

## 22 HILBERT'S MACHINE EXTENDED

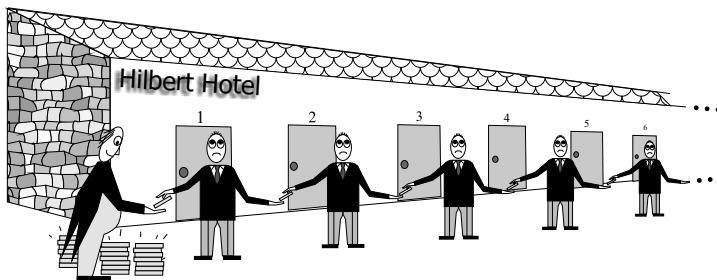
(Draft chapter of the book *Infinity put to the test* by Antonio León<sup>1</sup>)

**Abstract.**—Inspired by the emblematic Hilbert Hotel, Hilbert machine is a conceptual super-machine whose functioning questions the consistency of the actual infinity hypothesis subsumed into the Axiom of Infinity.

**Keywords:** Hilbert Hotel, supertask, actual infinity, axiom of infinity.

### 22.1 HILBERT'S HOTEL

1. In the next discussion we will make use of a supermachine inspired by the emblematic Hilbert's Hotel. But before beginning, let us relate some of the prodigious, and suspicious, abilities of the illustrious Hotel.



**Figura 22.1** – The power of the ellipsis: An infinitist way of making money.

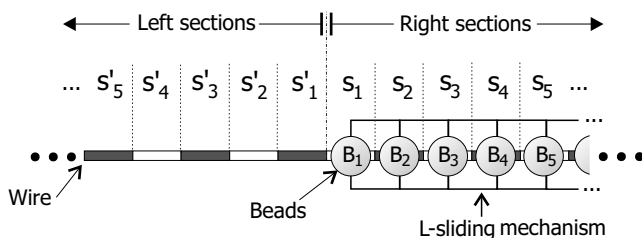
2. Its director, for example, has discovered a fantastic way of getting rich: he demands one euro to  $R_1$  (the guest of the room 1);  $R_1$  recovers his euro by demanding one euro to  $R_2$  (the guest of the room 2);  $R_2$  recovers his euro by demanding one euro to  $R_3$  (the guest of the room 3); and so on. Finally all guests recover his euro, because there is not a last guest losing his money. Our crafty director then demands a second euro to  $R_1$  which recovers again his euro by demanding one euro to  $R_2$ , which recovers again his euro by demanding one euro to  $R_3$ , and so on and on. Thousands of euros coming from the (infinitist) nothingness to the pocket of the fortunate

<sup>1</sup>Next publication

director.

3. Hilbert's Hotel is even capable of violating the laws of thermodynamics by making it possible the functioning of a perpetuum mobile: in fact we would only have to power the appropriate machine with the calories obtained from the successive rooms of the prodigious hotel in the same way its director gets his euros.

4. Unbelievable as it may seem, infinitists justify all those absurd pathologies, and many others, in behalf of the *peculiarities* of the actual infinity. They prefer to assume any pathological behaviour of the world before examining the consistency of the pathogene. In the next discussion, however, we will come to a contradiction that cannot be easily subsumed in the picturesque nature of the actual infinity.



**Figure 22.2** – Hilbert's machine just before performing the first L-sliding.

## 22.2 DEFINITIONS

5. In the following conceptual discussion we will make use of a theoretical device, inspired by the emblematic Hilbert Hotel, that will be referred to as *Hilbert machine*, composed of the following elements (see Figure 22.2):

- 1) An infinite horizontal wire divided into two infinite parts, the left and the right side:
  - a) The right side in turn is divided into an  $\omega$ -ordered sequence of disjoint and adjacent sections  $\langle S_n \rangle$  of equal length labeled from left to right as  $S_1, S_2, S_3, \dots$ . They will be referred to as right sections.
  - b) The left side is also divided into an  $\omega$ -ordered sequence of disjoint and adjacent sections  $\langle S'_n \rangle$  of equal length, the same length as the right sections, and labeled now from right to left as  $\dots, S'_3, S'_2, S'_1$ ; being  $S'_1$  adjacent to  $S_1$ . They will be referred to as left sections.

- 2) An  $\omega$ -ordered sequence of labeled beads  $\langle b_n \rangle$  strung on the wire, so that they can slide on the wire as the beads of an abacus, being each bead  $b_i$  initially strung on the center of the right section  $S_i$ .
- 3) All beads are mechanically linked by an sliding mechanism that slides simultaneously all beads the same distance along the wire.
- 4) The sliding mechanism is adjusted in such a way that it slides simultaneously each bead exactly one section to the left (L-sliding).

6. Obviously, Hilbert's machine is a theoretical artifact, and its functioning is a simple thought experiment that illustrates a formal argument to test  $\omega$ -order, the order type of the well ordered set  $\mathbb{N}$  of the natural numbers in their natural order of precedence, whose ordinal number is  $\omega$ , the least transfinite ordinal [2, §15, Theorem A, p.160]. This is not, therefore, a discussion of the physical restrictions and consequences of performing a particular sequence of physical actions.

7. Since the sections  $\langle S'_i \rangle$  of the left side of the wire are  $\omega$ -ordered each section  $S'_n$  has an immediate successor  $S'_{n+1}$  just on its left. In accord with the hypothesis of the actual infinity all those infinitely many left sections exist as a complete totality in spite of the fact that there is no last section completing the sequence.

8. We will assume Hilbert's machine always works according to the following:

**Restriction P8.**-An L-sliding will be carried out if, and only if, after being performed all beads remain strung on the wire. Otherwise, the L-sliding will be undone so that every bead recover its previous position and then the machine stops.

9. Let us begin by proving that for each  $v \in \mathbb{N}$  the first  $v$  L-slidings can be carried out according to Restriction P8. Assume this assertion is not true. There will be a natural number  $u \leq v$  such that it is impossible to perform the  $u$ th L-sliding according to Restriction P8. But this is impossible because whatsoever be the section  $S'_k$  occupied by  $b_1$  just before performing the  $u$ th L-sliding, there always be a left section  $S'_{k+1}$  contiguous to that section, so that  $b_1$  can L-slide to that section  $S'_{k+1}$  and every ball  $b_{i,i>1}$  to the section previously occupied by  $b_{i-1}$ . Therefore, the  $u$ th L-sliding can be carried out according to Restriction P8. Consequently our assumption is not true and for each  $v \in \mathbb{N}$  it is possible to carry out the first  $v$  L-slidings according to Restriction P8. We would come to the same conclusion by

an inductive argument similar to any of those developed in the previous chapters.

**10.** The following inductive argument leads to the same conclusion as the previous one P9 (Modus Tollens). It is clear that the first L-sliding can be performed:  $b_1$  slides to  $S'_1$  and every  $b_{i;i>1}$  to the section previously occupied by  $b_{i-1}$ . Suppose that, for any natural number  $n$  any, the first  $n$  L-slidings can be carried out. Since each L-sliding moves each ball one section to the left, all balls will have been moved  $n$  sections to the left, so that  $b_1$  will be in the left section  $S'_n$  since  $S'_1$  is  $n$  sections to the left of the  $S_1$ , the section initially occupied by  $b_1$ . And since  $S'_n$  has an adjacent left section  $S'_{n+1}$ ,  $b_1$  can slide to  $S'_{n+1}$  and each  $b_{i;i>1}$  to the section previously occupied by  $b_{i-1}$ . So, if for any  $n$  the first  $n$  L-slidings can be carried out, the first  $n+1$  L-slidings can also be carried out. And since the first L-sliding can be carried out, we conclude that for any  $v \in \mathbb{N}$  the first  $v$  L-slidings can be carried out.

### 22.3 HILBERT MACHINE CONTRADICTION

**11.** Assume that while the successive L-slidings can be carried out, they are carried out. It is immediate to prove the following:

**Theorem P11.**—Once performed all possible L-slidings all balls remain strung on the wire.

*Proof.*—It is an immediate consequence of Restriction P8: if an L-sliding removes a bead from the wire that L-sliding would be undone and the machine stops with every ball strung on the wire.

**12.** But it is also immediate that:

**Theorem P12.**—Once performed all possible L-slidings no bead remains strung on the wire.

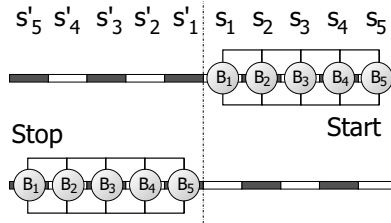
*Proof.*—Let  $b_v$  be any bead and assume that once performed all possible L-slidings it is strung on the right section  $S_k$ . It must be  $k < v$  because all L-slidings are towards the left, the direction towards which the indexes of  $\langle S_i \rangle$  decrease. Since  $b_v$  was initially on  $S_v$  only a finite number  $v - k$  of L-slidings would have been performed, and then it would not have been possible to perform the the first  $v - k + 1$  L-slidings, which goes against P9 and P10 because  $v - k + 1$  is a natural number. A similar reasoning can be applied if  $b_v$  were finally strung on a left section  $S'_n$ , being now the number of performed L-slidings exactly  $v + n - 1$  and then it would not have been possible to perform the first  $v + n$  L-slidings, which also goes against P9 and P10. Thus, since  $b_v$  is any bead, if all possible L-slidings have been performed, then no bead remains strung on the wire. Note this

is not a question of indeterminacy but of impossibility: the set of possible sections any ball  $b_v$  could be finally occupying is the empty set.

**13.** A point of note on the above argument is that it is not necessary to know if the number of performed L-slidings is finite or infinite. It is only necessary to assume that, under the hypothesis of the actual infinity, all possible L-slidinings have been carried out.

#### 22.4 DISCUSSION

**14.** Let us compare the functioning of the above Hilbert machine ( $H_\omega$  from now on) with the functioning of a finite version of the machine (symbolically  $H_n$ ). This finite machine has a finite number  $n$  of both right and left sections (Figure 22.3). A finite sequence of  $n$  beads are initially strung on the right side of the wire, each bead  $b_i$  strung on the center of the right section  $S_i$ . It is immediate to prove that  $H_n$  can only perform  $n$  L-slidings because not having a left section  $S'_{n+1}$ , Restriction P8 will stop the machine with each left section  $S'_i$  occupied by the bead  $b_{n-i+1}$  and all right sections empty, and this is all. No contradiction is derived from the functioning of  $H_n$ . Thus for any natural number  $n$ , the corresponding machine  $H_n$  is a consistent theoretical artifact. Only the infinite Hilbert's machine  $H_\omega$  is inconsistent.



**Figure 22.3** – A finite machine of five sections.

**15.** What contradiction P11-P12 proves is not the inconsistent functioning of a supermachine. What it proves is the inconsistency of  $\omega$ -order itself (Principle of Independence). Perhaps we should not be surprised by this conclusion. After all, an  $\omega$ -ordered sequence is one which is both complete (as the actual infinity requires) and uncompletable (there is not a last element that completes the sequence). On the other hand, and as Cantor proved [1], [2],  $\omega$ -order is an inevitable consequence of assuming the existence of infinite sets as complete totalities. An existence axiomatically

stated in our days by the Axiom of Infinity, in all axiomatic set theories including its most popular versions ZFC and BNG [4], [3]. It is therefore that axiom the ultimate cause of contradiction P11-P12.

## Chapter References

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