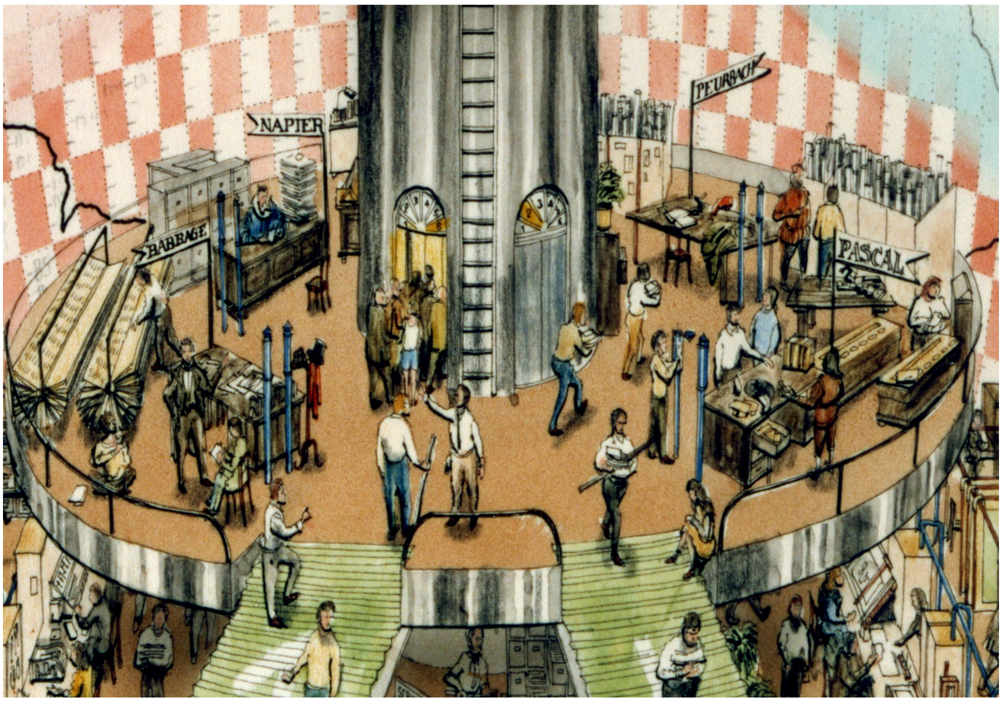


FIGURE 5: The upper floor. Banners identify the main characters (see also Table 1).

The upper floor, with the desks of the four senior clerks, is shown in Fig. 5. A banner on each desk identifies a major figure in the history of computing: Babbage, Napier, Peurbach and Pascal. Beside each desk stand a pair of pneumatic tubes for dispatching results.

Historical Characters in the Image

Several scholars and savants are depicted in the painting of the forecast factory. The artist, Stephen Conlin, provided a numerical key to the most important of these. It is reproduced in Figure 6.

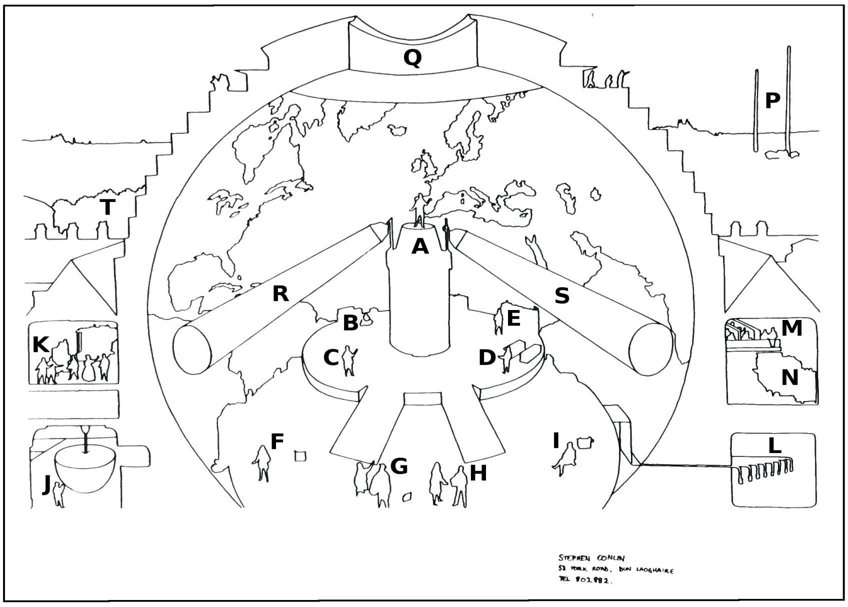


Figure 6: Labelled sketch by the artist, Stephen Conlin, identifying historical characters in the image (See Table 1).

A list of the individuals corresponding to each letter in the key was prepared by Prof Byrne at the time the painting was completed. Table 1 is an expanded version of this list.

TABLE 1

A	Lewis F. Richardson (1881-1953) in the pulpit, directing operations.
B	John Napier (1550–1617) inventor of logarithms, which had a profound influence on the course of astronomy, and of science in general.
C	Charles Babbage (1791-1871), mathematician, inventor and mechanical engineer, originated the concept of a programmable computer and designed highly advanced mechanical calculating machinery.
D	Blaise Pascal (1623–1662) French mathematician, inventor, writer and philosopher. When only 18 years old, he constructed a mechanical calculator capable of addition and subtraction, called the *Pascaline*.
E	Georg von Peurbach (1423–1461), Austrian astronomer and instrument maker who arranged for the first printed set of sines to be computed. He also computed a set of eclipse tables, the *Tabulae Eclipsium*, which remained highly influential for many years.
F	Edmund Gunter (1581-1626), English clergyman and mathematician, inventor of the logarithmic ruler.
G	William Oughtred (1574-1660), English mathematician and Anglican minister, inventor of the slide rule. Walter Lilly (c. 1900), Lecturer in Mechanical Engineering, Trinity College Dublin, with his circular rule.
H	Gottfried Wilhelm von Leibniz (1646-1716), mathematician and philosopher, who invented the first mass-produced mechanical calculator. His 'Stepped Reckoner', which performed addition, subtraction, multiplication and division, is illustrated on the table behind him, between Leibniz and George Fuller (one-time Professor of Engineering at Queen’s College, Belfast) with his spiral rule.
I	Per Georg Scheutz (1785-1873), Swedish lawyer, translator, inventor and builder of the first practical difference engine. Scheutz's calculator was used for generating tables of logarithms.

J	Sir G. I. Taylor (1886-1975), distinguished hydrodynamicist, grandson of George Boole.
K	The Arithmetic Research Room. Left to right: Lord Kelvin (1824-1907) and his brother James Thomson (with a ball and disk integrator); Percy Ludgate (1883-1922), Irish inventor of an Analytical Engine; Ada Lovelace (1815-1852), daughter of Lord Byron and friend of Babbage; George Boole (1815-1864), inventor of Boolean algebra.
L	Tube Room, or "quiet room", in which weather information is communicated within the forecast factory by pneumatic tube and to and from the outside world by wireless telegraphy.
M	Hollerith machines in the research department.
N	Scheutz Difference Engine in the research department.
P	Radio masts for reception of observations and transmission of forecasts.
Q	Public viewing gallery.
R	A rosy light – shone on computers who are forward in their computations.
S	A blue light – shone on computers who are behind in their computations.
T	Recreation area, since "*those who compute the weather should breathe of it freely*".

Pneumatic carriers were systems that propelled cylindrical containers through a pipe network using compressed air. Pneumatic tube networks were popular in the late 19th and early 20th centuries for transport of mail, documents or money within a building, or even across a city. Their use in Richardson's forecast factory is similar to their use in large retail stores, to transport documents to and from a centralized *Tube Room*, where operators could process or redistribute them.

Fig. 7 shows the Tube Room. Blue pneumatic tubes can be seen throughout the building. An electrical switch-board on the right controls distribution of forecasts by radio transmission. The antenna is near the top right side of the main picture.

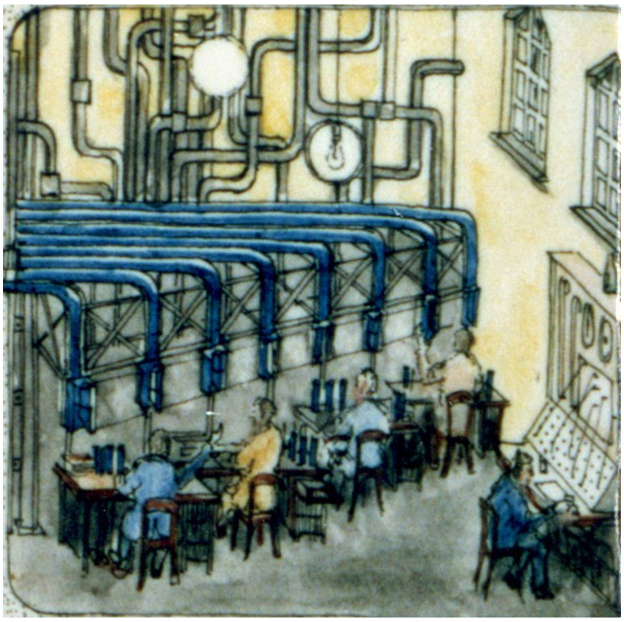


FIGURE 7: Tube Room for pneumatic carriers. The network extends throughout the forecast factory.

"In a neighbouring building there is a research department, where they invent improvements. But there is much experimenting on a small scale before any change is made in the complex routine of the computing theatre."

FIGURE 8: Computer Laboratory. The apparatus on the lower level is Scheutz's Difference Engine. On the upper level, Hollerith machines are shown.

In the building on the right of Fig. 1 there is a large room containing computing equipment (Fig. 8). Presumably, this is where senior operatives are developing strategies for improving the forecasting operations. The banner reads “Scheutz Difference Engine”.

“In a basement an enthusiast is observing eddies in the liquid lining of a huge spinning bowl, but so far the arithmetic proves the better way. In another building are all the usual financial, correspondence and administrative offices.”

FIGURE 9: A large hemispheric bowl spinning on a turntable, for geophysical experiments. The figure standing below the tank is Sir G. I. Taylor. More water tanks are seen to the left.

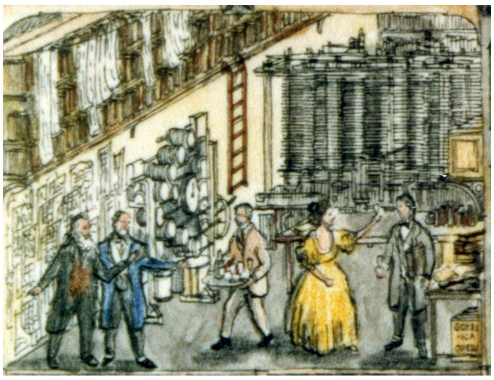


FIGURE 10. Left: The machine with dials is the tide-predicting machine of Kelvin. The machinery behind Ada Lovelace is Babbage's Analytical Engine. Right: Tide predicting machine at the Science Museum, London. (For identities of the characters, see Table 1, entry K).

In Fig. 10 we see Kelvin's tide-predicting machine. This machine was designed by William Thomson (Lord Kelvin) in 1876. This machine combined ten tidal components. It could trace the heights of the tides for one year in about four hours. [Image Attribution: William M. Connolley at the English language Wikipedia]

“Outside are playing fields, houses, mountains and lakes, for it was thought that those who compute the weather should breathe of it freely.”

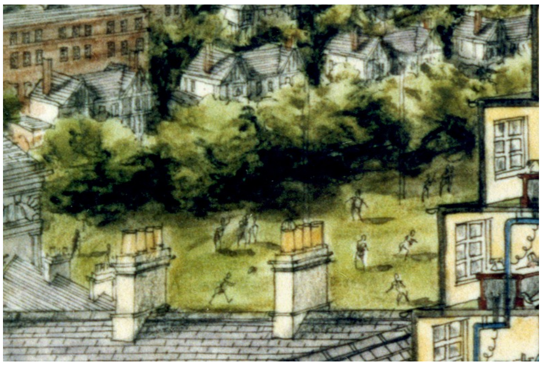


FIGURE 11. Fun and games in the park behind the Forecast Factory.

Richardson, with his Quaker background, was no slave-driver. He anticipated the need for what we now call a good work-life balance. The above quotation is indicative of his humanitarian spirit. He spent the last few decades of his life studying the statistics of warfare in the hope of identifying the causes of human conflict.

Summary

The above extracts are just a small sample of what the original image contains. Examination of the high-resolution image with a computer visualisation program is a rewarding experience and will reveal a wealth of other interesting details.

Acknowledgements

My thanks first to Prof. John Byrne for allowing a copy of his painting to be made and used, and for consultation regarding the background to it, and to Dr Dan McCarthy, Trinity College Dublin, who brought the painting to my attention, and arranged the high-resolution scan of it. Special thanks to the artist, Stephen Conlin, for generously permitting reproduction of the image and for information about it.

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