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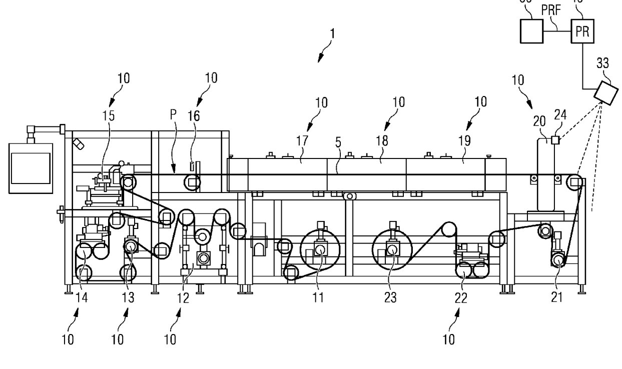
(54) **METHOD AND SYSTEM FOR COMPUTER-IMPLEMENTED TRACKING OF PRODUCTION HISTORY OF A CONTINUOUS WEB**

(57) The invention relates to a method for computer-implemented tracking of production history of a continuous web (5), which is processed in a production system (1), comprising at least one sub-system (10) applied to perform one or more specific operations. The web (5) is transported along a curved given path (P) through the production system (1) by winding/unwinding from/onto a coil (11, 23). The following steps are performed at each time point of one or more time points during the operation of the production system (1):
a) obtaining measured data (MD) of the web (5) while being transported along the path (P), the measured data (MD) being current time-stamped measured data (MD) acquired by at least one of a sensor (31, 32, 33) or a measuring device installed at or in the vicinity of the production system (1) along the path (P), where a spatial position of each sensor (31, 32, 33) and measuring device with respect to the given path (P) is known;
b) obtaining movement information (MI) of the web (5);
c) determining production-relevant features (PRF) of the web (5) by processing the time-stamped measured data (MD) and the movement information (MI) of the web (5) by mapping the time-stamped measured data (MD) to physical points of regions of the web (5).

FIG 1



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Description

[0001] The present invention relates to a method and a system for computer-implemented tracking of production history of a continuous web. In particular, the present invention relates to the process of manufacturing battery cells having a continuous electrode carrier material.

[0002] The description of the background art and the invention is made, by way of example only, by reference to the process of manufacturing battery cells. It is to be understood that the problem as well as the described solution can be applied to many other factory automation domains where multi-step assembly monitoring of continuous or discrete products is crucial.

[0003] The process of manufacturing battery cells involves many production steps, all of which have an influence on the end-of-line cell quality. Since the production of an individual cell takes a substantial amount of time and production costs are high, an early identification of faulty cells or cell components, respectively, would safe both money and time. Up to now, the battery cell production industry has been faced with relative high scrap rates greater than 10%. Hence, there is a need for improvement of production processes.

[0004] With many individual processing steps, it is a challenge to track defects or deviations upstream and/or downstream the production line. In particular, if at the end of a production line a battery cell does not meet expected quality requirements, it would be desirable to recall production history of all subcomponents within the battery cell, especially the individual segments of the assembled electrode materials in its history. Deviation of individual electrode segments can now be re-evaluated and process improvements at the root cause can be executed. A known solution to track production relevant information is to introduce space indices, e.g., relative to the cell's electrode materials for all process recording, such as parameters critical to quality/process, recipes used, etc. This enables electronic production recordings and/or queries based on segments or positions on electrodes. However, this procedure is time consuming and complex.

[0005] It is an object of the present invention to provide a method and a system for computer-implemented tracking of production history of a continuous web which, in an easy manner, allows tracking and tracing of certain quality parameters.

[0006] These objects are solved by the independent claims. Preferred embodiments are set out in the dependent claims.

[0007] The invention provides a method for computer-implemented tracking of production history of a continuous web, which is processed in a production system. The continuous web may be, in particular, a continuous electrode carrier material used for battery cell production. The production system comprises at least one sub-system applied to perform one or more specific operations, where the continuous web is transported along a (curved) given path through the production system by winding/unwinding from/onto a coil.

[0008] According to the method of the invention, the following steps a) to c) are performed at each time point of one or more time points during the operation of the production system.

[0009] In step a), measured data of the continuous web are obtained while being transported along the given path. In the following, the term "measured data" refers to digital data. The term "obtaining measured data" means that the data are received by a processor implementing the method of the invention. The measured data are current time-stamped measured data (i.e., real time data) acquired by at least one of a sensor or a measuring device installed at or in the vicinity of the production system along the given path. The spatial position of each sensor and measuring device with respect to the given path is known.

[0010] In step b) movement information of the continuous web is obtained. The term "obtaining movement information" means that the movement information, such as a speed or speed variations of the continuous web, is received by the processor implementing the method of the invention.

[0011] In step c) production relevant features of the continuous web are determined by processing the time-stamped measured data and the movement information of the continuous web by mapping the time-stamped measured data to physical points of the continuous web.

[0012] The method of the invention provides an easy and straightforward method for providing production-relevant features of respective physical points of regions of the continuous web which, when stored in a data base, enable tracking of production history of the continuous web. The production-relevant features of respective physical points of regions of the continuous web represent a virtual electrode web representation containing production-relevant features of physical points of regions of the continuous web.

[0013] Knowledge about the production history of the continuous web allows search for production anomalies for failure identification and root cause analysis at a later point in time. Furthermore, an identification of cause-and-effect relationships is possible. As a further advantage, an increase in positioning resolution of web segments can be achieved. Moreover, (re-)identification and linking of spatial segments downstream production processes by providing an information fingerprint without/or with significantly less invasive markers as in the past is possible.

[0014] Tracking of the production history enables an online-adaption of control parameters depending on feature information of current web segments. It furthermore allows early stopping of production cycles due to quality alerts or decision support for recycling such that components with a huge number of defects do not need to be scrapped as a whole. All these items help to reduce scrap, increase efficiency and, thus, save cost or energy during the battery cell production. Lifetime and quality of produced battery cells at the end of production can be therefore optimized.

[0015] The method as described herein can be derived from existing production equipment using standard factory automation systems. They already allow continuous, i.e., high-resolution, spatial feature mapping. The acquired measured data allow generation of characteristic fingerprints through spatially aligned and consistent feature vectors.

[0016] According to a preferred embodiment, the spatial position of each sensor and measuring device with respect to the given path is determined by a one-time reference calibration. The one-time reference calibration is executed before steps a) to c), as set out above, are performed. For reference calibration, the following steps are performed.

[0017] In step a1), spatial markers are attached on the continuous web. The spatial markers may be removable markers or laser-code print marks on the edges of the continuous web.

[0018] In step a2), the continuous web is moved during calibration at a given velocity. Preferably, the velocity does not change during the whole reference calibration. Further preferred, the velocity is slow, i.e., slower than the speed with which the continuous web is moved along the given path during a regular production process.

[0019] In step a3), time steps are acquired, whenever a position of a certain sensor or a measuring device is crossed. Such sensors can be optical sensors, such as cameras. The camera may work in the infrared spectrum of light. The measuring device may be a device for determining the thickness of a coating, a temperature sensor, a humidity sensor and so on. The certain sensors or measuring devices are mounted along the production path of the given process.

[0020] In step a4), time gaps between two adjacent positions are transformed into relative spatial distances or absolute coordinates of a first frame using a pre-defined first point of origin. A first frame may be regarded as a coordinate system of the production system. It is referred to as a machine (production) coordinate system herein as well.

[0021] The first point of origin may correspond to a part of the production system, optionally being marked with a unique marker placed within the field of view of an optical sensor.

[0022] Preferably, the first point of origin corresponds to a fixed marker observable in the field of view of the sensor located at an end of the given path. The term "end of the given path" is to be understood that all production steps before winding onto the coil have been finished. The sensor observing the fixed marker may be located close to the winding coil. However, it may be arranged at a different place in an end section of the given path after the specific production steps have been finished.

[0023] According to a further preferred embodiment, projected positions of each sensor and measuring device along the given path are stored. The protected positions relate to the first frame in which the (curved) given path is unwinded.

[0024] According to a further preferred embodiment, a pre-defined second point of origin of a second frame of the continuous web is obtained by processing measured data of a certain sensor or measuring device. The second frame may be regarded as a web coordinate system.

[0025] In particular, the second point of origin corresponds to a visible characteristic of the continuous web observable in the field of view of the sensor located at the end of the given path. A practical choice for defining such an origin of the continuous web is a leading edge of a coating area (in case the production system and its sub-system executes coating), as it can be easily recognized by optical image processing. Furthermore, it is unlikely that coated areas are cut-off later along the production processes.

[0026] According to a further preferred embodiment, the second frame refers to the continuous web fully unwinded along its length dimension, where each physical point can be identified by coordinates along the unwinded length dimension and perpendicular to the length dimension, which runs along a width direction of the continuous web.

[0027] Coordinates in the second frame may comprise a further information about a side of the continuous web, i.e., an upper side or a lower side.

[0028] According to a further preferred embodiment of the present invention, in step c) the following steps are performed.

[0029] In step c1), for each physical point or region of points on the continuous web, the moment in time when the corresponding sensor or measuring device positioned along the direction of movement was crossed is computed.

[0030] In step c2), the time-stamped measured data is queried to obtain the features which are associated to the corresponding sensor or measuring device. Querying the time-stamped measured data may be made by retrieving them from a data base.

[0031] In step c3), the set of retrieved features is stored for each point or region on the continuous web in a data base. The time-stamped measured data and the information about the physical place on the continuous web constitute a "feature vector".

[0032] The spatial position of the certain sensor or measuring device or a spatial interval between two adjacent sensors and, optionally, the side information may be processed as a unique identifier.

[0033] According to a further preferred embodiment, the method according to one or more embodiments as set herein above is performed for a second subsequent production step, where a particular physical point or region of points on the continuous web is re-identified by matching a resulting feature vector which exhibits the highest similarity score in their corresponding feature domains. This enables identification and tracking web positions or segments across separated process steps. Improving the accuracy of the position determination or (re-identification of feature patterns) provides a link between different production processes and may be approached via Bayesian methods, such as "Kalman filters" or "Particle Filters".

[0034] Besides the above method, the invention refers to an apparatus for computer-implemented tracking of production history on a continuous web, where the apparatus is configured to perform the method according to the invention or one or more preferred embodiments of the method according to the invention.

[0035] In addition, the invention refers to a production system comprising an apparatus as set out above.

[0036] Furthermore, the invention refers to a computer program product with a program code, which is stored on a non-transitory machine-readable carrier, for carrying out the method according to the invention or one or more preferred embodiments thereof when the program code is executed on a computer.

[0037] An embodiment of the invention will now be described in detail with reference to the accompanying drawing.

Fig. 1 is a schematic illustration of a production system comprising a controller for performing an embodiment of the invention.

Fig. 2 is a schematic illustration showing the step of determining production-relevant features by mapping time-stamped measured data and movement information of the continuous web.

Fig. 3 shows a schematic flow chart of the method according to the invention.

[0038] Generally, web production machines are applied to printing, coating or laminating continuous flat materials such as paper, textiles and plastics. They are used in many product and industry segments such as packaging and foil materials, printing services or adhesive coatings. Web machines combine several processing steps such as cutting, rolling and positioning that often extend over the entire shop floor.

[0039] The following description will be based, by way of example, on a coating process, in which active materials, so called battery slurry, are applied to a continuous web, i.e., an electrode carrier material. It is to be understood that the same or similar concepts can be transferred to other processes, like subsequent calendaring, slitting or cell assembly steps as well.

[0040] Fig. 1 shows a schematic illustration of a system 1 according to an embodiment of the present invention. The production system 1 consists of a coating machine for coating of a continuous web 5 in form of a continuous electrode material. The continuous web 5 is transported along a given curved path P through the production system 1, thereby being unwinded from an un-winding coil 11 and winded onto a winding coil 23. In-between, the continuous web 5 passes a plurality of sub-systems 10 of the production system 1. In the order starting from the un-winding coil 11 to the winding coil 23 the following sub-systems 10 are passed along the path P which are relevant for coating and providing measurements of relevant production and condition parameters: corona 12, moving cylinder 13, edge control device 14, coating device (coater) 15, wet layer thickness measurement device 16, dryer unit 17, dryer unit 18, dryer unit 19, surface weight measurement device 20, moving cylinder 21, and edge control device 22. Each of these sub-systems 10 may comprise a number of cylinders along which the web 5 is guided and redirected.

[0041] The production system 1 furthermore comprises a number of sensors 31, 32, 33 and measuring devices where only sensor 33 at the end of the given path P is illustrated in Fig. 1. Sensor 33 located at the end of the path P is an optical and/or infrared camera and placed such that a unique marker 24 is in the field of view of the sensor 33. The marker 24 represents, as will be described below, a first point of origin of a first frame MF. The first frame MP corresponds to a machine coordinate system, where the machine is represented by the production system 1.

[0042] The sensors 31, 32, 33 and measuring devices are mounted along the path P of the given process of the production system 1. Generally, sensors may be optical and/or infrared cameras, and so on. Measuring devices may be adapted to determine a coating layer thickness or a humidity of the coated material in one or more of the dryer units 17, 18, 19. A sensor and/or measuring device may also be adapted to acquire data in the surrounding of the production system 1, such as temperature or humidity.

[0043] Each of the sensors 31, 32, 33 and the measuring devices is communicatively connected to an apparatus 40 comprising a processor PR. Measured data MD acquired by the sensors 31, 32, 33 and the measuring devices are transferred to the apparatus 40 and stored in a data base 50 which is connected to the apparatus 40.

[0044] In order to be able to track a production history of the continuous web 5, a one-time preparatory step has to be carried out in which information about the spatial positions and other measurement properties for each of the sensors 31, 32, 33 and measuring devices along the given path P is gathered. This preparatory step consists of determining a one-time reference calibration for measuring/determining the spatial positions of the sensors 31, 32, 33 and the measuring devices along the curved path P.

[0045] First, spatial markers (not illustrated) are attached on the continuous web 5. The spatial markers may be removable or generated by semi-invasive techniques, such as by applying laser-code print marks on the edges on the continuous web 5. Next, the web 5 is moved at the path P during this reference calibration at a given velocity. Preferably, the velocity does not change during the calibration process. In order to be able to have precise calibration information, it is preferred to move the web 5 at slow velocity (i.e., at a velocity which is less than the usual moving velocity of the web 5 during regular operation of the production system 1). Whenever a certain sensor position is crossed, a timestamp is acquired. Then, time gaps between two adjacent positions can be transformed into relative spatial distances or absolute coordinates of the first frame MF (machine frame) using the already mentioned pre-defined first point of origin (marker) 24.

[0046] Fig. 2 illustrates this setup and the definitions in a simplified manner. At the upper part of Fig. 2 an unwinded path UP along its length dimension is illustrated. Along the unwinded path UP the sub-systems 10 of the production system 1 and the sensors 31, 32, 33 and measuring devices are arranged. In the illustration of Fig. 2, for simplification reasons, only the un-winding coil 11, the coating device 15 and sensors 31, 32, 33 are shown. Sensor 33 corresponds to the aforementioned sensor at the end of the path P. As further already mentioned, the fixed marker 24 which is observable in the field of view of sensor 33 constitutes the first point of origin of the first frame MF (machine frame).

[0047] Each of the sensors and the sub-systems has a respective position P0, P1, P2, where a timestamp is acquired if a respective position of a certain sensor or measuring device is crossed. In Fig. 2, position P2 is crossed at time T_0. Position P1 of sensor 32 is crossed at time t = T 1. As the velocity of the moving web 5 is known, the distance d between each two adjacent positions can be determined. The distance d between positions P1 and P2 is outlined as d(T_1, T_0). Starting from the predefined first point of origin 24, the spatial positions of each the sensors 31, 32, 33 and measuring devices can be obtained.

[0048] The spatial positions are transformed into absolute coordinates p(T_0), p(T_1) with respect to the origin of the marker 24. The projected positions P0, P1, P2 of each sensor 31, 32, 33 and measuring device along the path is then stored in the data base 50.

[0049] To be able to track production relevant features PRF of the web 5 a pre-defined second point of origin 6 of a second web frame WF corresponding to a web coordinate system of the web 5 is obtained by processing measured data MD of a certain sensor 31, 32, 33 or measuring device. A practical choice for designing such origin on the web 5 is the leading edge of the coating area CA, as it is easily recognizable by optical image processing of the measured data MD of the camera (sensor) 33. More generally, the second point of origin is a visible characteristic of the web 5.

[0050] In Fig. 2, the unwinded web 5 along the unwinded path UP is illustrated at two different times T_0 and T_1 along time-axis t. The coated area is denoted with CA on the web 5. As can be seen from the unwinded web 5 at time t=T 0, the leading edge of the coating area CA crosses sensor 33 and the marker 24 in the field of view of the sensor 33, respectively. At t=T_1, web 5 has moved according to the measured velocity of transport of the web 5 such that a physical point of web PPW which crossed sensor 31 at time t=T_0 now crosses sensor 32 at t=T_1.

[0051] For identification of physical points of regions of the web 5 it must be considered that electrode carrier material typically consists of two sides, namely an upper side 5u and a lower side 51. In the coating process of Fig. 1, for example, the two sides are typically processed subsequently. An additional identifier s is used to distinguish between both sides 5u, 51. Also, for some sensor measurements, like optical images, positions on the web 5 are not solely defined by the coordinate along the direction of movement (x-axis) but also along the orthogonal axis (y-axis).

[0052] The second frame DF refers to the continuous web fully unwinded along its length direction. Each physical point, PPW can be identified by coordinates along the unwinded, length dimension x and perpendicular to the length dimension x, which runs along a width direction y of the continuous web 5. A coordinate in the second frame WF therefore consists of three values x, y, s as attached to the physical point PPW in Fig. 2. The origin of the second frame thus has the coordinate (0,0, s).

[0053] Computer-implemented tracking of the production history of the web 5 is made by performing the following steps at each time point of one or more time points during the operation of the production system.

[0054] In a first step (S1 in Fig. 3), measured data MD of the web 5 are obtained while the web 5 is transported along the path P (see Fig. 1). The measured data are current time-stamp measured data MD which are acquired by the sensors 31, 32, 33 and any measuring device installed at or in the vicinity of the production system 1 along the path P. The measurements can comprise complex data structures, such as RGB images or hyperspectral infrared measurements. They also can comprise simple scalar values, such as temperature, humidity readings, or coating layer-thickness, or any combination thereof. It is to be noted that some of the sensors and measurement devices may be arranged in a room where the production system is built. For example, temperature, humidity values can be measured in the surrounding of the production system 1.

[0055] While being transported along the given path, a movement information MI of the continuous web 5 is obtained (S2 in Fig. 3). The movement information MI of the web 5 is continuously measured, e.g., via angular encoders or bar code scanning systems. The movement information is also stored as high-resolution time-series data. This allows to compute the distance travelled by the web 5 along the path P at any moment in time.

[0056] With these pre-requisites, production-relevant features PRF of the web 5 can be determined (S3 in Fig. 3). The determination takes place by processing the acquired time-stamped measured data MD and the movement information MI of the web 5 by mapping the time-stamped measured data MD to physical points or regions of the continuous web. This mapping corresponds to a coordinate transfer between the coordinates of the first frame MF to the coordinates of the second frame WF. As a result, a virtual electrode web representation containing production-relevant features PRF of physical points of regions of the continuous web 5 can be achieved. The production-relevant features PRF can be stored in the data base 50.

[0057] To do so, for each physical point or region of points on the web 5 one can compute the moment in time when the corresponding sensor 31, 32, 33 or measurement device position along the direction of movement of the web 5 was crossed. This can be achieved by applying the measurement of movement as a function of time. Next, time-series measured data MD acquired beforehand can be queried to obtain the features which are associated to the corresponding sensor 31, 32, 33 or measuring device. Finally, the set of retrieved features is stored for each point or region on the continuous web 5 in the data base 50. The data base structure can be either centrally or at a "shop-floor-level". The spatial position or spatial interval plus (upper/lower) side information can be used as a unique identifier.

[0058] Mapping of the movement of the web 5 along the path P, as observed from the web frame, is made as follows: first, an origin T_0 along the time axis t is introduced. T_0 is conveniently defined as the moment in time, when the origin 6 of the x-axis in the web frame WF (i.e., the leading edge of the coating area CA) coincides with the origin 24 along the web's path in the machine frame MF (i.e., the position of the marker 24 in the field of view of the sensor 33 at the end of the path P). In this moment all coordinate values of x correspond to the position along the path P.

[0059] Assuming that a measurement of the web velocity v(t) in the machine frame MF is available, by using a sensor measuring the velocity of the web 5, it can be calculated how much the web 5 has moved in time interval $\Delta t=t-T_0$:

$$\Delta p(\Delta t) = \int_{T_0}^{t} v(t')\,dt'$$

[0060] Thus, the position along path P at a certain point x_0, y_0, s_0 of the web 5 for any moment in time can be computed by:

$$p_{x_0}(t) = p_{x_0}(T_0) + \Delta p(\Delta t) = x_0 + \int_{T_0}^{t} v(t')\,dt'$$

[0061] Thereby, $p_{x0}(T_0) = x_0$ is assumed since x-axis and path P overlap at $t=T_0$ by definition. In practice, the time integral over the velocity may be approximated by summation over discrete measurements of the velocity of the web v(t).

[0062] In order to map features like temperature or camera images according to the calculations above, the positions of the corresponding sensors 31, 32, 33 and measuring devices relative to the origin of the path P are used. As described above, relative distances are calculated by using the calibration run.

[0063] With the method described above, recording and mapping production features onto the electrode web within each dedicated process is possible. A (re-)identification and tracking of web positions or segments across separate processes can be made as follows. Assuming that a set of features has been correctly mapped to a physical point or point of regions of the web 5 in some production step A) (e.g., coating as described above), that particular segment can be re-identified by applying a similar procedure along a different production step B (e.g., calendaring) and then matching resulting feature vectors. In particular, given the spatial position and corresponding feature vector from the representation of step B, it can be searched for the spatial position during step A which exhibits the highest similarity in the corresponding feature domains. Such a solution can be used as a refinement or fine-calibration of physical positions across distinct processes where other solutions (e.g., laser markers as defined position) would only provide a coarse spatial resolution. Laser markers can simplify the search complexity in the features space by providing reasonable position interval limits, however.

[0064] Improving the accuracy of position determination or (re)identification of feature patterns to provide a link between the frame production processes can be approached via Bayesian methods, such as "Kalman Filters" or "Particle Filters": starting from rough prior knowledge, e.g., the approximate location of web segments according to printed bar codes, each additional feature provides further information to recalibrate the matching score between web segments observed at different stages along the production, eventually allowing positioning accuracy in the range of a few centimeters, or better.

Claims

1. A method for computer-implemented tracking of production history of a continuous web (5), in particular a continuous electrode carrier material, which is processed in a production system (1), comprising at least one sub-system (10)

applied to perform one or more specific operations, where the continuous web (5) is transported along a given path (P) through the production system (1) by winding/un-winding from/onto a coil (11, 23), wherein at each time point of one or more time points during the operation of the production system (1) the following steps are performed:

a) obtaining measured data (MD) of the continuous web (5) while being transported along the given path (P), the measured data (MD) being current time-stamped measured data (MD) acquired by at least one of a sensor (31, 32, 33) or a measuring device installed at or in the vicinity of the production system (1) along the given path (P), where a spatial position of each sensor (31, 32, 33) and measuring device with respect to the given path (P) is known;
b) obtaining movement information (MI) of the continuous web (5) ;
c) determining production-relevant features (PRF) of the continuous web (5) by processing the time-stamped measured data (MD) and the movement information (MI) of the continuous web (5) by mapping the time-stamped measured data (MD) to physical points of regions of the continuous web (5).

2. The method according to claim 1, wherein the spatial position of each sensor (31, 32, 33) and measuring device with respect to the given path (P) is determined by a one-time reference calibration, in which the following steps are performed:

a1) attaching spatial markers on the continuous web (5);
a2) moving the continuous web (5) during calibration at a given velocity;
a3) acquiring timestamps whenever a position (P0, P1, P2) of a certain sensor (31, 32, 33) or a measuring device is crossed;
a4) transforming time gaps between two adjacent positions (P0, P1, P2) into relative spatial distances or absolute coordinates (p(T_0), p(T_1)) of a first frame (MF) using a pre-defined first point of origin (24).

3. The method according to claim 2, wherein the first point of origin (24) corresponds to a part of the production system (1), optionally being marked with a unique marker placed within the field of view of an optical sensor (31, 32, 33).

4. The method according to claim 2 or 3, wherein the first point of origin (24) corresponds to a fixed marker observable in the field of view of the sensor (33) located at an end of the given path (P).

5. The method according to one of claims 2 to 4, wherein projected positions (P0, P1, P2) of each sensor (31, 32, 33) and measuring device along the given path (P) are stored.

6. The method according to one of the preceding claims, wherein a pre-defined second point of origin (6) of a second frame (WF) of the continuous web (5) is obtained by processing measured data (MD) of a certain sensor (31, 32, 33) or measuring device.

7. The method according to claim 6, wherein the second point of origin (6) corresponds to a visible characteristic of the continuous web (5) observable in the field of view of the sensor (33) located at the end of the given path (P).

8. The method according to claim 6 or 7, wherein the second frame (WF) refers to the continuous web (5) fully unwinded along its length dimension, where each physical point (PPW) can be identified by coordinates along the unwinded, length dimension (x) and perpendicular to the length dimension (x), that runs along a width direction (y) of the continuous web (5) .

9. The method according to claim 8, wherein coordinates (x, y) in the second frame (WF) comprise an information (s) about an upper side (5u) or a lower side (51) of the continuous web (5) .

10. The method according to one of the preceding claims, wherein in step c) the following steps are performed:

c1) computing for each physical point or region of points on the continuous web (5) the moment in time when the corresponding sensor (31, 32, 33) or measuring device position (P0, P1, P2) along the direction of movement was crossed;
c2) querying the time-stamped measured data (MD) to obtain the features (PRF) which are associated to the corresponding sensor (31, 32, 33) or measuring device;
c3) storing the set of retrieved features (PRF) for each point or region on the continuous web (5) in a data base

11. The method according to claim 10, wherein the spatial position (P0, P1, P2) of the certain sensor (31, 32, 33) or measuring device or a spatial interval between two adjacent sensors (31, 32, 33) and, optionally, the side information (s) are processed as a unique identifier.

12. The method according to one of the preceding claims, wherein the method according to one of the preceding claims is performed for a second subsequent production step, where a particular physical point (PPW) or region of points on the continuous web (5) is re-identified by matching a resulting feature vector which exhibits the highest similarity score in their corresponding feature domains.

13. An apparatus for computer-implemented tracking of production history of a continuous web (5), in particular a continuous electrode carrier material, which is processed in a production system (1), comprising at least one sub-system (10) applied to perform one or more specific operations, where the continuous web (5) is transported along a given path (P) through the production system (1) by winding/un-winding from/onto a coil (11, 23), wherein the apparatus (40) comprises a processor (PR) configured to perform a method comprising the following steps:

a) obtaining measured data (MD) of the continuous web (5) while being transported along the given path (P), the measured data (MD) being current time-stamped measured data (MD) acquired by at least one of a sensor (31, 32, 33) or a measuring device installed at or in the vicinity of the production system (1) along the given path (P), where a spatial position of each sensor (31, 32, 33) and measuring device with respect to the given path (P) is known;
b) obtaining movement information (MI) of the continuous web (5) ;
c) determining production-relevant features (PRF) of the continuous web (5) by processing the time-stamped measured data (MD) and the movement information (MI) of the continuous web (5) by mapping the time-stamped measured data (MD) to physical points of regions of the continuous web (5).

14. The apparatus according to claim 13, wherein the apparatus (40) is configured to perform a method according to one of claims 2 to 12.

15. A production system (1) comprising at least one sub-system (10) applied to perform one or more specific operations, where the continuous web (5) is transported along a given path (P) through the production system (1) by winding/un-winding from/onto a coil (11, 23), thereby passing at least one of a sensor or a measuring device, each of them being adapted to acquire measured data (MD), wherein the production system (1) comprises an apparatus according to claim 13 or 14.

16. A computer program product with program code, which is stored on a non-transitory machine-readable carrier, for carrying out a method according to one of claims 1 to 12 when the program code is executed on a computer.

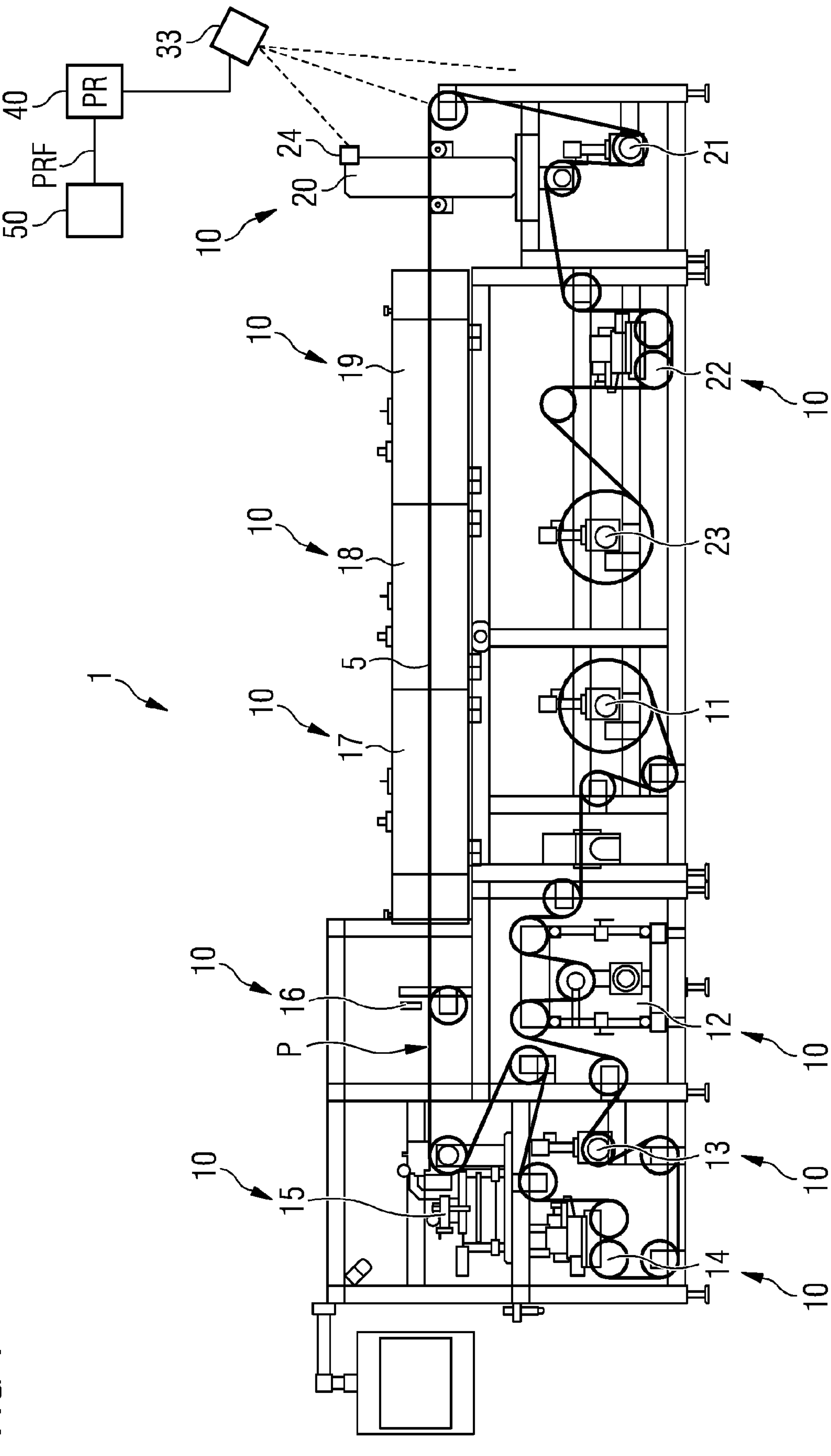


FIG 1

FIG 2

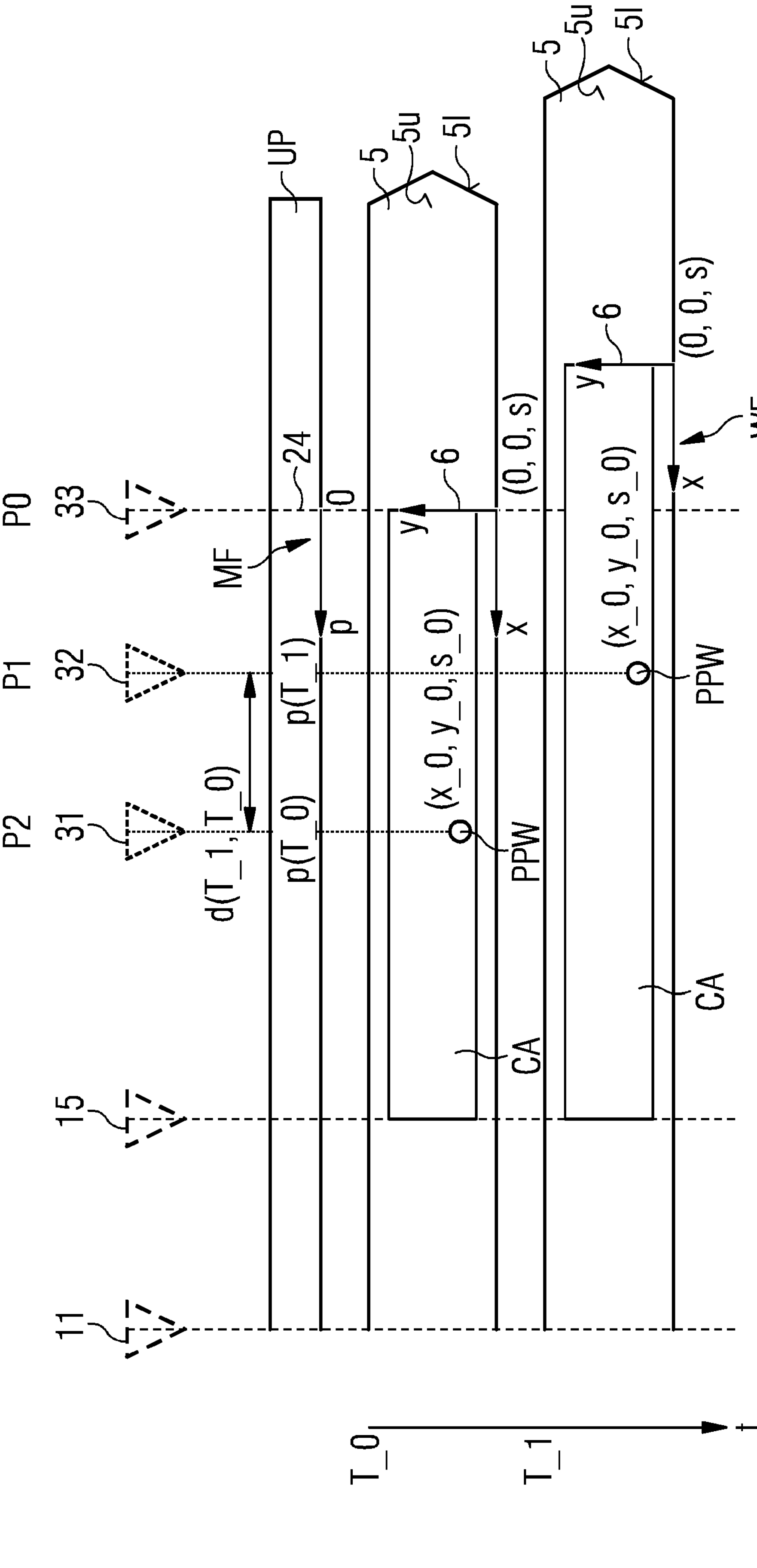
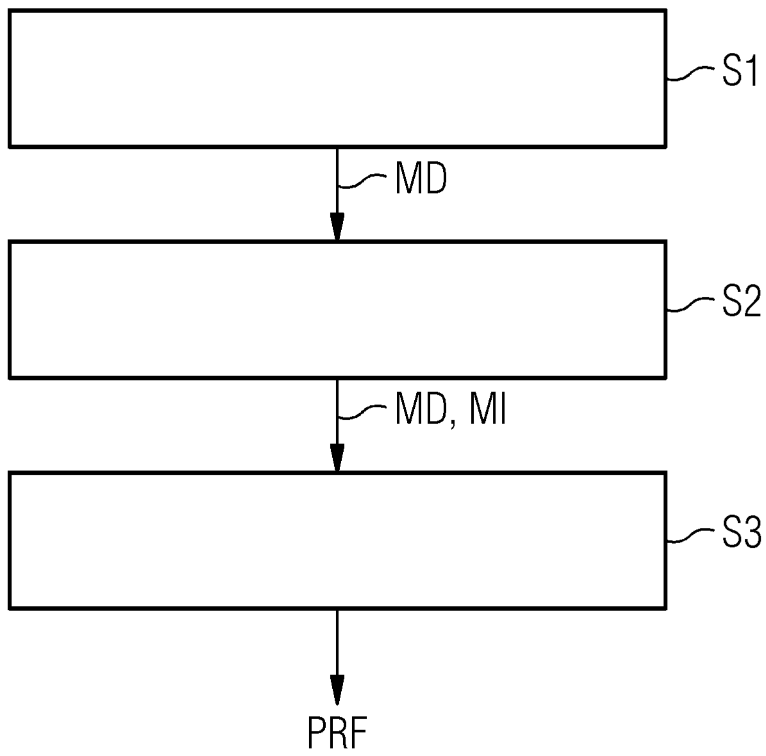

P0
P1
P2
33
32
31
15
11
UP
24
MF
0
p
p(T_1)
p(T_0)
d(T_1, T_0)
5
5u
5l
6
y
x
(0, 0, s)
(x_0, y_0, s_0)
PPW
CA
WF
T_0
T_1
t

FIG 3



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EUROPEAN SEARCH REPORT

Application Number
EP 22 18 5937

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2002/030704 A1 (KORNGOLD BRUNO ALEXANDER [NL] ET AL) 14 March 2002 (2002-03-14) * the whole document * -----	1-16	INV. B65H26/02
A	DE 10 2009 029082 A1 (VOITH PATENT GMBH [DE]) 3 March 2011 (2011-03-03) * the whole document * -----	1,13,15, 16	
A	US 5 628 574 A (CROWLEY H W [US]) 13 May 1997 (1997-05-13) * the whole document * -----	1,13,15, 16	
A	US 2017/307542 A1 (WATANABE KOICHIRO [JP] ET AL) 26 October 2017 (2017-10-26) * the whole document * -----	1,13,15, 16	
A	EP 0 730 686 A1 (RETECH AG [CH]) 11 September 1996 (1996-09-11) * the whole document * -----	1,13,15, 16	
			TECHNICAL FIELDS SEARCHED (IPC)
			B65H

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	2 January 2023	Haaken, Willy

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02-01-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002030704 A1	14-03-2002	DE 60027896 T2	30-11-2006
		EP 1197454 A1	17-04-2002
		JP 2002236015 A	23-08-2002
		US 2002030704 A1	14-03-2002
DE 102009029082 A1	03-03-2011	NONE	
US 5628574 A	13-05-1997	NONE	
US 2017307542 A1	26-10-2017	CN 106796182 A	31-05-2017
		CN 106796183 A	31-05-2017
		CN 106796184 A	31-05-2017
		CN 107076679 A	18-08-2017
		CN 109616602 A	12-04-2019
		JP 5815909 B1	17-11-2015
		JP 6017091 B2	26-10-2016
		JP 6017092 B2	26-10-2016
		JP 6017093 B2	26-10-2016
		JP WO2016056253 A1	27-04-2017
		JP WO2016056378 A1	27-04-2017
		JP WO2016056379 A1	27-04-2017
		JP WO2016056380 A1	27-04-2017
		KR 20170046183 A	28-04-2017
		KR 20170047402 A	04-05-2017
		KR 20170054514 A	17-05-2017
		KR 20170066430 A	14-06-2017
		US 2017307542 A1	26-10-2017
		US 2017307543 A1	26-10-2017
		US 2017307971 A1	26-10-2017
		US 2017317327 A1	02-11-2017
		WO 2016056253 A1	14-04-2016
		WO 2016056378 A1	14-04-2016
		WO 2016056379 A1	14-04-2016
		WO 2016056380 A1	14-04-2016
EP 0730686 A1	11-09-1996	AT 171738 T	15-10-1998
		EP 0730686 A1	11-09-1996
		JP H10503245 A	24-03-1998
		US 5873392 A	23-02-1999
		WO 9514805 A1	01-06-1995

EPO FORM P0459

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