Kempelen's chess playing pseudo-automaton and Racknitz' explanation of its controls 1789

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Abstract

This paper deals with one of the most charming bluffs in the history of technology: the chess playing pseudo-automaton built by WOLFGANG VON KEMPELEN in 1769. Its secret was never completely revealed, and it created an unimaginable flood of attempts at explanation, among which RACKNITZ' attempt seems to come closest to reality. A hidden human player inside the automaton could follow events outside and control the machine by means of a sophisticated kinematic system. We both give a survey on the publications about the subject and a modern kinematic interpretation of RACKNITZ' explanation. A computer simulation confirms that RACKNITZ had rebuilt the automaton and that this machine must have been working fine.

Keywords: Chess playing machine, spatial kinematics, early robotics, mechanical bluff, pantograph.

1 Introduction

So, it is a deception? Yes, but a deception that bestows honour upon its perpetator.
KARL GOTTLIEB VON WINDISCH, 1783

Of all the traces left in European cultural, scientific and technical history by the civil servant, scholar, poet and mechanic WOLFGANG VON KEMPELEN (1734–1804), his chess playing pseudo-automaton remains the most noteworthy.[1])

In the year 1769, KEMPELEN presented a mechanical chess player at the court of MARIA THERESIA, which, because of its oriental costume, became known as the "Turk". After extensive tours in Europe (1783–84, 1818–1825) and the USA (1826–1838) it was destroyed in a fire at Pearl's Museum in Philadelphia in July 1854.[2])

In the year that KEMPELEN's "Turk" burned, the German physicist and naturalist HERMANN VON HELMHOLTZ remarked in a lecture in Königsberg that the 18th century anthropomorphic automatons, these unique pieces from the workshops of JACQUES DE VAUCANSON or of JACQUET-DROZ and his son, had seen their day:

"We are no longer trying to build machines that can fulfill a thousand duties for one person, on the contrary, we demand that a machine can fulfill one duty and thereby replace a thousand people."[3])

[1]) The submitted essay arose from a project at the University for Applied Arts Vienna, which was supported by the *Fonds zur Förderung wissenschaftlicher Forschung*. The authors would like to thank B. FELDERER, G. KARLHUBER and H.P. SCHRÖCKER for all their advice and discussions.

[2]) The source material was systematically recorded by G. ALLAN ([1]) and A. VAN DER LINDE ([17]) for the first time. The most important essay on KEMPELENs "Turk" is M. FABER's epilog to the RACKNITZ-reprint [9] which gives a concise overview on the entire literature about the "Turk" (for details see [5]). The "Kempelen-Archiv Wien", which is being established at Vienna's University for Applied Arts already has about 1200 entries under "Kempelen".

[3]) [14], p.52 quoted also by [7], p. 190.

The year it was destroyed, the late-baroque "Turk" had long been an antique, it had not worked for years and was almost forgotten. The every-day life was ruled by punchcard-controlled looms, steam trains, factories with strictly divided labour forces and by the institutions of the modern administrative state, which were themselves modelled in the image of a machine. In the first half of the 19th century the rapid expansion of the leisure industry, similarly, led the individual automatons, meant for entertainment, to be mass produced and thereby blurred the distinction between the construction of automatons and toy production.[4]) This confirms VON HELMHOLTZ's theory about the end of the era of the automatons and their mystique.

Nevertheless, KEMPELEN's android is quite out of the ordinary: Between 1770 and 1836 it was one of the technological sensations of the world. Countless articles, fliers, news stories and investigations appeared throughout Europe. As opposed to VAUCANSON's Duck and JAQUET-DROZ's performing androids which dextrously simulated fundamental body movements, KEMPELEN's chess player seemed to have grasped rationality. Since the Middle Ages, chess had been seen as a symbol of human intelligence, reason and the freedom of choice, it was considered as "royal" game, since it was the most difficult of all games. A mechanical simulation of the game fulfilled the dreams of the likes of D'HOLBACH or LA METTRIE for mechanical materialism; KEMPELEN's chess player meant the disappearance of the very residue of heavenly spirit from the man-machine. As Edgar Allan Poe remarked in 1836 this would have made the "Turk"

> "beyond all comparison the most wonderful of the inventions of mankind" ([20], p. 365).

If it had functioned autonomously: but of course it did not. A hidden player inside controlled the chess playing puppet (Fig. 1). In fact the "Turk" was one of the most charming bluffs in the history of technology. Because the inventor Kempelen as well as the subsequent owner NEPOMUK MAELZEL kept their silence about how the "Turk" functioned. This philosophically charged trick created an unimaginable flood of attempts at explaining the "Turk" which in a framework of Technological and Cultural history are of as much interest as the automaton itself[5])

JOSEPH FRIEDRICH ZU RACKNITZ' description and analysis of "Herrn von Kempelen's chess player and imitations thereof" (fig. 2) which appeared in 1789 in Leipzig and Dresden is regarded in many ways as a final and pivotal point in the recording of the "Turk". In his attempt at an explanation, RACKNITZ used some of the most important findings that had appeared in writings during the 1880's. This allowed him to take up the arguments of HINDENBURG, BOECKMANN and NICOLAI which spoke against the theory of an autonomous chess playing automaton and at the same time suggested the presence of human interaction at every move the "Turk" made. On the other hand, JOHANN LORENZ BOECKMANN in Carlsruhe had solved the problem of how a player inside could follow events outside, with his theory of magnetic needles. Two basic questions remained: *a*) How was the player hidden in the machine and *b*) how was the machine controlled by him.

RACKNITZ was eventually to become the first to construct two intricate replicas of KEMPELEN's automaton which enabled him to describe the controls of the "Turk" in detail. The question we have to face is whether the controls in RACKNITZ's replicas were truly functional, or not. [6])

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[4]) On the relationship between industrialization and the construction of automatons in Germany and Austria: [13], [21] and [26]. On the Austrian administration: [12] with further bibliography.

[5]) Many topics for discussion arise from the case study of the "Turk", which are relevant to the present. For example (a) within a framework of the history of the metaphors and motifs of "people in machines" as reflected in literature, cinema and philosophy from the Romanticists to the present ([24], p. 60-67), notes 151 and 301; Strouhal 1999 with further bibliography. (b) Within the framework of the perception of the "Turk" as a philosophical and historical mentality, representing the utopian materialisation of a thinking machine, nearly one hundred years before Babbages "Analytical Engine" and nearly two hundred years before ALAN M. TURINGs first experiments with chess computers. ([24], p. 148–158). (c) In its politico-ideological function as the materialization of the modern "Disciplinary Subjects", after [?] and as a prelude to "Taylorisation" of the working world. (d) Within the framework of the history of science to illuminate the relationship between showmanship and science, which in the second half of the 18th century were not seen so incompatibly as in our contemporary understanding (Ref: Description of the Rollers by [25], [21], [23]). Finally, (e) in a pedagogical, historical framework of the denigration of visuality and dialogue at the height of the age of Enlightenement, according to [23].

[6]) According to the Anglo-American literature of the 19th century ([27], [3], [4], [20]) a competitor to RACKNITZ's attempt at explaining the controls of the Turk, can be included. Instead of a pantograph, the player simply reachs into the arm

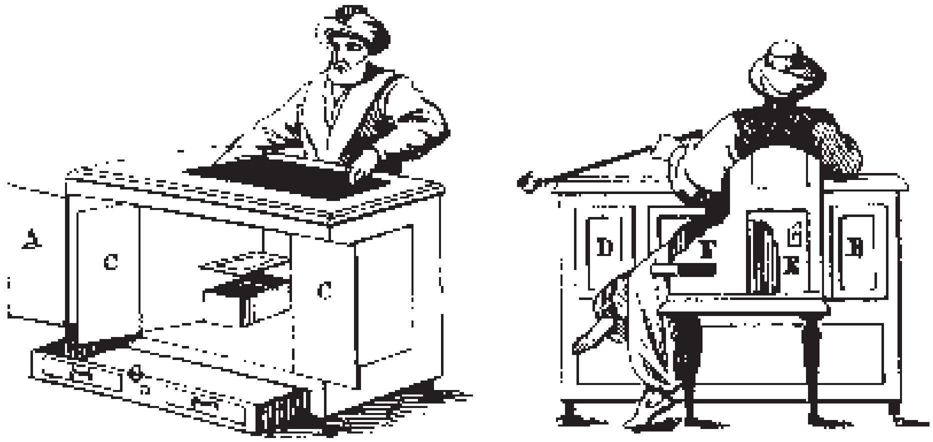

Figure 1: Some pictures from [4].

2 Details on the presentation and some explanations

Before we can discuss the questions of the controls, it is necessary to accurately describe the automaton and the way it was presented by KEMPELEN.[7])

Presenting himself to the audience as a serious mechanic, KEMPELEN started his performance by announcing that the following presentation was a deception, a mechanical illusion. The automaton consisted of a life size puppet in Turkish traditional dress, sitting cross-legged against the back of a wooden chest (Fig. 1). The chest (approximately 150 x 68 x 117 cm) was mounted on rollers to prevent any interference from ropes or wires under or from behind the stage. On top of the chest was a counter-sunken chess board.

The front of the chest displayed three doors; each separated into two sections. Under the doors, a drawer contended the full length of the chest. Before beginning, KEMPELEN opened both sections, one after the other. In the left compartment there was a confusion of cogs, rollers and levers. The right side was practically empty. It contained two quadrants and a cable winch at the top, as well as a pillow. He also opened the lower drawer, which held the chess pieces. One after the other he shone the light of a candle into each section. The movement of the candle was visible behind the chest, which excluded the possibility of a trick with mirrors. Finally the puppet would be shown sitting at the back of the chest.[8])

After this presentation, a volunteer from the audience was invited to participate in a game. The "Turk"

of the "Turk". He follows the game through a peephole in the chest of the puppet and grasps the pieces with a trigger mechanism in the lower arm. This "simple" explanation is largely refuted by an article which appeared in 1834 in the "Magasin Pittoresque" ([18]). Although doubt remains about its authenticity the text is attributed to the French Chess player JACQUES–FRANCOIS MOURET who piloted the "Turk" during the Paris trip and explained its controls along the lines of RACKNITZ's description. In November 1989 JOHN GAUGHAN, an expert in magic tricks, presented a replica of the "Turk" at a congress of magic historians, which claimed to be a perfect copy ([10]). Although reluctant by nature to share information, GAUGHAN let it be known during an interview that a pantograph mechanism formed the basis of the guidance system.

[7]) After first presenting it in 1769 and the few performances in the following year at Preßburg and Vienna, WOLFGANG VON KEMPELEN turned his hand to other projects, despite (or because) of the spreading acclaim. By order of textscMaria Theresia, KEMPELEN led the settlement of the Temesvar Banat and amongst other things was in charge of the security of Hungarian salt production, was concerned with constructing steam engines, water pumps and talking machines. For an extensive biography compare [16] with other bibliography. The chess machine was only shown again at the beginning of the 1780's. From 1783–84, a two year sabbatical granted by the Emperor JOSEPH II, allowed KEMPELEN to travel through Europe with his chess player and his new talking machine. On the return trip from London and Amsterdam, KEMPELEN passed through Germany. Source materials document evidence of performances by the "Turk" of varying duration and success, in Augsburg, Frankfurt, Leipzig, Regensburg and Dresden.

[8]) In this section of the chest there was also a smaller chest. At the beginning of the presentation this was displayed several metres away. The smaller box had no other function than to create confusion. Some observers suspected it of containing a magnet which steered the "Turk".

always took the first move and played left-handed. It announced "check" by nodding its head three times. After a dozen moves or so, the machine was wound up, apparently to give the player the chance to clear his throat under the cover of the noise.

After the game, the "Turk" answered questions from the audience by pointing at the appropriate golden letters on a board. Afterwards, KEMPELEN himself was available for questioning.[9])

From the first performances at the beginning of the 1770's the interest was predominantly in the "Turk" functioning autonomously, which was considered to be entirely possible. Typical of this are LOUIS DUTENS letters of 1771 and the first reports from KARL GOTTLIEB VON WINDISCH in 1773. WINDISCH (1725–1793) was a journalist and senator who later became mayor of Preßburg. He fully represented the Enlightenment and like KEMPELEN himself, was a freemason and had strong bonds with KEMPELEN's family.

Because of this, WINDISCH's letters about KEMPELEN's chess player should be seen as advertising tracts, however changes are observable in them between 1773 and 1783. In 1773, without fear of ruining his reputation as a man of the Enlightenment, WINDISCH gave the first critics who suspected the presence of a player in the machine this answer:

"I have carefully inspected the table and the machine several times and I can assure you with all confidence that there remains not the slightest grounds to such a suspicion" ([28], pp. 230/231).

His letters of 1783 lack such precise statements, nevertheless, the idea of the "Turk" being at least partially autonomous was still adhered to until the 1780's, despite the high level of education of the various authors[10]): In 1783 JOHANN PHILLIPP OSTERTAG, professor in Regensburg, for example, could not exclude the possibility of an "intellectual entity with a clear insight into the rules of the game" (Quoted from [9], p. 72). HINDENBURG and EBERT recognised that a human intervention was necessary, but concluded that it consisted of a magnetism which moved an internal clockwork and striking mechanism. This magnetic power was not effective for every move: "Principally, it works mechanically", only occasionally, "several moves are made independently" ([15], p. 39), most of the time, however, the "Turk" plays prearranged games, in other words, automatically. Even in 1785 JOHANN LORENZ BOECKMANN is uncertain when he writes:

"A machine capable of making all of the millions of different movements by itself, in other words, through its inner organisation (even if we want to consider that possibility for a second) would have to be constructed in an astonishing manner, with endless work and craftsmanship.", ([2], pp. 49–50).

BOECKMANN argued that the short production time in 1769 spoke against KEMPELEN's chess player being an automaton but he did not exclude the possibility that it could be.

Gradually an attitude of scepticism settled over the possibility of an automaton which could play chess. The great man of the Enlightenment, FRIEDRICH NICOLAI, however, was convinced of its impossibility. He writes:

[9]) The fact that the "Turk" not only played chess but could obviously hear and understand was of particular interest to the observers. For the German translators of [4], p. 329 this was the final proof that the "Turk" was not an autonomous automaton. ("this could not have been predicted"), whilst [8], p. 30, considered the question and answer game to be more of a conundrum than the computation of the chess game. According to EBERT the "Turk" could even have passed a Turing-Test!

[10]) JOHANN PHILLIPP OSTERTAG (1734–1801), who had studied under the mathematicians Böhm and Stritter, was the headmaster at the Landesgymnasien of Weilburg (1763) and Regensburg (from 1776). He was a translator of Greek and Latin and also left papers on Mathematics, Physics and Astronomy. KARL FRIEDRICH HINDENBURG (1741 - 1808) initially studied a mixed bag of subjects at the University of Leipzig and worked as a private tutor. In 1771 he completed his mathematical studies and in 1786 took up a professorship of Physics in Leipzig. He is seen as the founder of the ("Combinatorische Schule") JOHANN JAKOB EBERT (1737 - 1810) also studied at the University of Leipzig and from 1769 was mathematics professor at the University of Wittenberg. This brief biographical note indicates the vagueness of the opinions of even mathematicians and physicists about the possibility of a "Man-Machine" at the end of the 18th century, and the strong emotional reactions the "Turk" must have aroused in less educated people. The following observation made by WINDISCH at one of the performances sounds plausible: "An elderly lady crossed herself with a pious sigh and moved towards a nearby window to avoid the evil spirit, which she definitely considered to be within or at least near the machine." (Windisch 1783, p. 12).

"No man of reason can accept the possibility of a machine playing chess by means of an internal mechanism, that is to say that it should undertake an action which requires reason and consideration." ([19], p. 420).

According to Nicolai even a chess player of little experience must realize that the number of programmed variations would be too high to allow chess to be played mechanically. This meant that the "Turk" was nothing more than a "sleight of hand", "a fraud". Nicolai also considered Kempelen's talking machine to be a deception. This great man of the Enlightenment had not actually seen either of the automatons and perhaps this very fact made him so sure of his case.

Joseph Friedrich Freiherr zu Racknitz (1744–1818) did not have this problem. The chamberlain, musician and co-founder of the Dresden Opera had studied the "Turk" at its appearance in Dresden, in 1784, when he made the acquaintance of Kempelen, himself.

In the introduction to his study, Racknitz initially turns against Nicolai's criticism and against a rash judgement of the "Turk". Racknitz was impressed by the difficulties of controlling the pseudo machine. The efficiency of the guidance system astonishes him most about the chess player.

After a detailed description, Racknitz then turns to various hypotheses about the way the machine functions and reaches the conclusion that only a hidden player could make the movement from within. From Boeckmann's analysis, Racknitz already knew how a player sitting in the chest could follow the game outside. The chess pieces had magnetic centres, so that touching a specific square, raised metal needles immediately underneath. By looking at the upper surface of his hidden compartment, the player could follow the last move and then duplicate the state of play on a pocket chess-board (Fig. 1).

Boeckmann, however paid little attention to the guidance system, merely mentioning "a similar attachment to the existing pantograph" ([2], p. 49). It was precisely how this functioned, that Racknitz found particularly interesting.

3 The analyzation of Racknitz' automaton

In the following, we will compare Racknitz' description with the drawings that were given ([22]). To us, only the mechanical aspect was of interest: How could the automaton be steered by the hidden human chess player? We tried to analyze the several kinematical aspects from a modern point of view and made a computational simulation of the automaton. To cut it short: Despite of some unclear statements and misleading details in the drawings, we found out that Racknitz most probably built an imitation of the "Turk" that worked well. The three-dimensional problem was cleverly reduced to two-dimensional part-problems.

The automaton had different functions that can be grouped into five different kinds of movements (the numbers and letters refer to the original (Fig. 2, see also Fig. 3):

1. The nodding of the head
   (a) Racknitz' description: A rope (*8*) runs from some fixed point of the head through tube (*10*). It wraps around a rod and is fixed on a trigger (*12*) at the end of a lever (*11*). In the neck, some spring (*7*) is placed that by default stretches the head upright (only Fig. 2). When the trigger (*12*) is pressed against the force of spring (*7*), the head bends until the trigger is released.
   (b) Our explanation:The described mechanism sounds reasonable. It is explained clearly and does not need further explanation.
2. The vertical rotation of the arm about the shoulder joint
   (a) Racknitz' description: The arm (upper arm, lower arm, hand) rotates about a vertical axis (tube (*15*)). Together with lever (*16*), tube (*15*) forms a "*lever of 1st kind*". Fixed with tube (*15*),

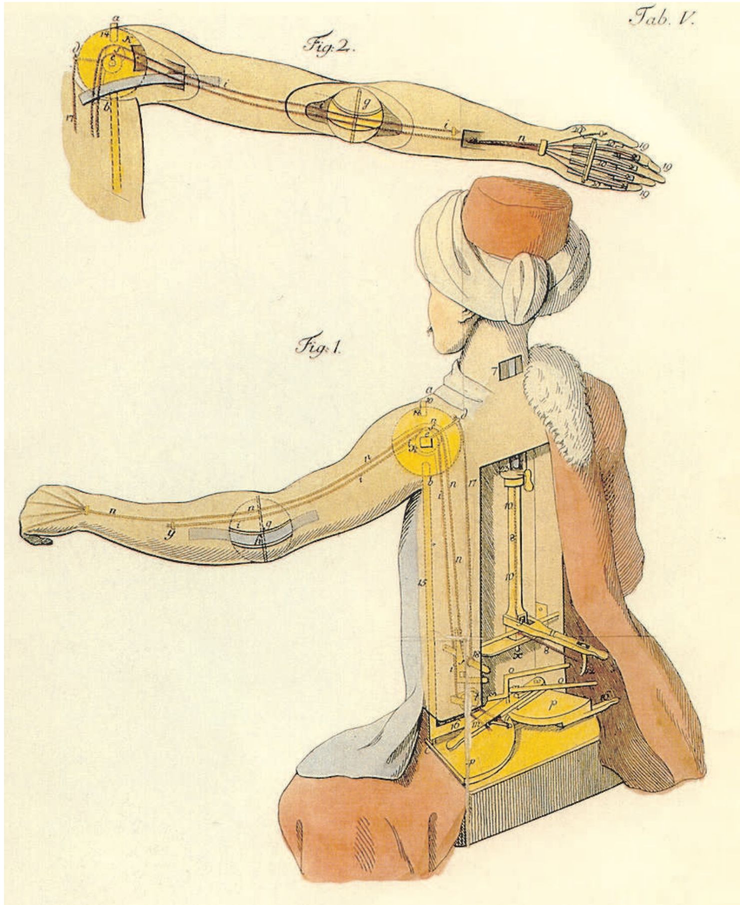

Figure 2: RACKNITZ' original from [22].

there is a half-sphere (k) that is supposed to simulate the shoulder. Through this half-sphere runs a horizontal rotation axis that supplies a connection of tube (*15*) and the arm. The rotation of the arm is done by lever (*16*) and can be quantified by means of a scale on the *quadrant* to the left. (Obviously, RACKNITZ means a quarter of a circular disk with the word "*quadrant*", although the drawing is misleading.)

(b) Our explanation: The prolongation of lever (*16*) is not explained in detail. On the contrary, this is one of the most sensitive parts in the whole mechanisms. The drawing is even misleading, since it seems that lever (*16*) is connected with the *quadrant* to the right (Fig. 2). Details of other original drawings, however, indicate that lever (*16*) was *not* connected to the *quadrant* to the right (Fig. 5) – which made things much clearer. Fig. 3 shows our simulation via computer. Henceforth, we will denote the vertical axis through the shoulder joint a_1.

3. The rotation of the entire arm about the horizontal axis in the shoulder joint

(a) RACKNITZ' description: A rope (*17*) is fixed at the half-sphere (k) by means of an "*lever of 3rd kind*" (d) and leads to a "*lever of 2nd kind*" (*18*) that can be fixed at a certain position by means of a spring (f)

(b) Our explanation:
The chess player only needs to be able to raise his arm to a certain height. The corresponding horizontal rotation axis will henceforth be denoted by a_3. In the upper position, the rotation axis through the ellbow – henceforth denoted by a_2 – must be vertical, i.e., parallel to the rotation axis a_1. through the shoulder joint. As a consequence, a composition of the two rotations about a_1 and

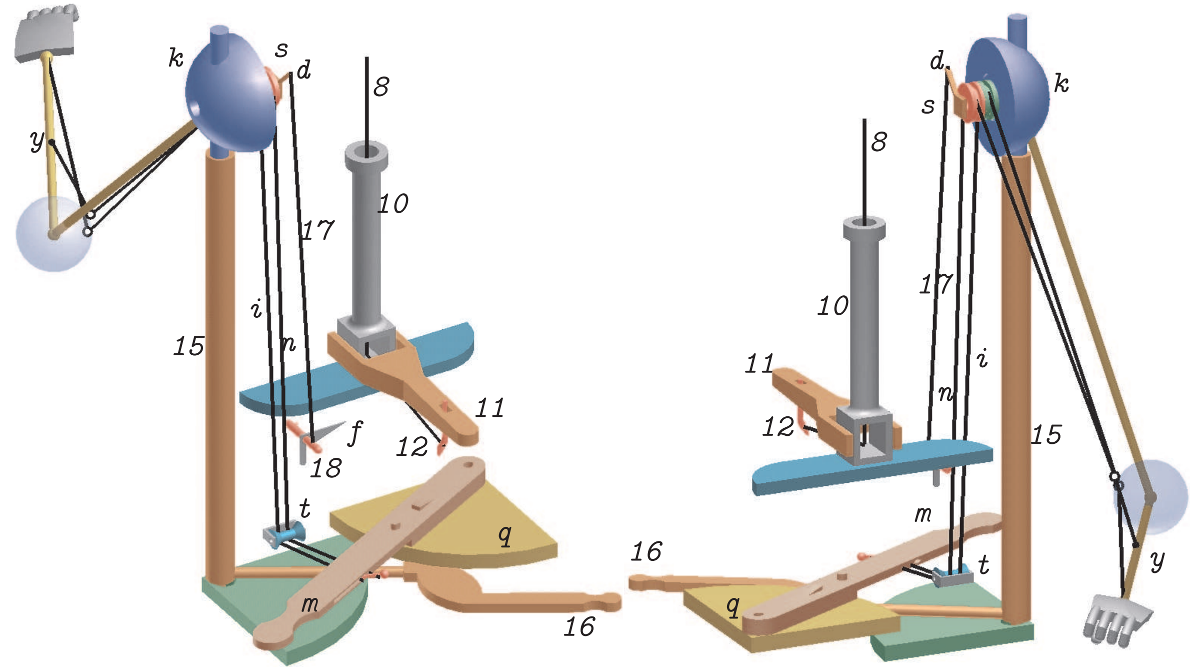

Figure 3: Our computer model, created and animated with Open Geometry ([11])

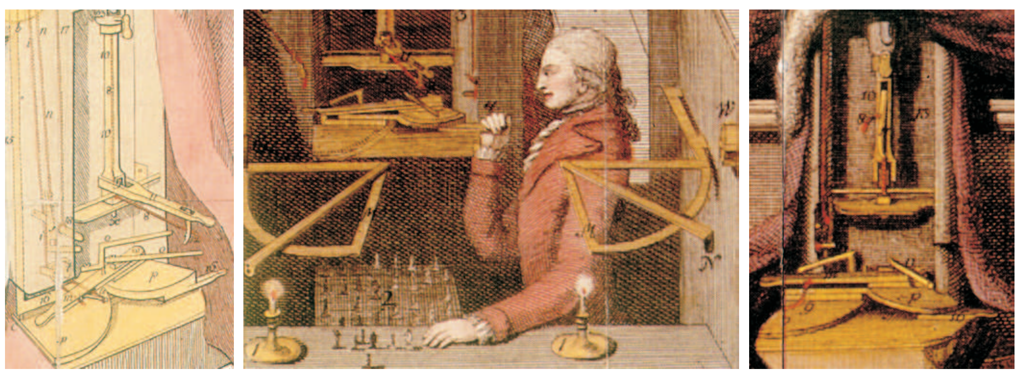

Figure 4: Details of three of Racknitz' original drawings.

a_2 can be treated two-dimensionally (Fig. 5, top view to the right)! Obviously, this distinct hight position is fixed by spring (f). The second (lower) position is not exactly determined. It is either the position of the arm on the pillow or the position where the hand is grapping a chess figure from above (and therefore is stopped in its motion as well). This kind of movement is stable and we think it was possible to work with it quite comfortable.

4. The rotation of the lower arm about the ellbow

(a) Racknitz' description: A rope (i) is fixed somewhere at a point y at the lower arm. It runs over some kind of roller or eyelet at the ellbow. Next, it runs over an additional spool s (with the horizontal a_3 through the half-sphere (k)). Then, rope (i) runs over another spool (t), and it is finally fixed at the lever (m). This lever rotates about another vertical axis a_4 through the midpoint of the *quadrant* to the right (p). When lever (m) is rotated, rope (i) is stressed or loosened, and the lower arm rotates about a_2 through the ellbow. A spring (h) (Fig. 2) at the ellbow garantees that the arm stretches when rope (i) is loosened.

(b) Our explanation: This is indeed an ingenious solution. The rotation about a_4 induces a (non-proportional) rotation about the momentary parallel axis a_2. By means of the rotations of lever (*16*)

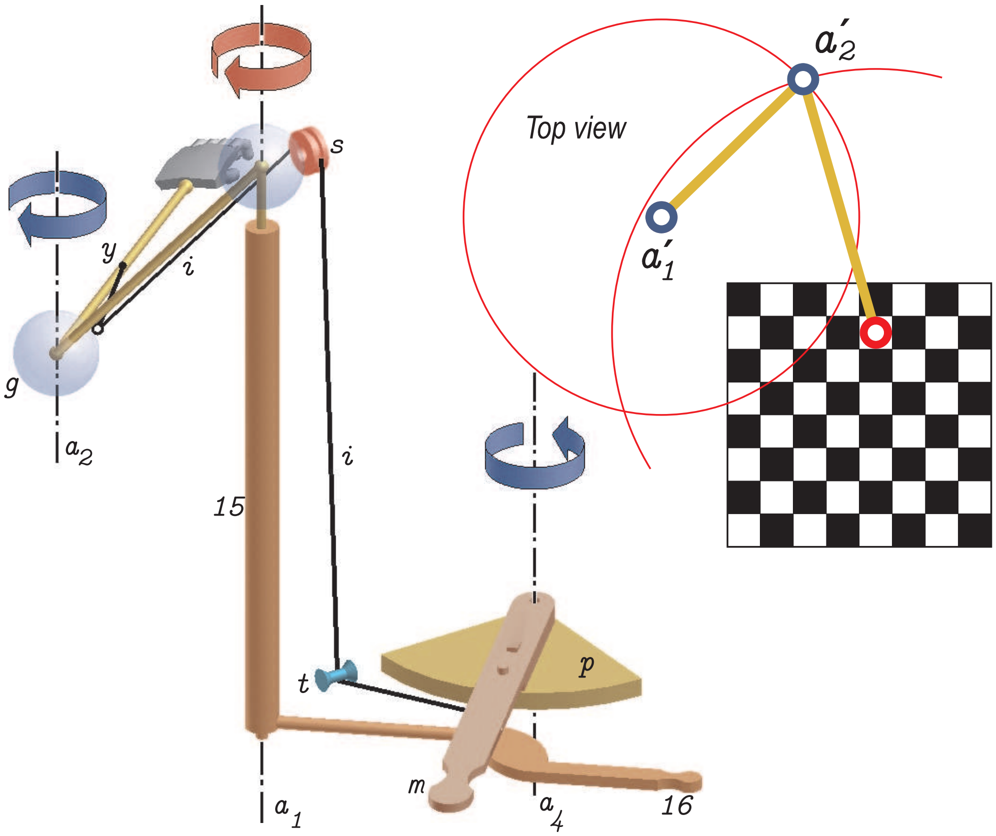

Figure 5: The two parallel rotation axes a_2 and a_4. To the right, one can see the top view and a construction of the arm position when the hand position is given.

and lever (m), the person in the machine can easily and smoothly apply two composed rotations about the parallel axes a_1 and a_2. Thus, he can move the hand of the puppet virtually anywhere within certain boundaries – theoretically even along a predefined path, e.g., along a straight line! Scales on the left and the right *quadrant* allow to find predefined position. The dimension of the problem is reduced from a complex spatial movement to two composed planar rotations.

5. The fingers

(a) Racknitz' description: A rope (n) leads from a fixed joint in the puppet's hand to a trigger (u) on lever (m). In between, it runs over a second spool or eyelet close to the ellbow, an additional spool on the horizontal axis a_3 and finally again over the spool t. When the trigger is pulled, rope (n) pulls five thin ropes inside the hand that close the fingers. Springs in the hand garantee that the fingers open when the trigger is loosened.

(b) Our explanation: There is not much to add. Hands like these where state of the art at the end of the 18th century.

Let us now briefly sum up and describe how we think that the mechanism worked: Besides the brain work of playing chess, the person in the puppet has to do the following when it is his turn:

1. Raise the arm of the puppet by means of lever (*18*) and fix the lever by means of spring (f).
2. Perform the rotation of lever (m) and lever (*16*) – one after the other or simultaneously – to well-defined markings in the *quadrants*. Fix the levers there by means of some levers that Racknitz briefly describes.

3. Lower the arm by means of lever (*18*), until the hand touches the (heavy) chess figure.

4. Pull and fix trigger (u) in order close fingers and grap the figure.

5. Raise arm, steer to new position.

6. Now there are two posibilities:

(a) There is no figure at the new position. Then lower arm, release figure (release trigger (u)), raise arm, move back to pillow, lower arm there.

(b) There is a figure at the new position. Then "touch this figur" sensitively. This was the sign for an assistant to remove the figure by hand (described in several sources). Now proceed as described above. Theoretically, it would have been possible to remove the figure with the puppet, deposit the figure somewhere at the side of the chess board, move to the own figure and proceed with step 2.

4 Conclusion and future work

The analyzation of RACKNITZ' description shows that he had in fact most probably built a machine that could fulfill all the tasks of KEMPELEN's automaton. The computer simulation, written with the program system OPEN GEOMETRY ([11]), works fine. Next we will try to rebuild RACKNITZ's machine physically. Furthermore, we plan to write an interactive computer simulation that can be run over the Internet (Java-code!). The final goal is to be able to play chess with a virtual automaton. Therefore we intend to implement the chess engine of a professional chess program ([6]).

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