

(19)



(11)

EP 3 705 195 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:

13.07.2022 Bulletin 2022/28

(51) International Patent Classification (IPC):

B07C 5/34 ^(2006.01) **B07C 5/36** ^(2006.01)

(52) Cooperative Patent Classification (CPC):

B07C 5/34; B07C 5/36; B07C 2501/0027

(21) Application number: **20161572.1**

(22) Date of filing: **06.03.2020**

(54) **AUTOMATIC MATERIAL RECOGNITION SYSTEM**

AUTOMATISCHES MATERIALERKENNUNGSSYSTEM

SYSTÈME DE RECONNAISSANCE AUTOMATIQUE DE MATÉRIAU

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **08.03.2019 IT 201900003437**

(43) Date of publication of application:

09.09.2020 Bulletin 2020/37

(73) Proprietors:

- **Carbotti, Michele**
74015 Martina Franca (TA) (IT)
- **Montaruli, Vincenzo**
76123 Andria (BT) (IT)

(72) Inventors:

- **Carbotti, Michele**
74015 Martina Franca (TA) (IT)
- **Dalena, Vito**
00159 Roma (RM) (IT)

(74) Representative: **Fezzardi, Antonio et al**

Studio Ferrario Srl
Via Collina, 36
00187 Roma (IT)

(56) References cited:

WO-A1-2017/089145

EP 3 705 195 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

[0001] The present invention relates to an automatic system for material recognition through tonal shock.

[0002] The present automatic material recognition system is entirely innovative and inventive because it emerges as an original technical solution to solve the problems which currently exist in the case illustrated by way of example related to the automatic recognition and separation of municipal solid waste, thereby minimizing the manufacturing and management costs of the automatic recognition systems themselves but which can be used equivalently and validly for the recognition of any material in general.

[0003] In the present description, reference will be made to a particular example of application related to municipal solid waste.

[0004] Various systems are known to date for the automatic recognition and separation of municipal solid waste, especially of the optical recognition type, through cameras or other electronic-computerized devices and the like.

[0005] WO 2017/089145 A1 discloses a method and an evaluation device for determining at least one material property of a piece of material through noise evaluation.

[0006] To date, the systems adapted to automatically recognize and separate municipal solid waste provided with electronic-computerized devices have substantially displayed the following obvious disadvantages:

- a limited and low memory usage, usually correlated with the problem of not being able to offer anything other than small available spaces for their implementation;
- high and excessive energy consumption, which does not allow, even when necessary, powering the entire automatic waste recognition and separation system with simple batteries or in any case minimizing electricity consumption.

[0007] Therefore, it is the object of the present system to solve said problems and disadvantages of the prior art by designing and manufacturing an innovative automatic system for material recognition through tonal shock, in particular, in the example described below, for the recognition and separation of municipal solid waste.

[0008] It is a further object of the present system to use devices and components which have a minimized cost and a zero environmental impact index, and which are also possibly completely recyclable, the construction and functional features being the same.

[0009] Such objects are achieved by implementing an automatic system for material recognition through tonal shock, as defined in the claims.

[0010] Such objects and the consequent advantages, as well as the features of the invention according to the present invention, will be more apparent from the following detailed description of a preferred solution, given by

way of non-limiting example with reference to the accompanying drawings, in which:

> Fig.1 is a two-dimensional, section view drawing of a first preferred but not limiting embodiment of an automatic material recognition system 1 through tonal shock, of material such as municipal solid waste 2, according to the present invention, from which the particular and innovative configuration of the system 1 itself can be inferred, which system substantially consists of a drum 4, of elastic type, adapted to emit a characteristic sound wave W_i , when it is struck by a dropped piece of a waste 2 to be recognized, with said specific subscript "i" correlated with the particular type of waste to be recognized and separated, all through reception means 5 of the sound wave W_i , processing means 6 of the acoustic signal and automation means 16 of the movable elements (7, 9, 11), the latter being adapted to separate glass 13 from aluminum 14 and plastic 15, respectively, in the preferred but not limiting example shown;

> Fig.2 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 in Fig. 1, in which it is now possible to infer the drop point onto said drum 4 of the waste 2, which is instantly recognized as glass 13, with its rebound on the drum 4 itself along the drop trajectory 3 and the emission of a specific sound wave W_1 , activating said reception means 5, processing means 6 and automation means 16 of the corresponding movable element 7 to the container compartment 23 for glass 13, respectively;

> Fig.3 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 referred to in the preceding figures 1 and 2, in which it is now possible to infer the drop of the glass waste 13, previously recognized by the system 1, towards the container compartment 23 for glass 13, now accessible due to the complete opening of the movable element 7 which closed it;

Fig.4 is a two-dimensional, section view showing a second preferred but not limiting embodiment of an automatic recognition system 1 of municipal solid waste 2 according to the present invention, from which the behavior of the system 1 itself can be inferred, if said drum 4 is struck by a piece of waste 2 different from the previous piece of waste recognized as glass 13, also to be recognized and separated;

Fig.5 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 in Fig.4, in which it is now possible to infer the drop point onto said drum 4 of the waste 2, which is now instantly recognized as aluminum 14, with its rebound on the drum 4 itself along the drop trajectory 3 and the emission of a specific sound wave W_2 , activating said reception means 5, processing means 6 and automation means 16 of the corresponding movable element 9 to the container compartment 24 for alumi-

num 14, respectively;

Fig.6 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 referred to in the preceding figures 4 and 5, in which it is now possible to infer the drop of the aluminum waste 14, previously recognized by the system 1, towards the container compartment 24 for aluminum 14, now accessible due to the complete opening of the movable element 9 which closed it;

Fig.7 is a two-dimensional, section view showing a third preferred but not limiting embodiment of an automatic recognition system 1 of municipal solid waste 2 according to the present invention, from which the behavior of the system 1 itself can be inferred, if said drum 4 is struck by a piece of waste 2 different from the previous piece of waste recognized as glass 13 and aluminum 14, also to be recognized and separated;

Fig.8 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 in Fig.7, in which it is now possible to infer the drop point onto said drum 4 of the waste 2, which is now instantly recognized as plastic material or plastic 15, with its rebound on the drum 4 itself along the drop trajectory 3 and the emission of a specific sound wave W_3 , activating said reception means 5, processing means 6 and automation means 16 of the corresponding movable element 11 to the container compartment 25 for plastic 15, respectively;

Fig.9 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 referred to in the preceding figures 7 and 8, in which it is now possible to infer the drop of the plastic waste 15, previously recognized by the system 1, towards the container compartment 25 for plastic 15, now accessible due to the complete opening of the movable element 11 that closed it;

Fig.10 is a drawing illustrating the preferred architecture of the acquisition, processing and energy saving means M, in particular consisting in the preferred example, shown by way of non-limiting example by an acquisition device 19 of the detected input data of the selected waste 2, by means of a microphone 18 and a timer device 17, and interfaced with a computing card 20, with the latter connected, in turn, to a memory card 21, storing data 22 relating to the classification and collection of the waste 2, and additional saving energy means 26;

Fig.11 is a drawing showing the collected data reception and processing electronic circuit L, consisting of a microcontroller 27, a reader 28 and a receiver device 5 of the sound wave W_i (in this example with the subscript $i=1, 2$ and 3, relating to the three examined pieces of waste 2, i.e.: glass bottles 13 with the "glass bottle" rhombus symbol; aluminum cans 14 with the "aluminum can" circle symbol; and plastic bottles 15 with the "plastic bottle" four-pointed star symbol);

Fig.12 is a drawing showing the Fourier transforms at an assigned lambda wavelength (in the example, lambda equal to 0.1), the latter correlated with the particular feature of the shock wave $W_{i<_j}$, said transform showing the level of the input signal power to the system 1 on the abscissa and the carrier peak frequency or most significant frequency level on the ordinate, to optimize the identification, selection and collection of individual pieces of waste 2;

Fig.13 is a block chart illustrating a first possible flow-chart F1 related to the operation of the management and control software of the designed system 1;

Fig.14 is another block chart illustrating a second possible flowchart F2 related to the operation of the management and control software of the designed system 1;

Fig.15 is a further block chart illustrating a third possible flowchart F3 related to the operation of the management and control software of the designed system 1.

[0011] As can be seen from the fifteen appended figures, which show a preferred but non-limiting solution of the present invention, the automatic recognition system 1 of municipal solid waste 2 firstly solves said problems still existing in the sector today, because we have devised an innovative and inventive automatic recognition means of waste 2, assisted by a timer device 17 and by an architecture M as well as:

- a reception device 5 of sound waves W_i , e.g. a microphone 18 possibly of passive type or another reception device 5 of the sound wave W_i (with index $i = 1, \dots, n$) emitted by yet another generic piece of waste 2 in the act of its dropping impact on a drum 4;
- a detected data acquisition, processing and transfer device 19 provided with a calculating card 20 within a microprocessor or microcontroller 27 (a microprocessor of the "Arduino Mega 2560 R3" type was adopted in the prototype made by way of non-limiting example only) and a memory card 21 for periodically recording the selected waste in a database 22;
- a plurality of separation means (7, 9, 11) of the waste 2 itself, thus recognized (13, 14, 15), sorted, weighed, and stored in appropriately sized container means (23, 24, 25);
- energy consumption abatement means 26 of the entire system (1), adapted to shut down the calculating card 20 of the microprocessor 27 when it is not in use, together with the necessary means for restarting the system 1 which restarts the system 1 only when necessary;
- and a storage device or memory card 21, adapted to store the information necessary for the classification of the progressively sorted quantities of municipal solid waste 2.

[0012] Said automatic recognition means of the waste

2, thus designed, is adapted to recognize the elastic shock sound wave W_i generated by every single piece of waste 2, when the latter interacts with the drum 4, through said acoustic sensor 5 and an automatic management program of the plurality of separation means (7, 9, 11) of the waste 2 itself.

[0013] Said identification means, according to an illustrative but non-limiting aspect of the invention, shown by example in Figures 1-9, consist of movable elements (7, 9, 11), hinged at one end and rotating about it in so that the other free end can describe a curvilinear trajectory (8, 10, 12) adapted to correspondingly allow the opening of the container underneath (23, 24, 25), corresponding to the waste identified (13, 14, 15) and thus selected.

[0014] According to another aspect of the invention, said microphone 18, in particular, is replaceable by any other acoustic type sensor 5, provided that the latter is validly supported by an automatic management program of a plurality of separation means (7, 9, 11) of the waste 2 itself thus correspondingly recognized (13, 14, 15), selected and weighed by the system 1 itself.

[0015] Said reception device 5 of the acoustic waves W_i is, therefore, in a preferred but non-limiting solution, a microphone 18, provided with an acoustic processor connected either remotely or not to a microprocessor 27, the latter in turn instantaneously activating the corresponding movable element (7, 9, 11) of the respective container (23, 24, 25) upon recognition of the particular selected waste (13, 14, 15), through an automation device 16.

[0016] A system 1 thus made is designed so that, after having been started and having checked that each of its components is working, it can enter a dormant state, waiting for specific input from the user. Such an input consists of closing a switch, which thus sends a low signal to one of the pins of the calculating card 20, indicating that the next acquisition is on its way. A threshold, at this point, is processed based on the average "Wi" signal and, as soon as it is exceeded, this indicates to the software that an object 2 has just struck the drum 4 used for the acquisition. The signal is recorded at this point with a sampling frequency of 3,333 Hz. This choice is coherent with a previous analysis of the sound frequencies related to the impacts, which are in any case lower than 1,800 Hz, and therefore which can be correctly or almost correctly analyzed through such a sampling rapidity. Sample after sample, the signal is saved in on a micro-SD card 21 in a text file in "csv" (comma-separated value) format. Such a file, once the acquisitions have been completed, is used through a script in "R" language for analysis to extract the features and thresholds to be used in the final classifier.

[0017] When input into the classification software, the data are cleaned, removing any failed acquisitions and corrupted data, to obtain a sample which is as true to reality as possible. It is worth noting that the need to do this also indicates the need to improve the robustness of the acquisition system to prevent similar phenomena

from occurring with the data to be classified, once the classifier thresholds have been established (Figure 12).

[0018] In the preferred but non-limiting example, shown in the diagram in Fig.12, reference was made to only three typical materials present in municipal solid waste 2 (glass 13, aluminum 14 and plastic 15) and the typical characteristic shock waves (W_1 , W_2 , W_3 , respectively), emitted on drum 4, when they are dropped onto the latter.

[0019] The features are extracted at this point. The latter are analyzed using simple linear regression, using the strategy known as "One Vs All", to establish the probability that the concerned object belongs to each type of material considered. This stratagem is appropriate to the intrinsic capabilities of system 1 because it allow establishing, in relation to its performance in terms of memory and computational power, the levels of potentiality and reliability of the system 1 itself, thus generating a model which must be simply acquired by default in the specifically designed system to allow a quick classification of the input signal, related to the particular types of waste 2 to be selected.

[0020] According to an aspect of the invention, the present system 1, fundamentally designed for the automatic recognition and separation of municipal solid waste 2 could very well be applied in other areas, such as, for example, but not limited to, the recognition and separation of waste in the agriculture field or other specific sectors of special industrial waste.

[0021] Said features considered in particular with this system 1 are:

- signal power;
- the most significant carrier frequency (excluding the first);
- the product of bandwidth and carrier power;
- the signal damping rate, obtained by an approximation averaging the ratios of the various signal samples, grouped in bins.

[0022] The frequencies are acquired by applying the "Welch Method" (Fig.12), a procedure which acquires overlapping signal windows and applies the Fourier transform (in our case, with "fft" algorithm) along the whole signal, adding the results together, which results in a lower frequency resolution but in a spectrum which is more readable and easier to analyze for the learning system.

[0023] Each of said frequencies is calculated on a signal which shows only the first impact of the object on the drum 4, the average of which is then reduced to zero. The following combinations of features have been tested for achieving the case illustrated by way of non-limiting example of the present system 1:

- The combination of signal power and the most significant carrier frequency, which gives a classification accuracy of about 97%, with a lambda adjust-

ment of 0.1 (Fig.12);

- The combination of signal power and the product of bandwidth and carrier power, which gives an accuracy of about 94%, with a lambda adjustment of 0.2;
- The combination of signal power and signal damping speed, which gives an accuracy of about 96%, with a lambda adjustment of 0.1.

[0024] For each combination, the lambda adjustment is calculated empirically, making various tests for its various values. In any case, it is worth noting that the adjustment process is essential to prevent the addition of polynomial features to the system, in order to model decision-making boundaries with greater freedom and avoid overfitting phenomena, which can cause an excessive adaptation to the training sample.

[0025] The features are coupled to prevent the explosion of the number of polynomial features (and therefore of thresholds to be stored), which is substantially due to the high number of combinations of polynomial features which would already be created, in general, with just one tuple of features.

[0026] Instead, by attempting to combine a trio of features and accepting the trade-off of slightly reducing the number of polynomial features (i.e. reducing the degree of the polynomial) input into the learning system, one goes from a sixth-degree polynomial to a fourth-degree polynomial. The experimental results in the case illustrated by way of non-limiting example of the present system 1 are:

- the triple combination of signal power, most significant carrier frequency and signal damping speed, which give an accuracy of about 97%, with a lambda adjustment of 0.1;
- the triple combination of signal power, most significant carrier frequency and the product of bandwidth and carrier power, which give an accuracy of about 92%, with a lambda adjustment of 0.1.

[0027] The preferred architecture of the acquisition, processing and energy saving means M for the system 1 (Fig.10) consists by way of non-limiting example in: a detected input data acquisition device 19 of the selected waste 2, by means of a microphone 18 and a timer device 17; the data acquisition device 19 is also interfaced with a computing card 20, with the latter, in turn, connected to a memory card 21, storing the data 22 relating to the classification and collection of the waste 2, and further saving energy means 26.

[0028] The reception and processing electronic circuit L of the collected data (Fig.11) in the preferred example of the system 1 (Fig.10), by way of non-limiting example only substantially consists of a microcontroller 27, a reader 28 and an acoustic sensor 5 (i.e. a microphone 18), operating as described and illustrated above.

[0029] A first possible flow chart F1 is shown in Fig.13: This relates to the operation of the management and con-

trol software of the designed system 1 and is characterized precisely for the step of sending to sleep 30 of the system 1 started after the step of starting or start S and setting-up 29 of the system, with the following step of querying 31 on the wake-up signal, which is repeated in case of negative response. If the latter is confirmed, the actual step of waking-up 32 starts, with the subsequent step of checking of the input signal 33 (which step is repeated in case of negative response), which followed, in the affirmative case, by the step of sampling 34 of the waste 2, which is thus determined and selected by the automatic recognition means using the microprocessor 27. At the affirmative response to the new query of the successive step of signal ended 35, the system 1 returns to the step of sending to sleep 30, thus repeating the mentioned cycle; otherwise, in case of negative response, the system goes to the step of querying 36 of the actual completion of the waste sampling period and, in the affirmative case, repeats a new step of sampling 34; otherwise, it repeats the step of querying 36 again, with saving to SD card 37.

[0030] A second possible flow chart F2 is shown in Fig.14: This differs from the previous one F1 for the step of setting-up and threshold reading 38 which is input (IN) to the system 1, as well as the steps after sampling 34, i.e. the step of signal power extracting 39, the subsequent step of converting in the frequency domain 40 with the Welch method, the following step of peak frequency extracting 41, with the further steps of normalizing 42 and data re-processing 43, the successive step of regularized logistic regression 44, with the successive outputting of the classification label (OUT) before the said characterizing step of sending to sleep 30 of the system 1 itself.

[0031] A third possible and final flow chart F3 is shown in Fig.15: This differs from the previous ones F1 and F2 for the step present immediately after the step of data setting-up 29, related to data acquisition 46 (signal power), which is very similar, however, to the previous step of signal power extracting 39, as well as the step of saving the normalization coefficients 47 of the output data (OUT) and the steps of saving of the output (OUT) threshold values 48 and of respective validating 49, with the following end of process signal E.

[0032] Advantageously according to the invention, the system 1 may be made to allow any sorting, recognition, and selection of a great plurality of types of waste, because it can be applied to any type of waste, even special types.

[0033] The advantages provided by this system are apparent because the system solves all said problems of the prior art providing the following obvious advantages:

- where necessary, even a limited and minimized use of memory, fully solving the problem usually related to the impossibility of having nothing else but small spaces available for its implementation;
- low levels of electrical power necessary for the op-

eration of the system and related minimized energy consumption, fully solving the problem usually related to the need for high power supplies, even allowing, if necessary, to power the entire system with batteries charged, in turn, by photovoltaic systems or, in any case, without negative impacts due to high consumption of electricity, which would partially affect the benefits obtained from the application of the same automatic system of recognition of municipal solid waste referred to in this invention.

[0034] The further advantages provided by this system are capable to be found in that it is also applicable to other types of automatic material recognition and separation systems, in general.

[0035] The additional, no less important advantages are the low manufacturing and installation costs of this system, as well as its ease of installation for both small and large installations.

[0036] It is also apparent that many adjustments, adaptations, additions, variants and replacements of elements with others which are functionally equivalent can be made to the exemplary embodiment described above by way of non-limiting example, without however departing from the scope of protection of the following claims.

KEY

[0037]

1. Automatic material recognition system (by way of example only, for municipal solid waste)
2. Municipal solid waste or other materials in general to be recognized
3. Trajectory of the solid waste 2 drop onto the drum 4
4. Drum or means adapted to emit a characteristic shock wave W_i following the impact of a piece of solid waste 2 onto it
5. Device for receiving the sound wave W_i emitted by the drum
6. Received data processing device
7. Movable element of the first container, e.g. glass
8. Opening angle of the movable element 7
9. Movable element of the second container, e.g. aluminum
10. Opening angle of the movable element 9
11. Movable element of the third container, e.g. plastic
12. Opening angle of the movable element 11
13. Glass
14. Aluminum
15. Plastic
16. Automation device for movable elements 7, 9 and 11
17. Timer device
18. Microphone
19. Data acquisition and transfer device

20. Calculating device or spreadsheet
21. Storage device or memory card
22. Received database related to waste classification and collection 2
23. Glass container means
24. Aluminum container means
25. Plastic container means
26. Energy consumption abatement means
27. Microprocessor or microcontroller
28. Micro-SD card reader
29. Step of setting-up of the system 1 in flowchart F
30. Step of sending to sleep of the system 1
31. Step of querying through wake-up signal
32. Step of waking-up of the system 1
33. Step of querying by the input signal to start sampling
34. Step of sampling of the system 1
35. Step of signal ended querying
36. Step of querying of the sampling period completion
37. Saving to SD card
38. Setup and input reading thresholds (IN)
39. Signal power extraction
40. Frequency domain conversion with the Welch method
41. Peak frequency extraction
42. Data normalization
43. Polynomial data processing
44. Regularized logistic regression
45. Output classification label (OUT)
46. Data acquisition (signal power)
47. Saving of normalization coefficients
48. Saving of threshold values
49. Validation

E End

F_i Operation flow charts of the system 1 ($i=1, 2, 3$)

L Waste data acquisition means electronic circuit diagram

M Acquisition, processing and energy saving means architecture

S Start of flow chart

W_i Characteristic sound wave ($i=1, 2$ and 3 , thus, W_1, W_2, W_3) of the impact on the drum 4 of the generic municipal waste 2.

Claims

1. A system (1) for the automatic recognition of a material (2), comprising:
 - automatic recognition means of a material (2) by impact,
 - a timing device (17), cooperating with said automatic recognition means, and
 - an architecture (M), said architecture (M) com-

prising:

- a reception device (5) of acoustic waves (W_i), adapted to receive a sound wave (W_i with index $i = 1, \dots, n$) emitted by a material (2) at a respective dropping impact on elastic means or drum (4);
- a device (19) for acquiring, processing and transferring information relating to one or more materials (2), recognized by said recognition means, said device (19) being provided with a computing card (20), within a microprocessor or microcontroller (27), and with a memory card (21) for periodically recording such information relating to one or more materials (2) which are recognized (13, 14, 15) in a database (22);
- a plurality of separation means (7, 9, 11), controlled by dedicated software means, for mutually separating the different materials (2), which was previously recognized (13, 14, 15), selected, weighted, and stored in specific containment means (23, 24, 25);
- means (26) for abating the energy consumption of the entire system (1), provided with dedicated software means to determine the shutdown of the calculating card (20) of the microprocessor (27) when it is not in use, as well as the automatic reactivation thereof following input by a user, and
- means (21) adapted to store information necessary for classifying the quantities of material (2) progressively selected.

2. A system (1) for the automatic recognition of a material (2), according to the preceding claim, **characterized in that** said reception device (5) of the acoustic waves (W_i) is an acoustic sensor or microphone (18), provided with an acoustic processor, and operationally connected to said microprocessor (27), configured for the actuation of said separation means (7, 9, 11) at the same time as the recognition of a selected material (13, 14, 15), through an automation device (16).

3. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** said system (1) comprises management and control software means configured to:

- determine the automatic activation of a system stand-by mode (1) following the completion of a step of system setting-up (1), comprising start-up operations of the system (1) and the operational control of respective hardware components, and
- restore an operative condition of the system (1) upon a specific input from the user,
- said specific input being determined through

the operation of switch means which determine the sending of a control signal to one of the pins of the calculating card (20).

4. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** said microprocessor (27) is a microprocessor of the "Arduino Mega 2560 R3" type.

5. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** said separation means (7, 9, 11) comprise movable elements (7, 9, 11) having two ends, said movable elements (7, 9, 11) being hinged to one of said ends and rotating around it so that the other free end describes a curvilinear trajectory (8, 10, 12) adapted to allow the opening of one of said container means (23, 24, 25) corresponding to the specifically identified material (13, 14, 15).

6. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** said system (1) is configured to recognize and separate solid municipal waste, agricultural waste or industrial waste.

7. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** it comprises software means configured to:

- record, for each material (2) subjected to acquisition, a respective signal detected at the impact moment of the material (2) on said elastic means or drum (4), with a sampling rate of 3,333 Hz, and
- save said signals related to each material (2), subjected to acquisition, on a micro-SID card (21) in "comma-separated value" (csv) text file format,
- said file being used, after completion of the acquisitions, for determining the thresholds and features to be used to establish a possibility of belonging of a given material (2) to a given predetermined type through a specific script,

said features comprising:

- signal power;
- most significant carrier frequency;
- product of bandwidth and carrier power;
- signal damping rate, obtained by an approximation averaging the ratios between the various signal samples, grouped in bins.

8. A system (1) for the automatic recognition of a ma-

terial (2), according to claim 7, **characterized in that** said frequencies are acquired by the Welch Method.

9. A system (1) for the automatic recognition of a material (2), according to claims 7 or 8, **characterized in that** that said features comprise the following combinations of:

- most significant signal power and carrier frequency;
- signal power and the product of bandwidth and carrier power;
- signal power and signal damping rate.

10. A system (1) for the automatic recognition of a material (2) according to claim 3, **characterized in that** such management and control software means are configured to:

- perform a step of querying (31) a wake-up signal during said stand-by condition (30) of the system (1), which step of querying is repeated in case of a negative response;
- in the case of affirmative response, perform a step of waking-up (32),
- after the step of waking-up (32), execute a step of input signal verifying (33), which step is repeated in case of negative response,
- in the case of affirmative response, executing a successive step of sampling (34) of the material (2), which is thus selected by said automatic recognition means, through the microprocessor (27).

11. A system (1) for the automatic recognition of a material (2) according to claim 10, **characterized in that** such management and control software means are also configured to execute a step of signal ended (35) after said step of sampling (34).

12. A system (1) for the automatic recognition of a material (2) according to claim 11, **characterized in that**, in the case of an affirmative response to said step of signal ended (35), said management and controlling software means are configured to reactivate said stand-by mode (30) of the system (1).

13. A system (1) for the automatic recognition of a material (2) according to claim 11, **characterized in that** in case of negative response to said step of signal ended (35), said management and control software means are configured to:

- execute a step of querying (36) on the actual completion of the material sampling period (2) ed,
- in the case of affirmative response, execute a further step of sampling (34).

14. A system (1) for the automatic recognition of materials (2) according to claim 11, **characterized in that** in case of negative response to said step of signal ended (35), said management and control software means are configured to:

- execute a step of querying (36) on the actual completion of the material sampling period (2) ed,
- in case of a negative response, repeat said step of querying (36), with corresponding saving to SD card (37).

15 Patentansprüche

1. System (1) zur automatischen Erkennung eines Materials (2), umfassend:

- automatische Erkennungsmittel eines Materials (2) durch Aufprall,
- ein Zeitmessgerät (17), das mit den automatischen Erkennungsmitteln zusammenwirkt, und
- eine Architektur (M), wobei die Architektur (M) umfasst:

- ein Empfangsgerät (5) von akustischen Wellen (W_i), das zum Empfangen einer Schallwelle (W_i mit Index $i = 1, \dots, n$) geeignet ist, welche durch ein Material (2) bei einem jeweiligen Fallaufprall auf elastische Mittel oder eine Trommel (4) ausgesendet wird;

- ein Gerät (19) zum Erfassen, Verarbeiten und Übertragen von Information bezüglich eines oder mehrerer Materialien (2), die durch die Erkennungsmittel erkannt werden, wobei das Gerät (19) mit einer Rechenkarte (20) innerhalb eines Mikroprozessors oder Mikrocontrollers (27) und einer Speicherkarte (21) zum periodischen Aufzeichnen von solcher Information, die sich auf ein oder mehrere Materialien (2) bezieht, welche in einer Datenbank (22) erkannt werden (13, 14, 15), versehen ist;

- mehrere Trennungsmittel (7, 9, 11), die durch dedizierte Softwaremittel gesteuert werden, zum wechselseitigen Trennen der verschiedenen Materialien (2), welche vorher erkannt (13, 14, 15), ausgewählt, gewogen und in spezifischen Aufnahmemitteln (23, 24, 25) gespeichert wurden;
- Mittel (26) zum Herabsetzen des Energieverbrauchs des gesamten Systems (1), die mit dedizierten Softwaremitteln zum Festlegen der Abschaltung der Rechenkarte (20) des Mikroprozessors (27), wenn sie nicht in Gebrauch ist, sowie der automati-

- schen Reaktivierung derselben im Anschluss an die Eingabe eines Benutzers versehen sind, und
- Mittel (21), die zum Speichern von Information geeignet sind, welche zum Klassifizieren der Mengen von Material (2), welches fortschreitend ausgewählt wird, notwendig ist.
2. System (1) zur automatischen Erkennung eines Materials (2) nach dem vorhergehenden Anspruch, **dadurch gekennzeichnet, dass** das Empfangsgerät (5) der akustischen Wellen (W_i) ein Schallsensor oder Mikrofon (18) ist, der/das mit einem akustischen Prozessor versehen und betriebsfähig mit dem Mikroprozessor (27) verbunden ist und zur Betätigung der Trennungsmittel (7, 9, 11) zur selben Zeit wie die Erkennung eines ausgewählten Materials (13, 14, 15) durch ein Automatisierungsgerät (16) konfiguriert ist.
 3. System (1) zur automatischen Erkennung eines Materials (2) nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das System (1) Verwaltungs- und Steuerungssoftwaremittel umfasst, die zu Folgendem konfiguriert sind:
 - Bestimmen der automatischen Aktivierung eines Systembereitschaftsmodus (1) im Anschluss an die Vervollständigung eines Schritts der Systemeinrichtung (1), der Hochfahrvorgänge des Systems (1) und die Betriebssteuerung von jeweiligen Hardwarekomponenten umfasst, und
 - Wiederherstelle einer Betriebsbedingung des Systems (1) auf eine spezifische Eingabe des Benutzers hin,
 - wobei die spezifische Eingabe über den Betrieb von Schaltmitteln bestimmt wird, die das Senden eines Steuersignals an einen der Kontakte der Rechenkarte (20) bestimmen.
 4. System (1) zur automatischen Erkennung eines Materials (2) nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Mikroprozessor (27) ein Mikroprozessor vom Typ "Arduino Mega 2560 R3" ist.
 5. System (1) zur automatischen Erkennung eines Materials (2) nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Trennungsmittel (7, 9, 11) bewegliche Elemente (7, 9, 11) mit zwei Enden umfassen, wobei die beweglichen Elemente (7, 9, 11) an eines der Enden angelenkt sind und um dieses drehen, sodass das andere freie Ende eine krummlinige Laufbahn (8, 10, 12) beschreibt, die dazu geeignet ist, die Öffnung von einem der Behältermittel (23, 24, 25) entsprechend dem spezifisch identifizierten Material (13, 14, 15) zu ermöglichen.
 6. System (1) zur automatischen Erkennung eines Materials (2) nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das System (1) zum Erkennen und Trennen von festen Siedlungsabfällen, landwirtschaftlichen Abfällen oder industriellen Abfällen konfiguriert ist.
 7. System (1) zur automatischen Erkennung eines Materials (2) nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** es Softwaremittel umfasst, die zu Folgendem konfiguriert sind:
 - Aufzeichnen, für jedes Material (2), das der Erfassung unterzogen wird, eines jeweiligen Signals, das im Aufprallmoment des Materials (2) auf das elastische Material oder die Trommel (4) erkannt wird, mit einer Abtastrate von 3.333 Hz, und
 - Abspeichern der Signale, die sich auf jedes Material (2) beziehen, welches der Erfassung unterzogen wird, auf einer Micro-SID-Karte (21) in "komma-separiertem" Textdateiformat (CSV),
 - wobei die Datei, nach der Vervollständigung der Erfassungen, zum Bestimmen der Schwellen und Merkmale benutzt wird, die zum Erstellen einer Möglichkeit, dass ein jeweiliges Material (2) zu einer jeweiligen vorbestimmten Art gehört, über ein spezifisches Skript benutzt werden sollen,
 wobei die Merkmale umfassen:
 - Signalstärke;
 - wichtigste Trägerfrequenz;
 - Produkt von Bandbreite und Trägerleistung;
 - Signaldämpfungsrate, die durch eine Annäherung, welche die Verhältnisse zwischen den verschiedenen Abtastungen, gruppiert in Klassen, mittelt, erhalten wird.
 8. System (1) zur automatischen Erkennung eines Materials (2) nach Anspruch 7, **dadurch gekennzeichnet, dass** Frequenzen durch das Welch-Verfahren erfasst werden.
 9. System (1) zur automatischen Erkennung eines Materials (2) nach Anspruch 7 oder 8, **dadurch gekennzeichnet, dass** die Merkmale die folgenden Kombinationen umfassen:
 - wichtigste Signalstärke und Trägerfrequenz;
 - Signalstärke und das Produkt von Bandbreite

und Trägerleistung;

- Signalstärke und Signaldämpfungsrate.

10. System (1) zur automatischen Erkennung eines Materials (2) nach Anspruch 3, **dadurch gekennzeichnet, dass** derartige Verwaltungs- und Steuerungswarenumittel zu Folgendem konfiguriert sind:

- Ausführen eines Schritts des Abfragens (31) eines Wecksignals während der Bereitschaftsbedingung (30) des Systems (1), wobei der Schritt des Abfragens im Falle einer negativen Reaktion wiederholt wird;
 - im Falle einer positiven Reaktion, Ausführen eines Schritts des Weckens (32),
 - nach dem Schritt des Weckens (32), Ausführen eines Schritts des Eingangssignalverifizierens (33), wobei dieser Schritt im Falle einer negativen Reaktion wiederholt wird,
 - im Falle einer positiven Reaktion, Ausführen eines nachfolgenden Schritts des Abtastens (34) des Materials (2), das dadurch durch die automatische Erkennungsmittel über den Mikroprozessor (27) ausgewählt wird.

11. System (1) zur automatischen Erkennung eines Materials (2) nach Anspruch 10, **dadurch gekennzeichnet, dass** derartige Verwaltungs- und Steuerungswarenumittel außerdem zum Ausführen eines Schritts des Signalbeendens (35) nach dem Schritt des Abtastens (34) konfiguriert sind.

12. System (1) zur automatischen Erkennung eines Materials (2) nach Anspruch 11, **dadurch gekennzeichnet, dass**, im Falle einer positiven Reaktion auf den Schritt des Signalbeendens (35), die Verwaltungs- und Steuerungswarenumittel zum Reaktivieren des Bereitschaftsmodus (30) des Systems (1) konfiguriert sind.

13. System (1) zur automatischen Erkennung eines Materials (2) nach Anspruch 11, **dadurch gekennzeichnet, dass**, im Falle einer negativen Reaktion auf den Schritt des Signalbeendens (35), die Verwaltungs- und Steuerungswarenumittel zu Folgendem konfiguriert sind:

- Ausführen eines Schritts des Abfragens (36) der aktuellen Vervollständigung der Materialabtastperiode (2),
 - im Falle einer positiven Reaktion, Ausführen eines weiteren Schritts des Abtastens (34).

14. System (1) zur automatischen Erkennung eines Materials (2) nach Anspruch 11, **dadurch gekennzeichnet, dass**, im Falle einer negativen Reaktion auf den Schritt des Signalbeendens (35), die Verwaltungs- und Steuerungswarenumittel zu Folgendem

dem konfiguriert sind:

- Ausführen eines Schritts des Abfragens (36) der aktuellen Vervollständigung der Materialabtastperiode (2),
 - im Falle einer negativen Reaktion, Wiederholen des Schritts des Abfragens (36) mit entsprechendem Abspeichern auf der SD-Karte (37).

Revendications

1. Système (1) pour la reconnaissance automatique d'un matériau (2), comprenant :

- un moyen de reconnaissance automatique d'un matériau (2) par impact,
 - un dispositif de synchronisation (17) coopérant avec ledit moyen de reconnaissance automatique, et
 - une architecture (M), ladite architecture (M) comprenant :

- un dispositif de réception (5) d'ondes acoustiques (W_i), apte à recevoir une onde sonore (W_i avec un indice $i = 1, \dots, n$) émise par un matériau (2) à un impact de chute respectif sur un moyen élastique ou un tambour (4) ;

- un dispositif (19) pour acquérir, traiter et transférer des informations relatives à un ou plusieurs matériaux (2), reconnu par ledit moyen de reconnaissance, ledit dispositif (19) étant pourvu d'une carte informatique (20), à l'intérieur d'un microprocesseur ou d'un microcontrôleur (27), et d'une carte de mémoire (21) pour enregistrer périodiquement lesdites informations relatives à un ou plusieurs matériaux (2) qui sont reconnus (13, 14, 15) dans une base de données (22) ;

- une pluralité de moyens de séparation (7, 9, 11) commandés par un moyen logiciel dédié, pour séparer réciproquement les différents matériaux (2), qui ont été préalablement reconnus (13, 14, 15), sélectionnés, pesés et stockés dans des moyens de contenance spécifiques (23, 24, 25) ;

- un moyen (26) de réduction de la consommation d'énergie du système complet (1), pourvu d'un moyen logiciel dédié pour déterminer l'arrêt de la carte informatique (20) du microprocesseur (27) lorsqu'elle n'est pas utilisée, ainsi que la réactivation automatique de celle-ci à la suite d'une entrée d'un utilisateur, et

- un moyen (21) apte à stocker des informations nécessaires pour classer les quan-

- tités de matériaux (2) progressivement sélectionnés.
2. Système (1) pour la reconnaissance automatique d'un matériau (2) selon la revendication précédente, **caractérisé en ce que** ledit dispositif de réception (5) d'ondes acoustiques (W_i) est un capteur acoustique ou un microphone (18), pourvu d'un processeur acoustique, et relié opérationnellement audit microprocesseur (27), configuré pour l'actionnement desdits moyens de séparation (7, 9, 11) en même temps que la reconnaissance d'un matériau sélectionné (13, 14, 15) par l'intermédiaire d'un dispositif d'automatisation (16). 5 10
 3. Système (1) pour la reconnaissance automatique d'un matériau (2) selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit système (1) comprend un moyen logiciel de gestion et de commande configuré pour : 15
 - déterminer l'activation automatique d'un mode de veille de système (1) à la suite de l'achèvement d'une étape de configuration de système (1), comprenant des opérations de démarrage du système (1) et la commande opérationnelle de composants matériels respectifs, et
 - rétablir un état opérationnel du système (1) lors d'une entrée spécifique de l'utilisateur,
 - ladite entrée spécifique étant déterminée par l'intermédiaire de l'opération d'un moyen de commutation qui détermine l'envoi d'un signal de commande à l'une des broches de la carte informatique (20). 20 25 30
 4. Système (1) pour la reconnaissance automatique d'un matériau (2) selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit microprocesseur (27) est un microprocesseur du type « Arduino Mega 2560 R3 ». 35 40
 5. Système (1) pour la reconnaissance automatique d'un matériau (2) selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** lesdits moyens de séparation (7, 9, 11) comprennent les éléments mobiles (7, 9, 11) comportant deux extrémités, lesdits éléments mobiles (7, 9, 11) étant articulés à l'une desdites extrémités et tournant autour de celle-ci de sorte que l'autre extrémité libre décrive une trajectoire curviligne (8, 10, 12) apte à permettre l'ouverture de l'un desdits moyens de contenance (23, 24, 25) correspondant au matériau spécifiquement identifié (13, 14, 15). 45 50
 6. Système (1) pour la reconnaissance automatique d'un matériau (2) selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit système (1) est configuré pour reconnaître et sépa- 55
 7. Système (1) pour la reconnaissance automatique d'un matériau (2) selon une ou plusieurs des revendications précédentes, **caractérisé en ce qu'**il comprend un moyen logiciel configuré pour :
 - enregistrer, pour chaque matériau (2) soumis à une acquisition, un signal respectif détecté au moment d'impact du matériau (2) sur ledit moyen élastique ou ledit tambour (4), avec une fréquence d'échantillonnage de 3333 Hz, et
 - sauvegarder lesdits signaux relatifs à chaque matériau (2), soumis à une acquisition, sur une carte micro-SID (21) dans un format de fichier texte « valeurs séparées par des virgules » (csv),
 - ledit fichier étant utilisé, après l'achèvement des acquisitions, pour déterminer les seuils et les caractéristiques à utiliser pour établir une possibilité d'appartenance d'un matériau donné (2) à un type prédéterminé donné par l'intermédiaire d'un script spécifique,
 lesdites caractéristiques comprenant :
 - une puissance de signal ;
 - une fréquence de porteuse la plus significative ;
 - un produit de largeur de bande et de puissance de porteuse ;
 - un taux d'amortissement de signal, obtenu par une approximation moyennant les rapports entre les divers échantillons de signaux, regroupés dans des compartiments. 60
 8. Système (1) pour la reconnaissance automatique d'un matériau (2) selon la revendication 7, **caractérisé en ce que** lesdites fréquences sont acquises par la méthode de Welch.
 9. Système (1) pour la reconnaissance automatique d'un matériau (2) selon la revendication 7 ou 8, **caractérisé en ce que** lesdites caractéristiques comprennent les combinaisons suivantes de :
 - une puissance de signal la plus significative et une fréquence de porteuse ;
 - une puissance de signal est le produit d'une largeur de bande et d'une puissance de porteuse ;
 - une puissance de signal et un taux d'amortissement de signal. 65
 10. Système (1) pour la reconnaissance automatique d'un matériau (2) selon la revendication 3, **caractérisé en ce que** ledit moyen logiciel de gestion et de commande est configuré pour : 70

- réaliser une étape d'interrogation (31) d'un signal de réveil au cours dudit état de veille (30) du système (1), ladite étape d'interrogation étant répétée en cas de réponse négative ;
 - en cas de réponse affirmative, réaliser une étape de réveil (32), 5
 - après l'étape de réveil (32), exécuter une étape de vérification de signal d'entrée (33), ladite étape étant répétée en cas de réponse négative, 10
 - en cas de réponse affirmative, exécuter une étape successive d'échantillonnage (34) du matériau (2), qui est ainsi sélectionné par ledit moyen de reconnaissance automatique, par l'intermédiaire du microprocesseur (27). 15
11. Système (1) pour la reconnaissance automatique d'un matériau (2) selon la revendication 10, **caractérisé en ce que** ledit moyen logiciel de gestion et de commande est également configuré pour exécuter une étape de fin de signal (35) après ladite étape d'échantillonnage (34). 20
12. Système (1) pour la reconnaissance automatique d'un matériau (2) selon la revendication 11, **caractérisé en ce que**, en cas de réponse affirmative à ladite étape de fin de signal (35), ledit moyen logiciel de gestion et de commande est configuré pour réactiver ledit mode de veille (30) du système (1). 25
13. Système (1) pour la reconnaissance automatique d'un matériau (2) selon la revendication 11, **caractérisé en ce que**, en cas de réponse négative à ladite étape de fin de signal (35), ledit moyen logiciel de gestion et de commande est configuré pour : 30
- exécuter une étape d'interrogation (36) de l'achèvement de la période d'échantillonnage de matériau (2), et 35
 - en cas de réponse affirmative, exécuter une autre étape d'échantillonnage (34). 40
14. Système (1) pour la reconnaissance automatique d'un matériau (2) selon la revendication 11, **caractérisé en ce que**, en cas de réponse négative à ladite étape de fin de signal (35), ledit moyen logiciel de gestion et de commande est configuré pour : 45
- exécuter une étape d'interrogation (36) de l'achèvement réel de la période d'échantillonnage de matériau (2), et 50
 - en cas de réponse négative, répéter ladite étape d'interrogation (36), avec une sauvegarde correspondante sur une carte SD (37). 55

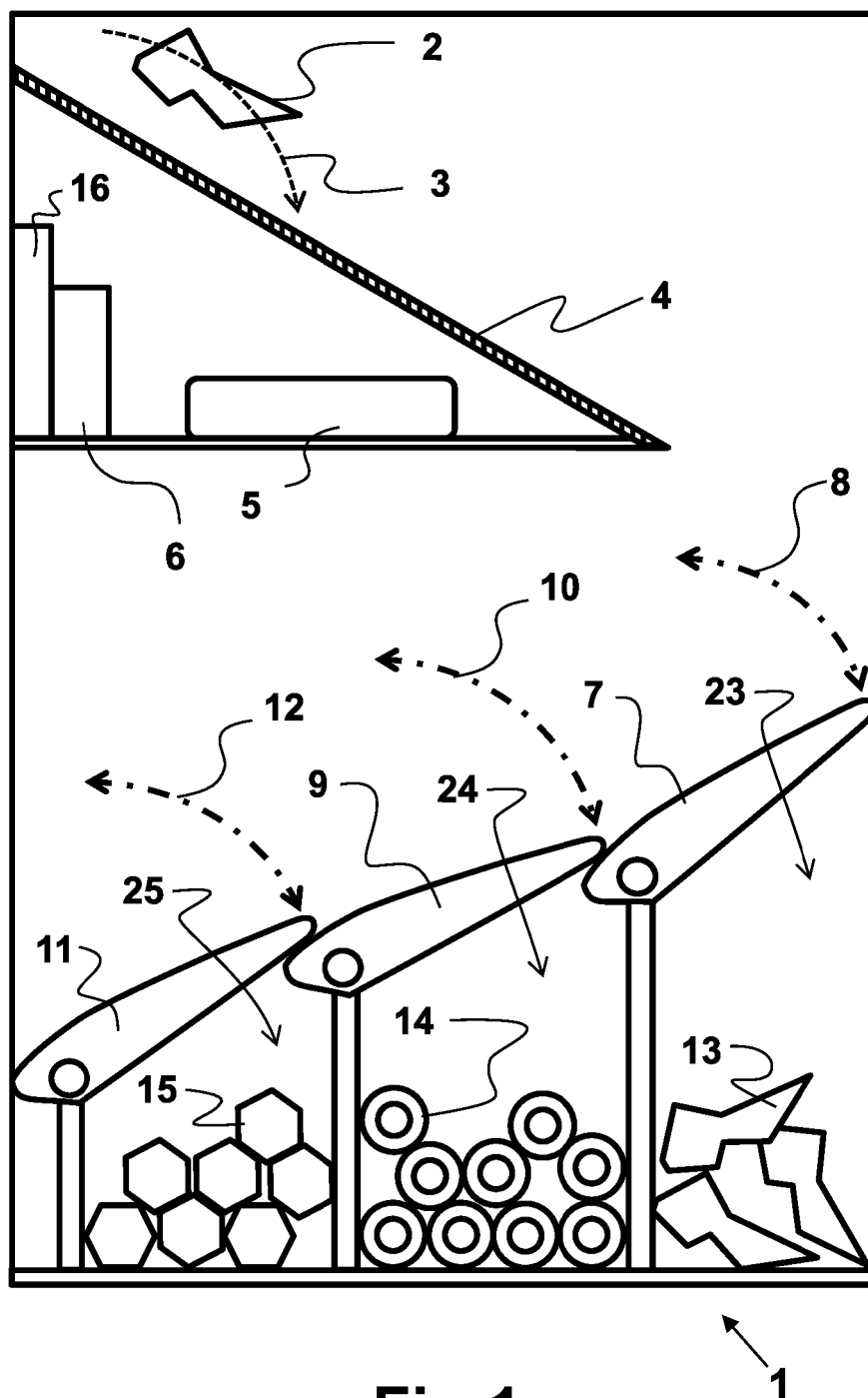


Fig.1

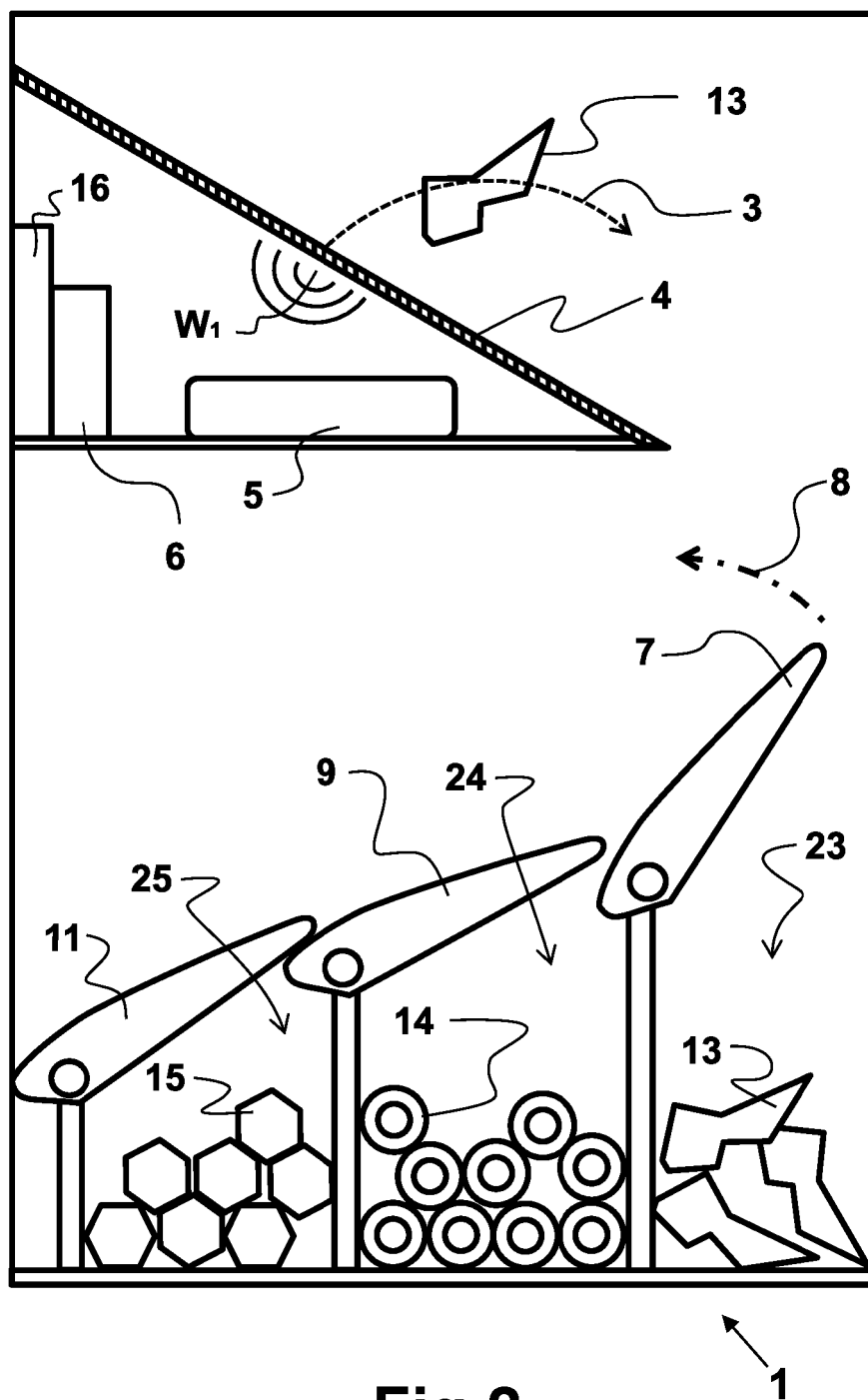


Fig.2

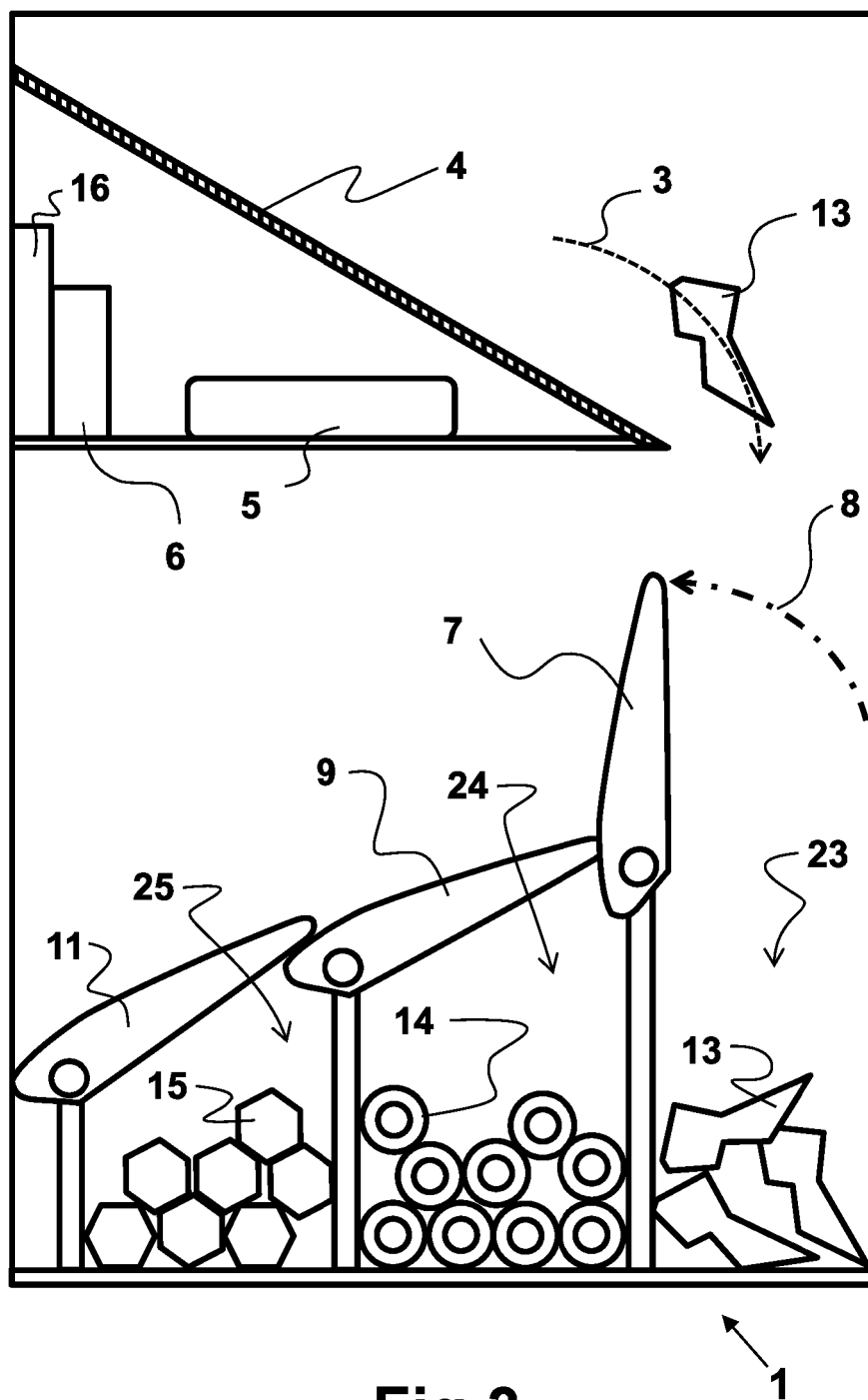
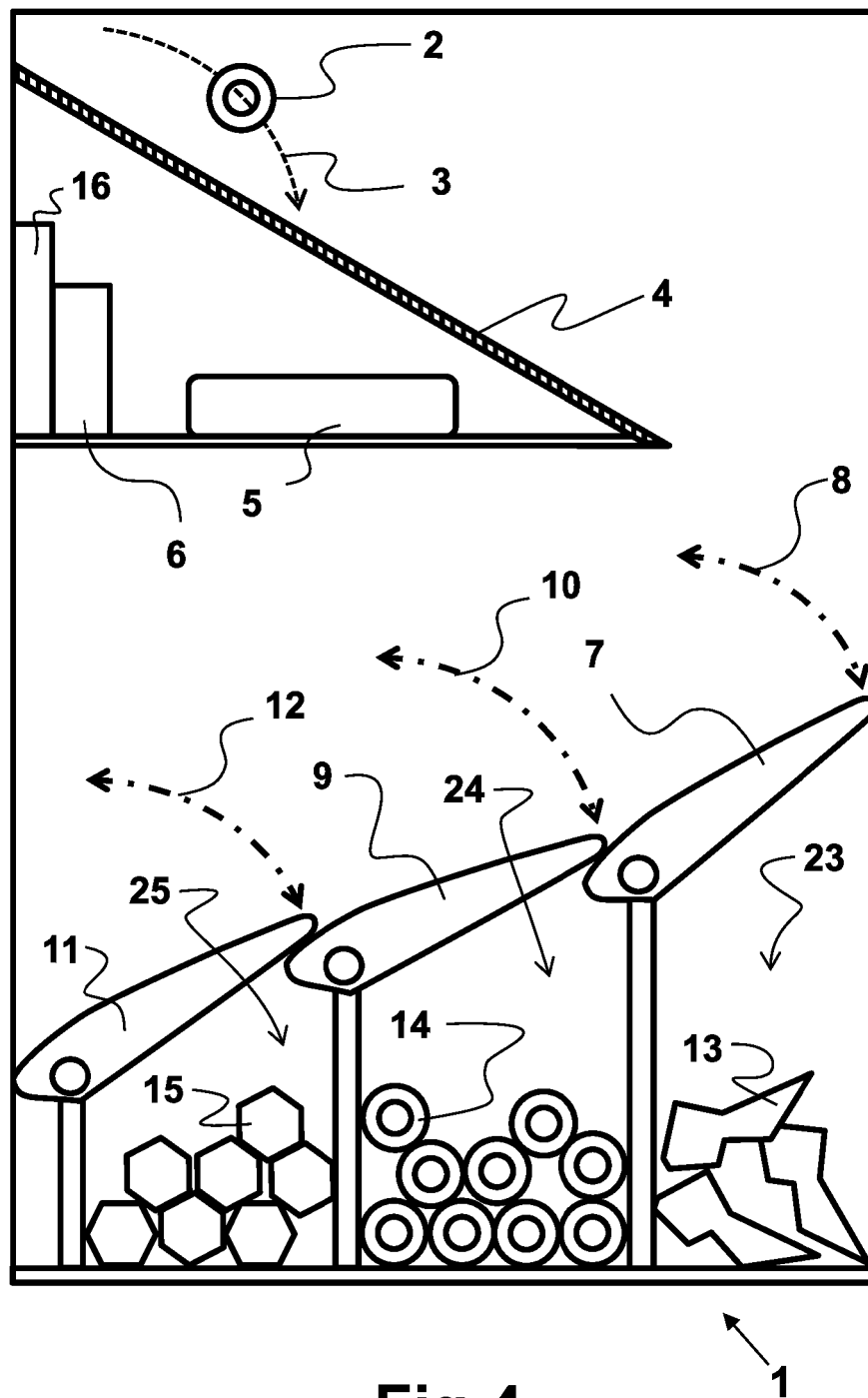
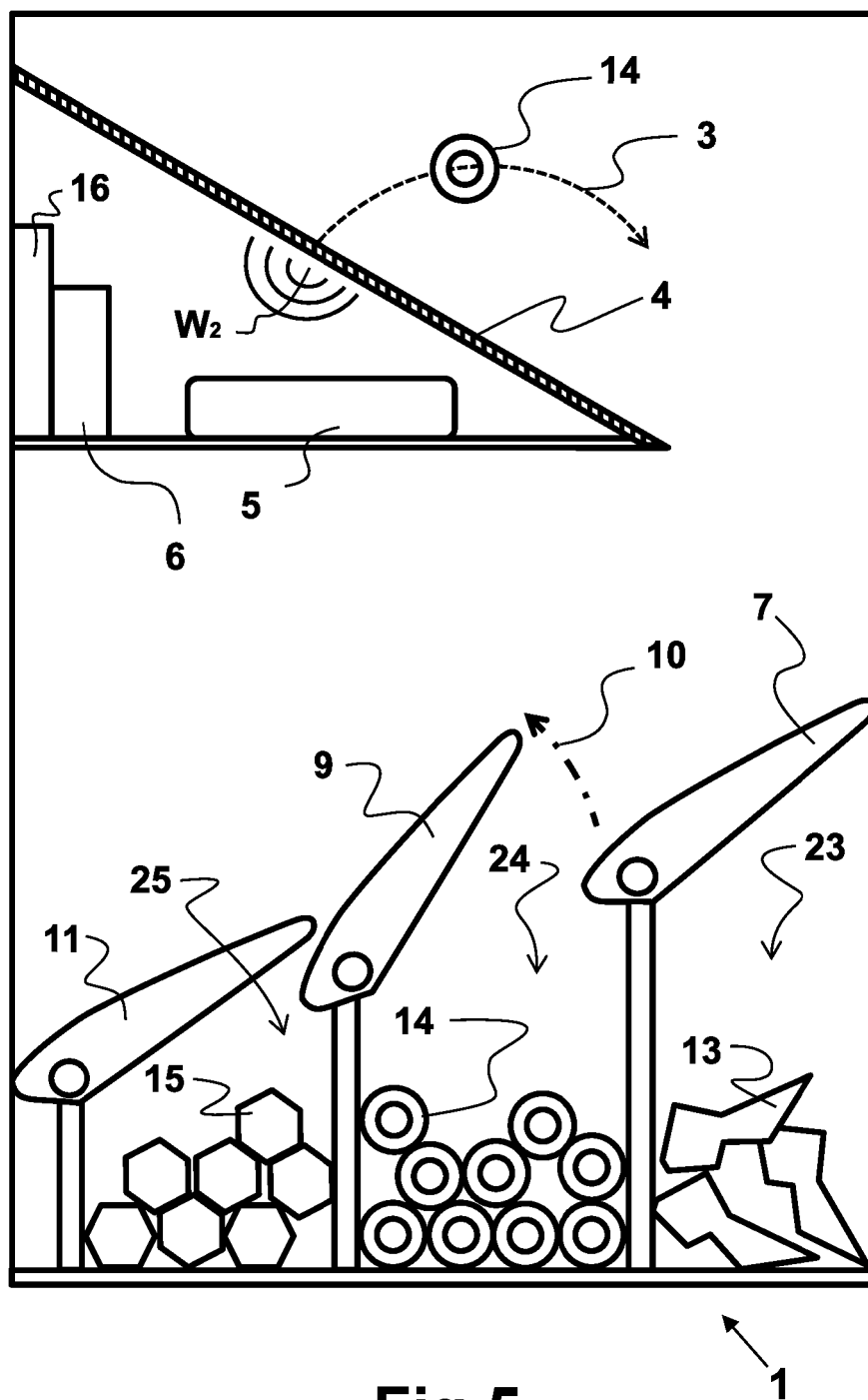
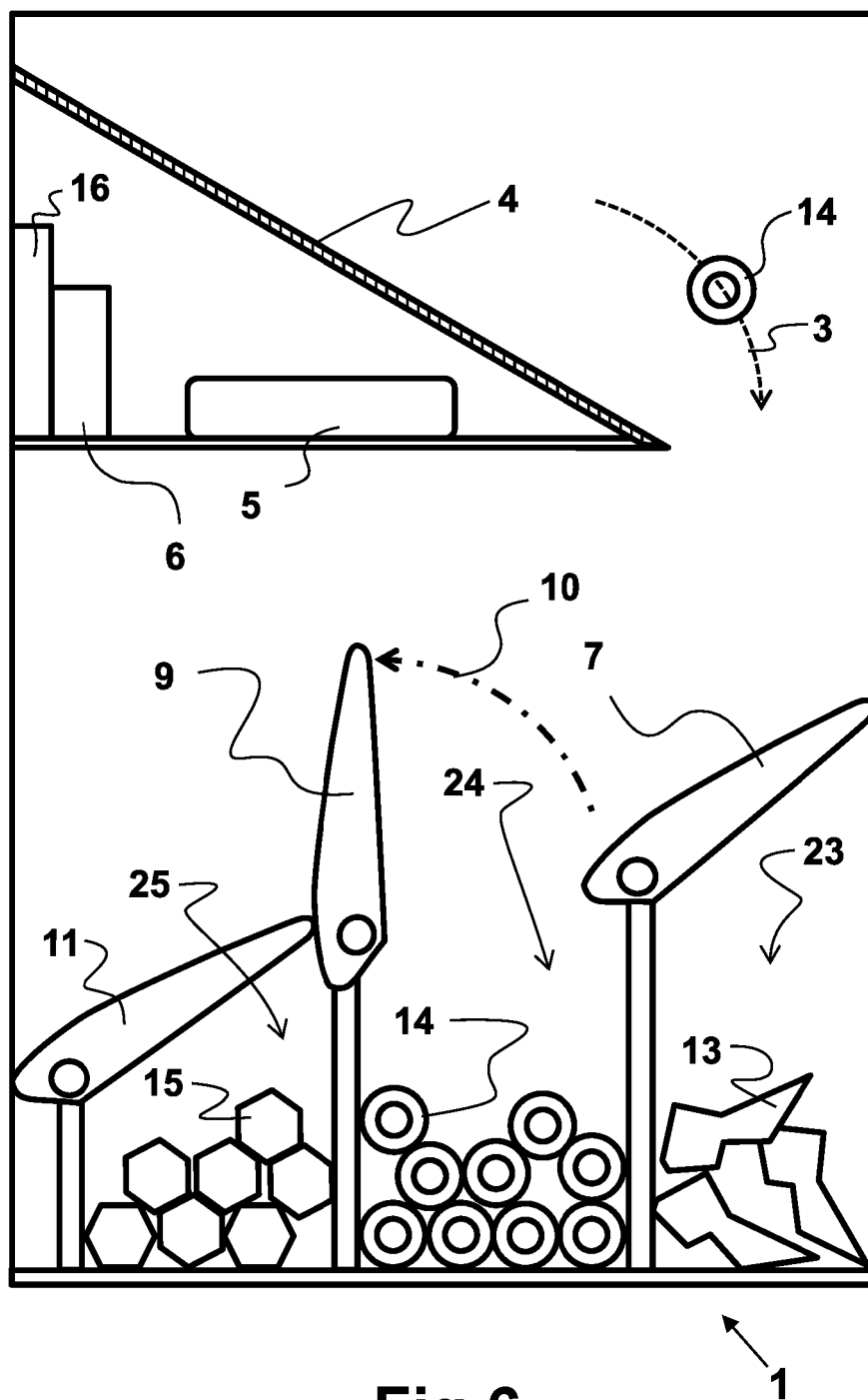


Fig.3







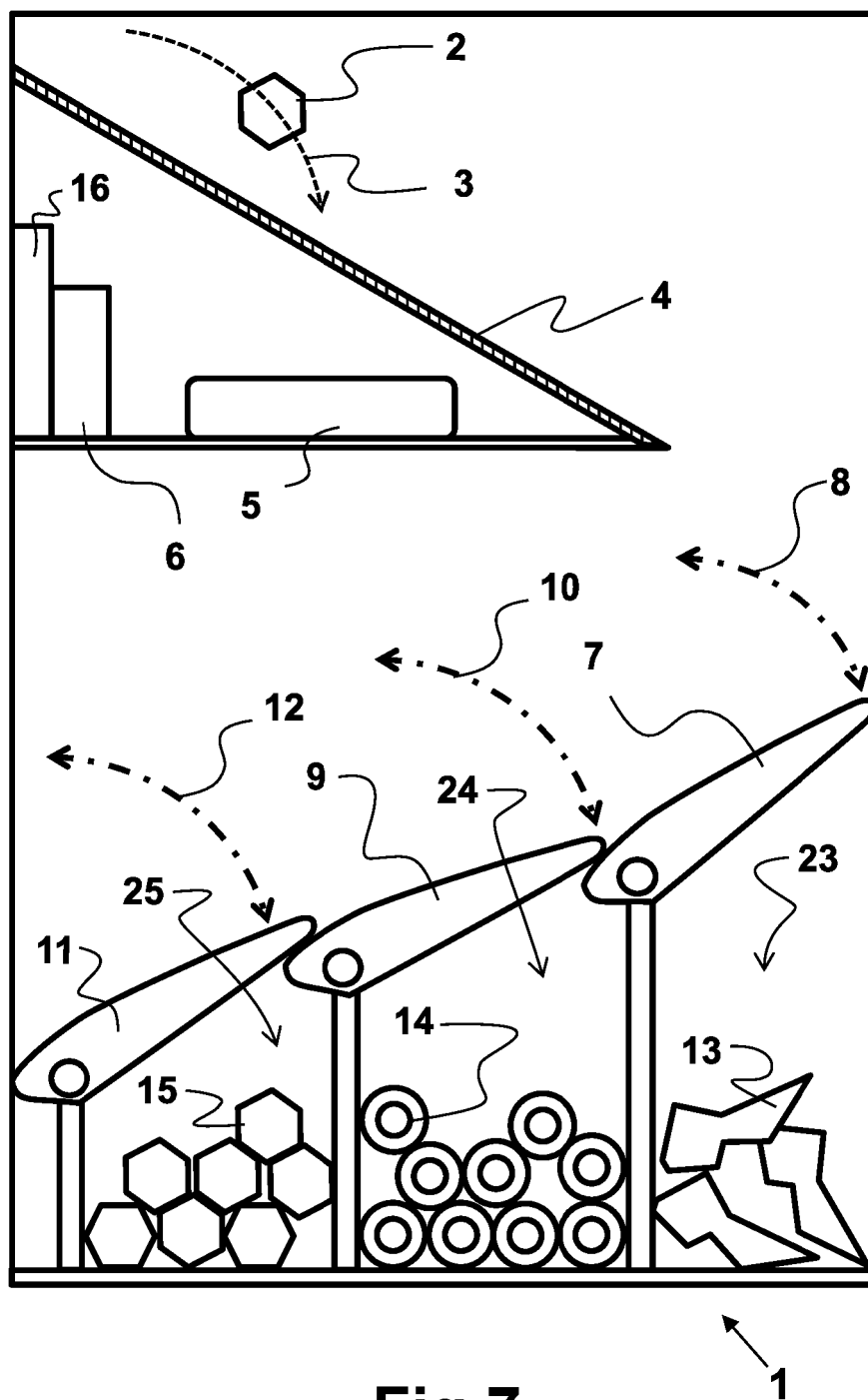


Fig.7

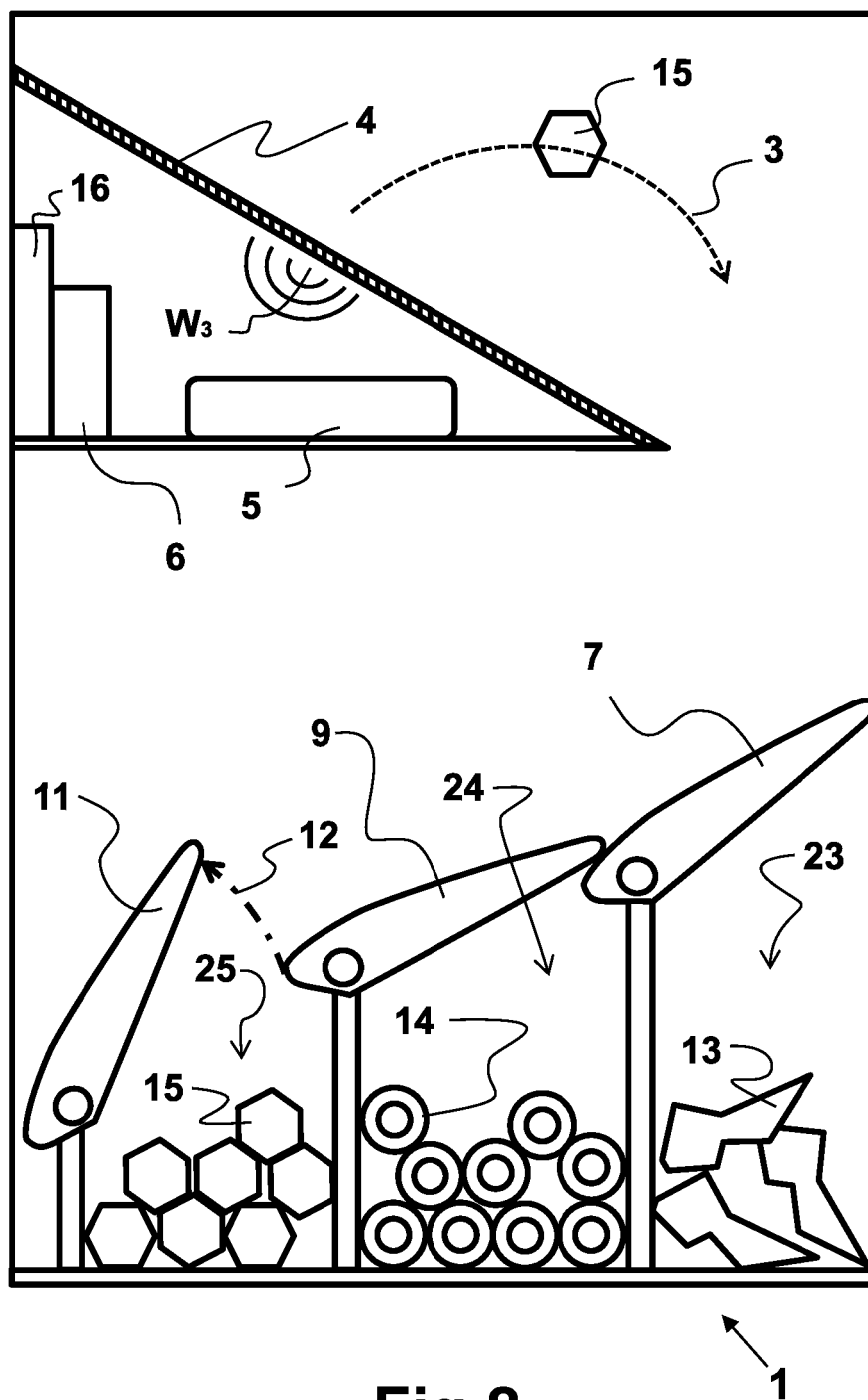
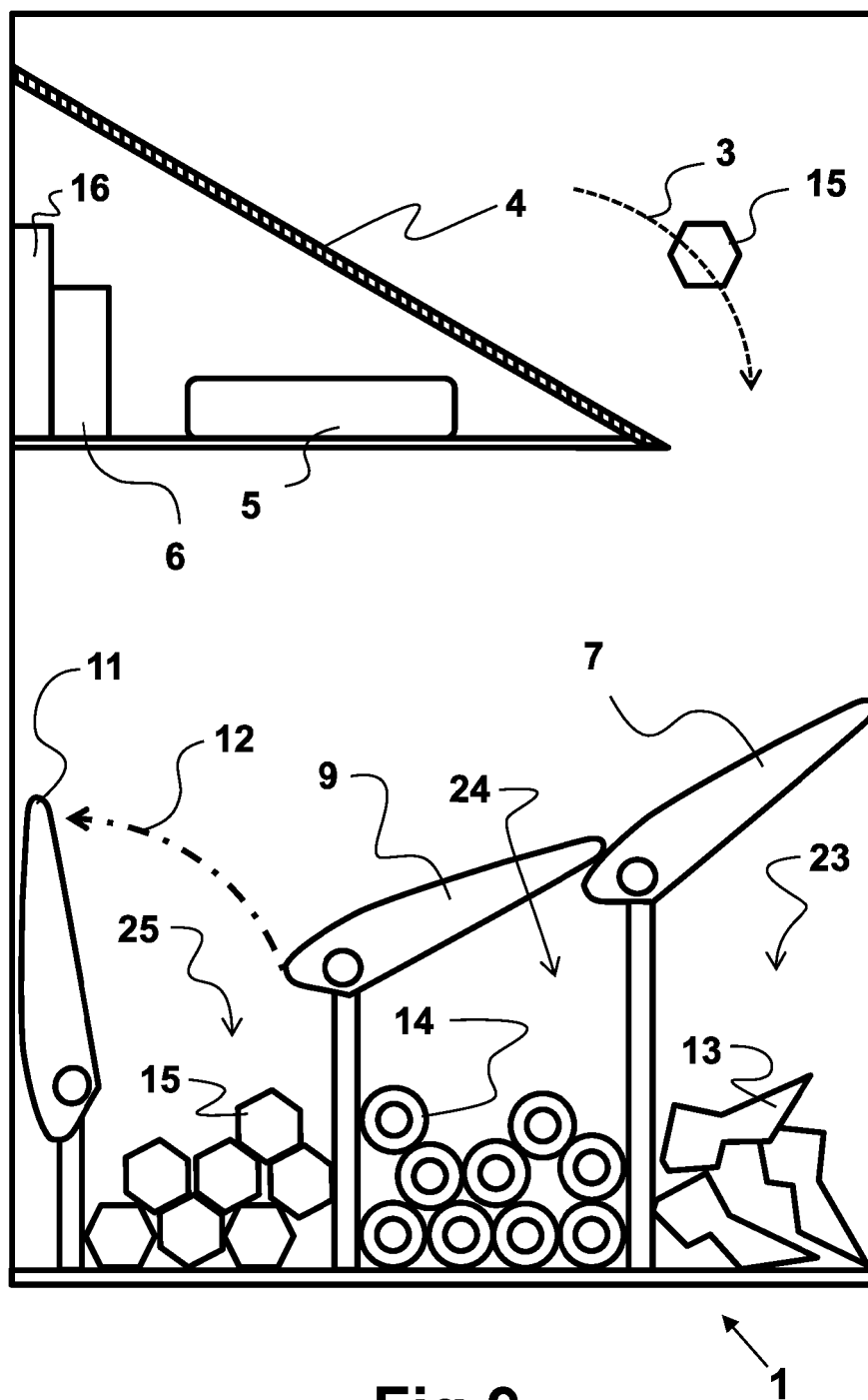


Fig.8



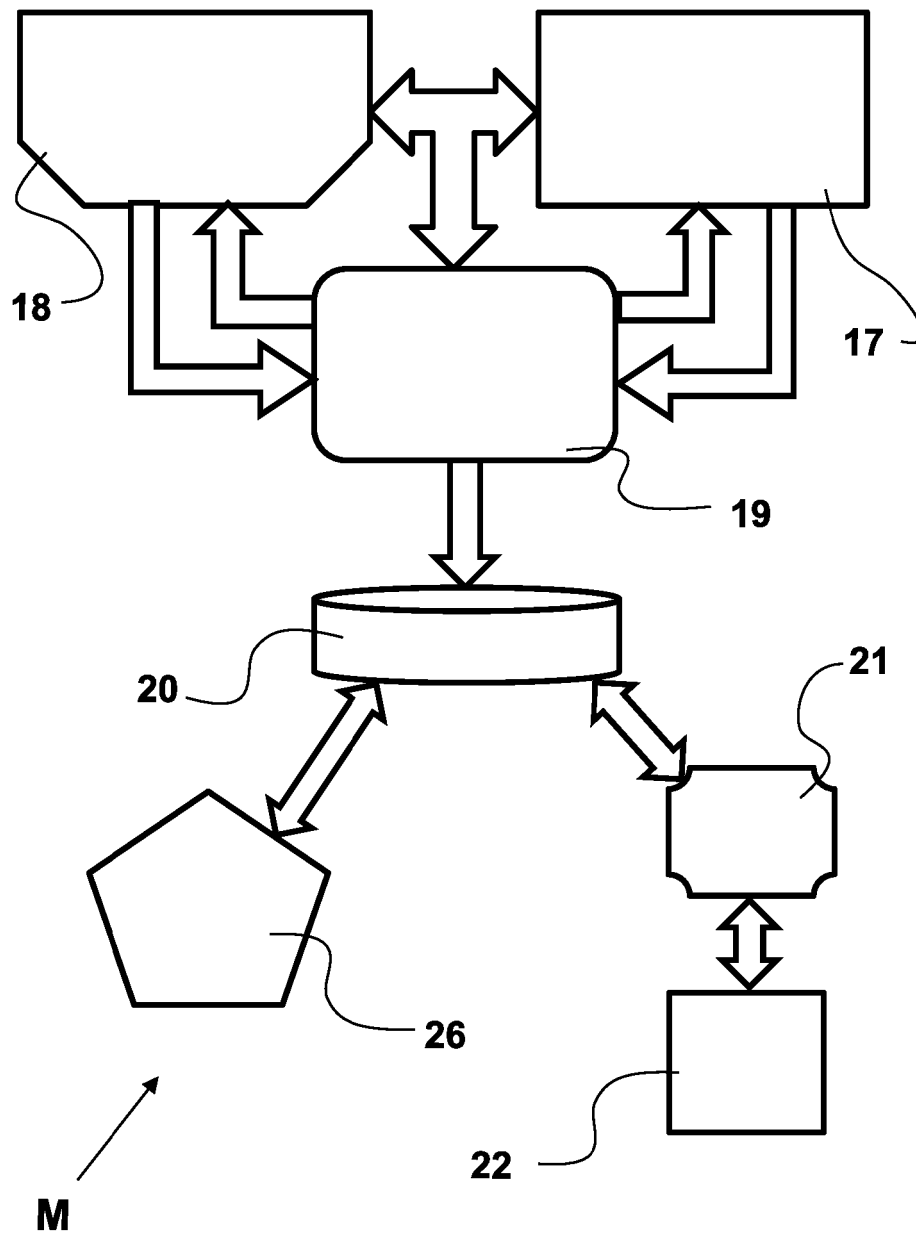


Fig.10

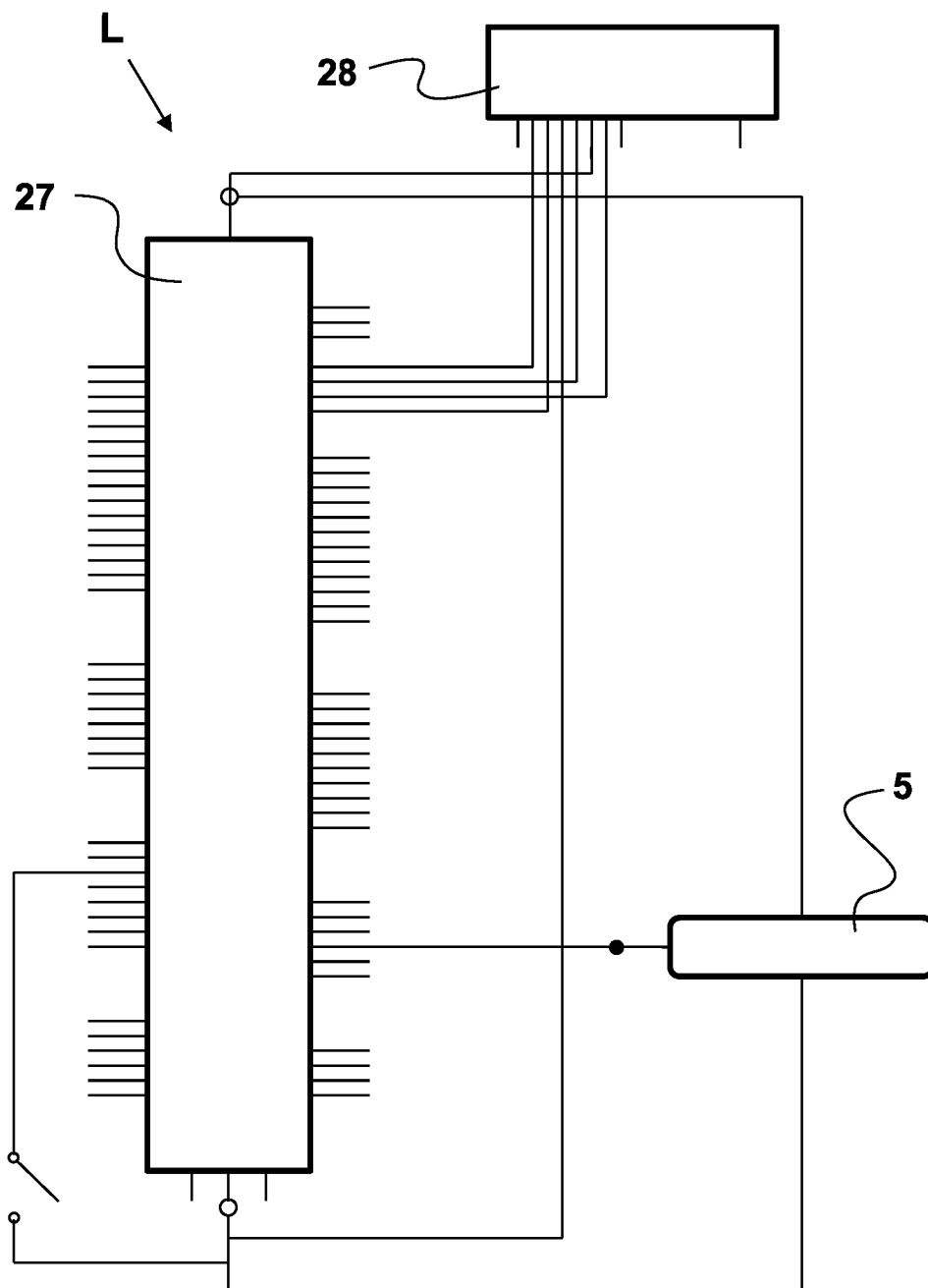


Fig.11

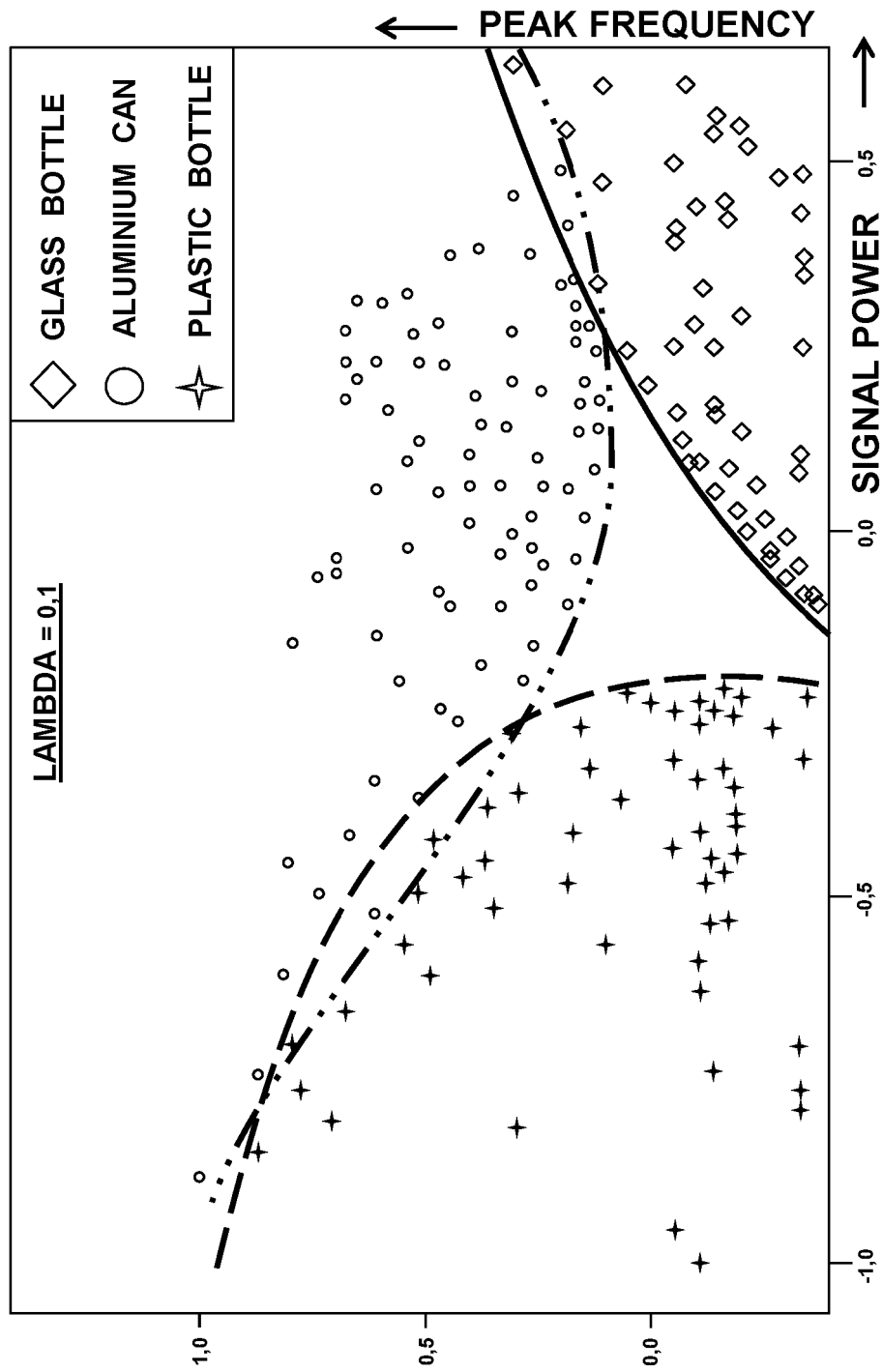


Fig.12

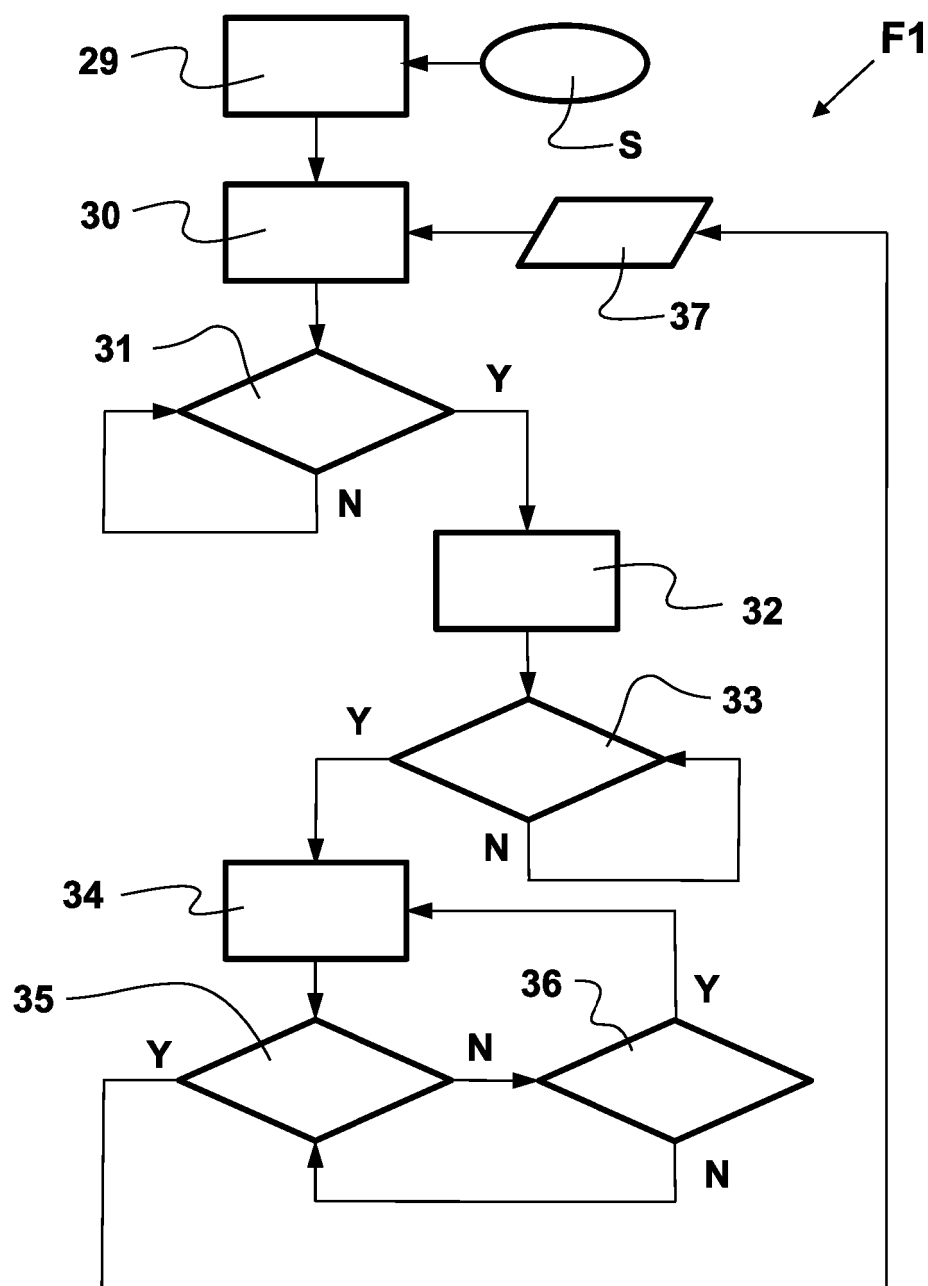


Fig.13

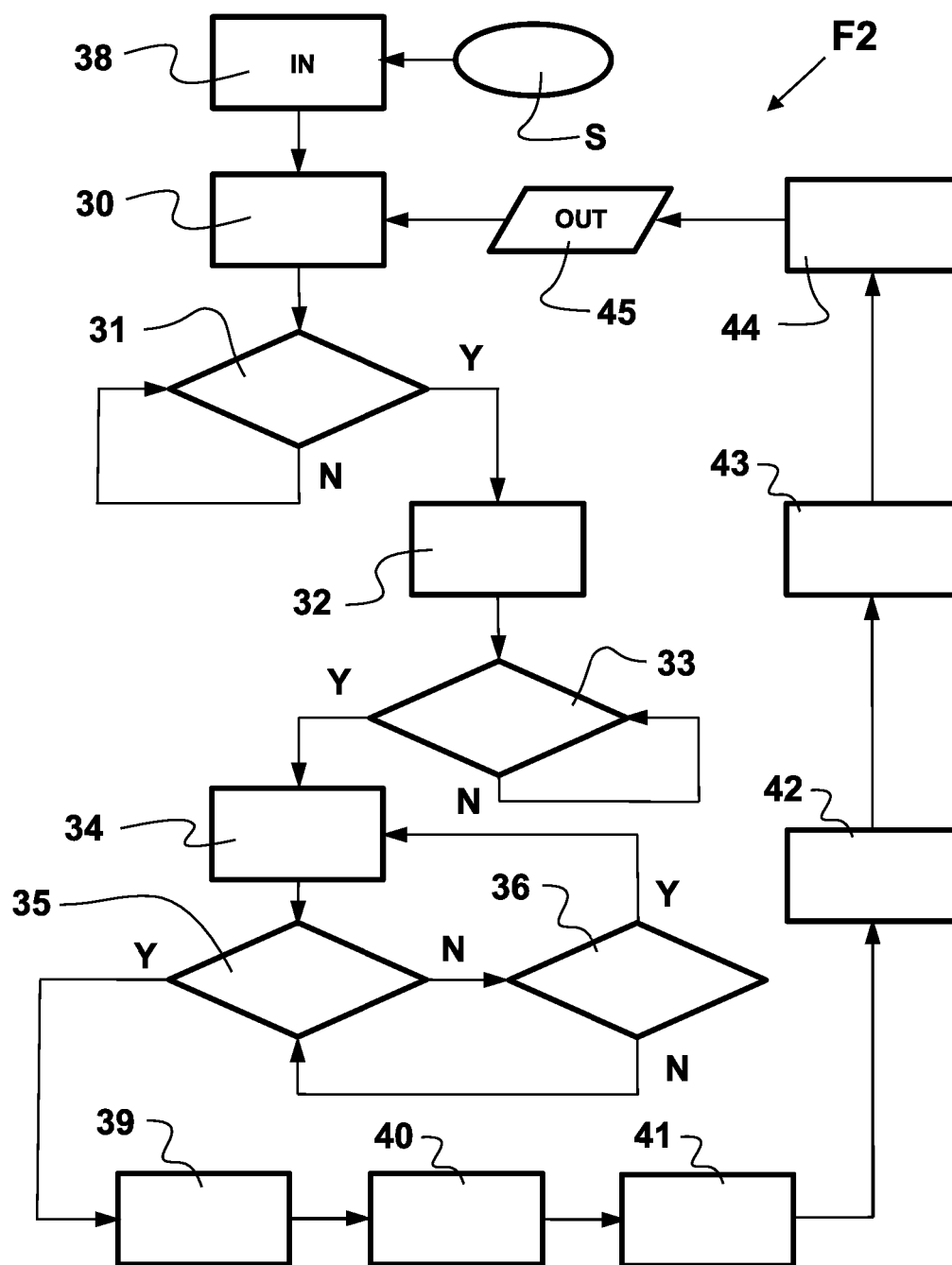


Fig.14

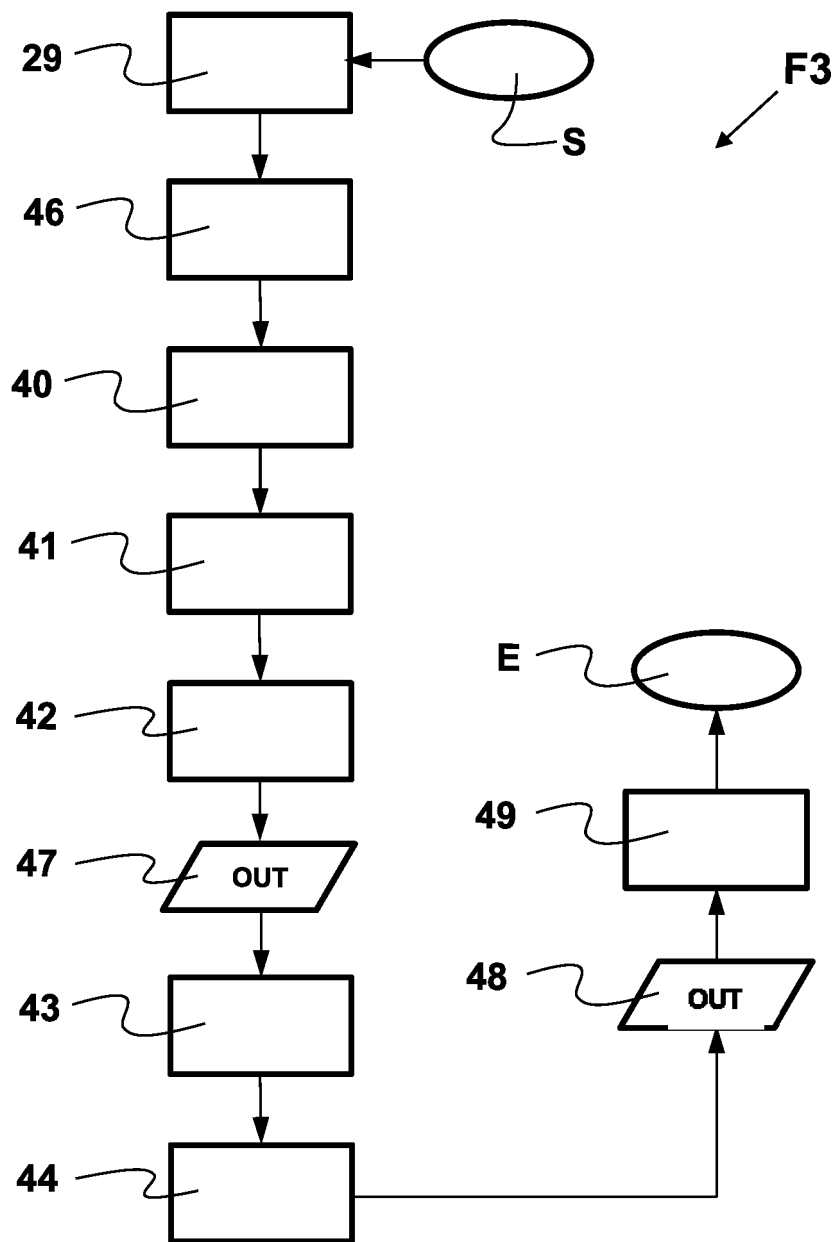


Fig.15

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2017089145 A1 [0005]