Torres y Quevedo

The first genuine attempt to design a chess playing machine was made in 1890 by the Spanish scientist Torres y Quevedo, who built a machine that played the ending of king and rook against king. The machine always played the side with the extra rook and it would always force mate (though not necessarily in the minimum number of moves). Since it is possible to give an explicit set of rules for making satisfactory moves in this particular ending, the problem is relatively simple, but the ideas incorporated in Torres' machine were quite advanced for those days.

The machine was created as a scientific toy in order to attract attention to the feasibility of Torres' theory on automation. He described his invention in a brief interview given to the Spanish journalist Jose Maria Carretero:

'It is an apparatus that plays chess with the king and the rook as if it were a person, knowing with absolute precision all moves that occur and always mating its opponent. Besides this, it warns its opponent, in a courteous manner, of any mistakes (i.e. illegal moves-DNLL) made by its opponent by means of a light, and after its opponent has made three mistakes it ceases playing, considering that its opponent is no match for it. . . . This apparatus has no practical purpose; but supports the basis of my thesis: that it is always possible to produce an automaton the actions of which always depend on certain circumstances and which obey certain rules that can be programmed when the automaton is being produced. Evidently these rules will be such as to be self-sufficient to determine the performance of the automaton without any uncertainty and at any given moment.'

Soon after it was built, Torres' machine was put on exhibition in Bilbao and Seville and it was also demonstrated at the conference of the Spanish Association for the Progress of Science in Villadolid. In 1914 the machine crossed the border into France, taking its inventor with it. It was exhibited in the laboratory of the Department of Physical and Experimental Medecine at the Sorbonne and an excellent account of its workings was given by the French scientist Henri Vigneron in *La Nature.* I am reproducing Vigneron's article here in full, because not only does it explain Torres' inventive machine, but also it gives a good account of the most interesting automata that had been built up to that time.

Robots
H. Vigneron

Mr. Torres y Quevedo, the renowned Spanish engineer, has been invited by the Franco-Spanish Research Centre to show his work in Paris. For this purpose he has brought with him some of the apparatus and machines which he has constructed and which are on display in the new laboratory of Physical and Experimental Mechanics at the Sorbonne, boulevard Raspail, whose director, Mr. Konigs, gave a warm welcome to the Spanish scientist and his machines.

Mr. Torres runs the Laboratorio de Automatica in Madrid, set up in 1907 by the Spanish government. This allows him to carry on his research into calculating machines whilst at the same time constructing machines for teaching and for the scientific research of various laboratories which depend on the State. In this way Mr. Torres is freed from financial problems and can show total impartiality in his dealings with the scientists who turn to him for help.

Mr. Torres, who has created among other things a most ingenious model of an airship, has been kind enough to provide us with highly interesting comments about himself, his work and his machines. The latter can be divided into two groups: robots and algebraic machines.

The term 'robot' is often applied to a machine which imitates the appearance and movements of a man or animal. So we are usually dealing with a machine containing its own source of energy which drives it (a spring, for example), and capable of performing certain actions, always the same, without any external influence. The most famous of these robots are the work of Vaucanson, such as the flute player which he described in a paper in 1728. In 1741 he exhibited a duck which could perform all the animal's functions, including feeding and digestion. Unfortunately his collection has not come down to us in its entirety, being scattered in many German museums. He had donated it to Queen Marie Antoinette for the Academic des Sciences, but as the king was dabbling in such matters against her wishes, she placed little value on Vaucanson's collection which was thus dispersed before reaching its destination.

There is another kind of robot which is much more interesting. Rather than imitate man's gestures, it imitates his actions and can occasionally replace him. The self-guiding torpedo, the scales which can weigh and differentiate coins automatically, and thousands of other well-known mechanisms represent examples of this type of robot. Many other examples which are much more interesting can be found in factories.

The major part of industrial progress is brought about by producing machines which can tackle work hitherto done by man. Gradually we are managing to automate most operations which were originally carried out by workmen, and we talk about complete automation when production can be achieved by the sole use of machines. Mr Torres divides this latter type of robot into two groups according to whether the circumstances which regulate their action are of a continuous or an intermittent nature.

Let us consider the self-guiding torpedo as an example of the first group. The horizontal rudder mechanism, whose task is to maintain the torpedo at a more or less fixed depth, is controlled by a chamber of compressed air which reacts to the water-pressure, and by a pendulum. Variations in depth result in the movement of a metal strip which separates the chamber of compressed air from the surrounding water; variations in tilt result in movement, relative to the torpedo, of the pendulum which remains vertical. The horizontal rudder is linked to the pendulum and the metal strip in such a way that each of these new movements compel it to return the torpedo to the required depth. We thus see that the problem here is to establish fixed mechanical linkages between three variables: pendulum, metal strip, rudder. This is the same type of problem as all those which are studied in the theory of kinematics as applied to the construction of machines, and is of no special interest to us here.

In the robots of the second group fixed linkages play no part. On the contrary, the aim is to change these links suddenly when circumstances demand. The principle is to stop or start a pulley, open or close a valve etc., usually with a very rapid movement. In other words the automation is effected by a sudden intervention at a given moment, thus controlling each different action of the machine.

In descriptions of machines we can find countless examples of these sudden interventions, but it is clear that this kind of automation does not form part of the theory of kinematics and has never been systematically studied. Mr Torres proposes to devote to it a special chapter of the theory of machines entitled 'automation' in which he would consider methods of constructing robots with much more complex programming (command) systems.

These robots will have SENSES such as thermometers, gyroscopes, dynamometers, pressure guages etc. Data received by the latter will be transmitted in the form of a movement: for example, a needle traversing a graduated scale.

These robots will have LIMBS i.e. mechanisms capable of carrying out given "orders" to perform certain operations. Such "orders" can be given by very simple means, even if complex operations are involved. This can be seen in the case of certain famous clocks like the ones at Rouen, Basle and Strasbourg, where a mechanism similar to the one used in an alarm-clock triggers off the movement of mechanical dolls which perform various actions.

Finally, these robots will have the necessary POWER in the form of batteries, water, compressed air etc., in order to keep the machines running and enable them to execute the essential operations.

Furthermore, and for Mr. Torrès this is the main problem of automation, the robots must be able to CHOOSE intelligently i.e. carry out the required operation after taking into account the data they are receiving from their "senses" or even the data already acquired. In other words, they should be able to imitate human beings by adapting their behaviour to the existing conditions.

In theory there is no difficulty in constructing apparatus for supplying the sense data, or in providing machines which will perform the operations designated by the robot. However, when it comes to constructing a robot which will determine its actions according to its ASSESSMENT of relevant data, the general opinion is that this can be done only in a few very simple cases. For example, it is thought that automation is possible for certain purely mechanical manual operations of a workman, whereas it will never be possible for those operations which demand the intervention of the mental faculties.

Mr. Torrès disagrees; for him it is self-evident that we can construct a robot all of whose actions depend on certain circumstances, numerous or otherwise, so long as we have a body of "rules" which we can impose arbitrarily at the design stage. This "program" will clearly have to be efficient enough to determine in all circumstances, without any doubt, the actions of the robot.

Not only does Mr. Torrès consider that the problem is not insoluble, but on the contrary he has provided us with a very elegant solution in the shape of a chess-playing machine. We shall describe this marvel of ingenuity later, once we have explained the guiding principles behind Mr. Torrès' method of constructing robots.

These principles basically depend on the use of an extremely simple electro-mechanical method. We said earlier that as a general rule any variation in the circumstances influencing the action of the robot will be indicated by a movement. Let us assume that it is a switch which is moved; instead of a needle moving along a graduated scale we will have an arm sweeping through a series of points, contacting each in turn.

If there are n switches and if we call the number of points linked with each of them P_1, P_2, $P_3 \ldots P_n$, then the total number of possible

positions to be considered will be the product $P_1 \times P_2 \times P_3 \ldots \times P_n$. To each of these positions a certain operation will be linked and triggered off by a very simple mechanism such as the attraction of the armature of an electro-magnet. Thus, each position will have its own electro-magnet and in order to carry out a specific operation the electrical connections will have to be arranged in such a way that each electro-magnet will be activated when the corresponding switch is in line. In the simplest case, when only one element is involved, the solution is the one presented in figure 13. The variations of this single element are reflected in the movements of switch M which contacts in turn each of the points A, B, C, D. In the diagram the connection is being made with electro-magnet E, so the operation linked with this will be carried out as soon as the electric circuit is completed at K.

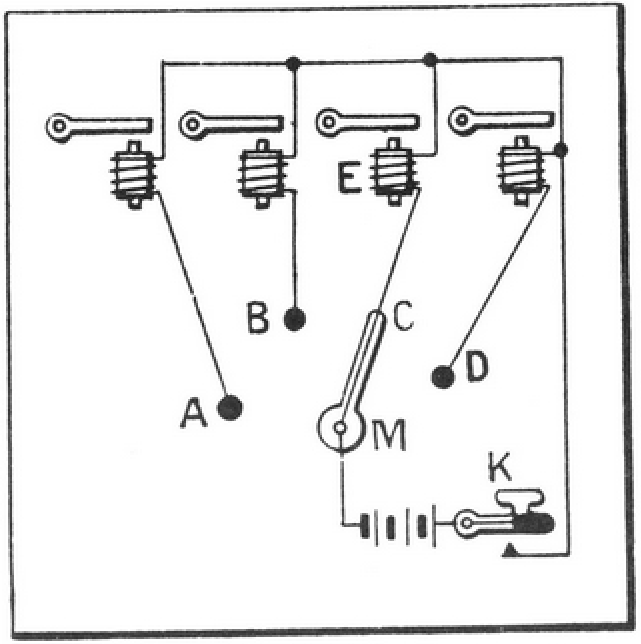

Fig. 13

Diagram showing the connections which allow four different operations to be carried out at choice.

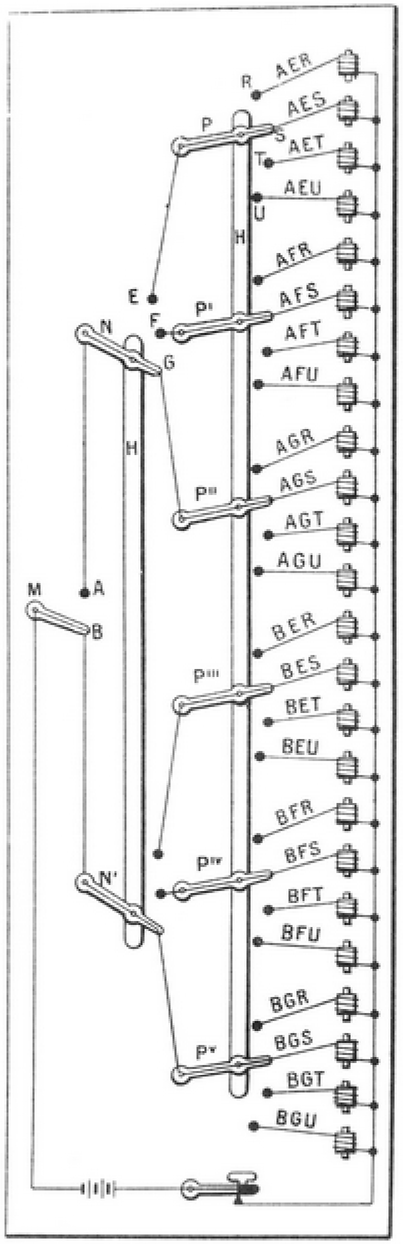

Fig. 14
Diagram showing how 24 different operations can be "selected".

In figure 14, there are three main switches M, N and P. The second involves in its movement another switch N^{I}, and the third brings in the Five switches P^{I}, P^{II}, P^{III}, P^{IV}, P^{V}.

M can take up positions A, B. N can take up positions E, F, G. P can take up positions R. S. T. U.

This system, then, allows 24 operations which can be carried out as soon as the corresponding electro-magnet is activated by completion of the circuit.

Of course, we can increase at will the number of switches and the number of points connected with each of them. In other words, we can increase indefinitely the number of particular cases that the robot will have to 'consider' when controlling its operations. There is no theoretical problem here, as there is no essential difference between the simplest machine and the most complex robot. Both can be reduced to a material system dependent upon the physical rules applied in their construction. The sole difference is that when these rules are complex, involving a certain amount of reasoning to deduce the corresponding manoeuvres, the machine which carries out the manoeuvres appears to possess in itself this ability to choose intelligently.

Indeed, this is the impression created by Mr. Torres' chess-playing machine. The object is to mate with rook and king against king, with a human chess player conducting the defence. As we have already stated, certain rules have to be established (programming) which the machine must always follow and which determine its response to any defence adopted by its opponent who has the black pieces.

Here are the rules applied by Mr. Torres in constructing the robot:

If the opponent plays an illegal move, a light comes on and the robot refuses to make a move. Once three such illegal moves have been made, the robot ceases to play altogether.

If, on the contrary, the defence plays correctly, the robot will carry out one of six operations, depending upon the position of the black king. In order to achieve this, Mr. Torres uses two zones on the chessboard: the one on the left consisting of the QR, QN and QB files, and the corresponding one on the right consisting of the KR, KN and KB files. We then have the six operations as shown in figure 15.

How are these operations carried out? Before we turn to the full picture given in figure 18, let us consider figures 16 and 17 which use the same graphical notation.

The black King					
is in the same zone as the rook	is not in the same zone as the rook and the vertical distance between the black king and the rook is				
	more than a square	one square, with the vertical distance between the two kings being			
		more than two squares	two squares, with the number of square representing their horizontal distance apart being		
			odd	even	zero
The rook moves away horizontally	The rook moves down one square	The king moves down one square	The rook moves one square horizontally	The white king moves one square towards the black king	The rook moves down one square
1	2	3	4	5	6

Fig. 15

The six possible operations of Torres' machine.

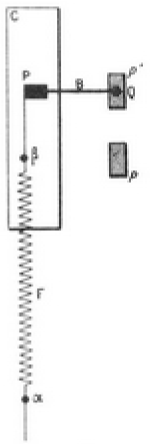

Fig. 16

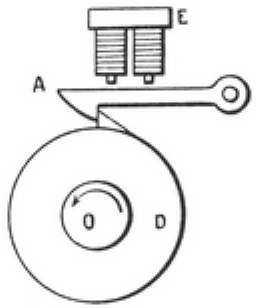

Fig. 17

Rectangle C in figure 16 represents a slide which can move vertically. It has an arm B fixed to it at P and whose end Q can contact points *P* or P^1 thus connecting either circuit. The wavy line F represents an extensible electrical conductor (e.g. spring) which connects moving point β to fixed point α without hindering the movement of the slide.

In figure 17, the disc D is dragged round by friction from the central moving spindle O unless prevented by the catch A. Each time that the electro-magnet E attracts its armature A, then disc D will make one complete rotation compelling the robot to carry out a specific manoeuvre.

Now let us examine the brain of the robot:

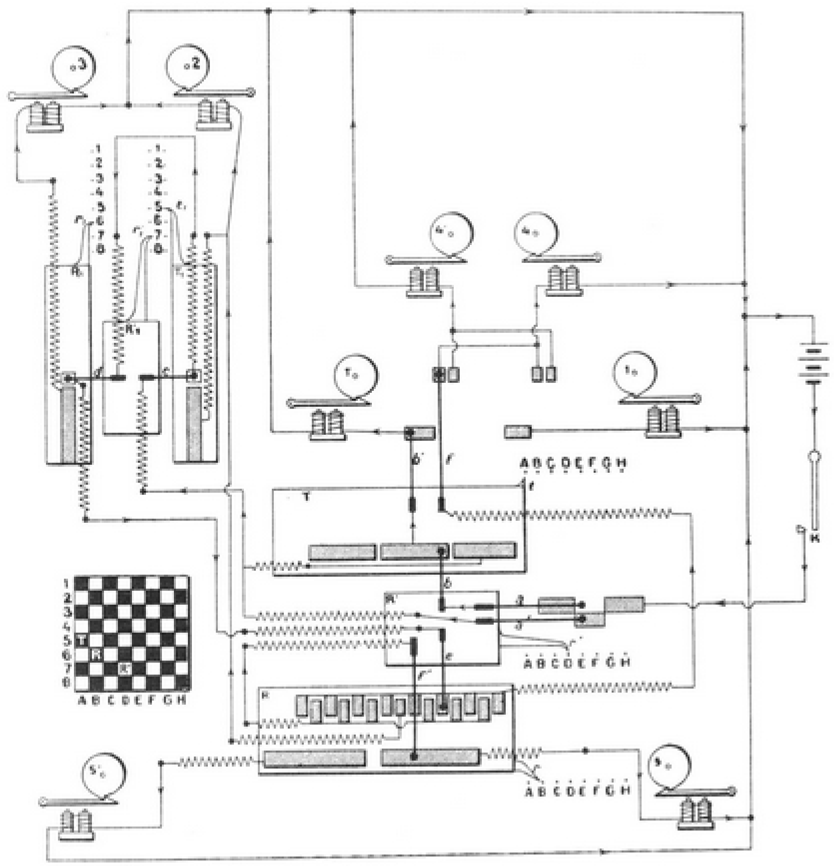

Fig. 18

Diagram showing how the chess player performs the various operations according to the positions of the pieces.

Corridor R indicates the horizontal position of the white king.
Corridor R′ indicates the same for the black king.
Corridor T indicates the horizontal position of the white rook.
Corridor R_1 indicates the vertical position of the white king.
Corridor R'_1 indicates the same for the black king.
Corridor T_1 indicates the vertical position of the white rook.

There are eight discs in the diagram, 1, 1′, 2, 3, 4, 4′, 5, 5′ which execute the following specific manoeuvres:

1 The rook moves to the QR-file.
1′ The rook moves to the KR-file.

2 The rook moves one square down.
3 The king moves one square down.
4 The king moves one square to the right.
4′ The king moves one square to the left.
5 The rook moves one square to the right.
5′ The rook moves one square to the left.

At the same time that the robot moves the piece, it also moves the corresponding slide to indicate the new position.

When the defender moves, the robot begins by comparing the new position of the black king with the one it occupied previously. If the move is illegal, a light comes on. Otherwise the circuit is completed at K and the robot carries out one of the six operations according to its programmed rules (see figure 15):

No.1 Let us suppose that the black king is in the same zone as the white rook, for example on QB2. The current passes along arms *a* and *b* then on to *b′* connecting with electro-magnet 1′ in the present case since the rook is in the left-hand zone. If the rook were in the right-hand zone, electro-magnet 1 would be the one activated.

No.2 The black king is not in the same zone as the rook and the vertical distance between them is more than one square. The current passes either through *a′* (the black king is in neither zone) or through *a* and *b* (the black king is not in the same zone as the rook). From there it goes to *c* and on to electro-magnet 2.

No.3 In the third hypothesis, the vertical distance between the black king and the rook in different zones is one square, but the vertical distance between the two kings is more than two squares. The current passes from *c* to *d*, then to electro-magnet 3.

No. 4 If, in the preceding conditions, the vertical distance between the kings is two squares and the horizontal distance between them is an odd number of squares, the current passes from *d* through *e* and *f*. It then goes to electro-magnet 4 if the rook is on the QR or KN file and to electro-magnet 4′ if the rook is on the QN or KR file.

No.5 With the same conditions as the preceding case but an even number of squares being the horizontal distance between the kings, the current passes from *d* through *e* and *f′*. It then goes to electro-magnet 5 if the black king is to the right of the white king, or to electro-magnet 5′ if the opposite is the case.

No.6 Finally, if both kings are on the same file (i.e. the horizontal distance between them is zero), the current activates electro-magnet 2 via *d* and *e*.

Such are the principles behind Mr. Torres' chess-playing machine. However, what we have been unable to describe is the ingenuity required to create such a robot. It is only when one sees it at work, checking the opponent's moves then carrying out the correct manoeuvre in reply that you can understand the truth of Mr. Torres' words: 'It is not difficult to conceive the theoretical possibility of a robot determining its action at a given moment by weighing up all the circumstances it must take into consideration to carry out its assigned task. Equally one can visualize a robot carrying out a series of actions in order to achieve a certain "result".'

In Mr. Konigs' laboratory Mr. Torres also displayed other machines which were just as original. The telekine, a machine which carries out orders sent by wireless, interpreting them correctly whilst taking into account various external factors. Algebraic machines representing continuous functions by means of movements which are continuous too. A machine for solving algebraic equations, and other machines, all of which are clear evidence of the knowledge and ingenuity of this eminent engineer.

Torres machine is still in good working order and can be seen in the museum at the Polytechnic in Madrid.