

(19) **United States**

(12) **Patent Application Publication**
Bram

(10) **Pub. No.: US 2013/0186055 A1**

(43) **Pub. Date: Jul. 25, 2013**

(54) **SYSTEM AND METHOD FOR THE
MANAGEMENT OF THE FLOW RATE OF A
FEED LINE**

Publication Classification

(51) **Int. Cl.**
D01H 13/32 (2006.01)
(52) **U.S. Cl.**
CPC *D01H 13/32* (2013.01)
USPC **57/90**

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(21) Appl. No.: **13/825,346**

(22) PCT Filed: **Sep. 22, 2011**

(86) PCT No.: **PCT/IB11/54165**

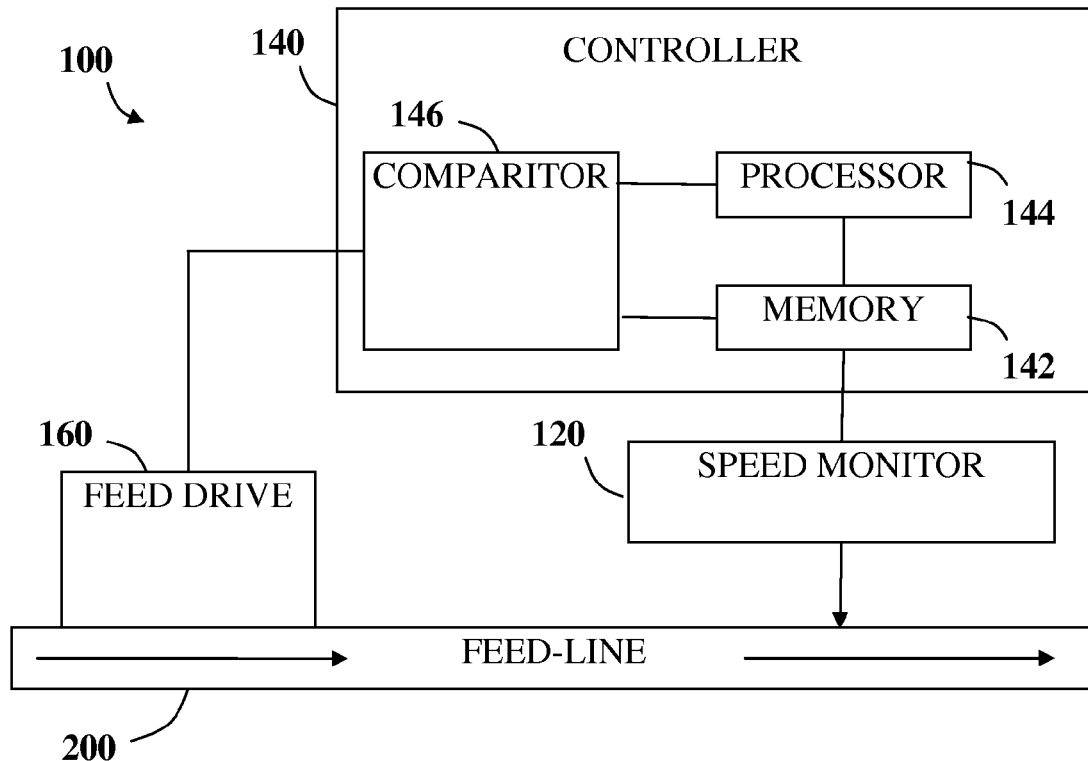
§ 371 (c)(1),
(2), (4) Date: **Mar. 21, 2013**

(57) **ABSTRACT**

A feed-line management system and associated method are presented for controlling flow-rate of at least one material. The system controls a feed driver to control the motion of the feed-line in response to statistical analysis of data received from a contactless speed monitor. The speed monitor may use an image processor to capture images of the feed line, identify features in the images and determine their speed of movement. The system may provide contactless motion control in industrial conditions, for example controlling yarn feeds in the textile industry.

Related U.S. Application Data

(60) Provisional application No. 61/386,479, filed on Sep. 25, 2010.



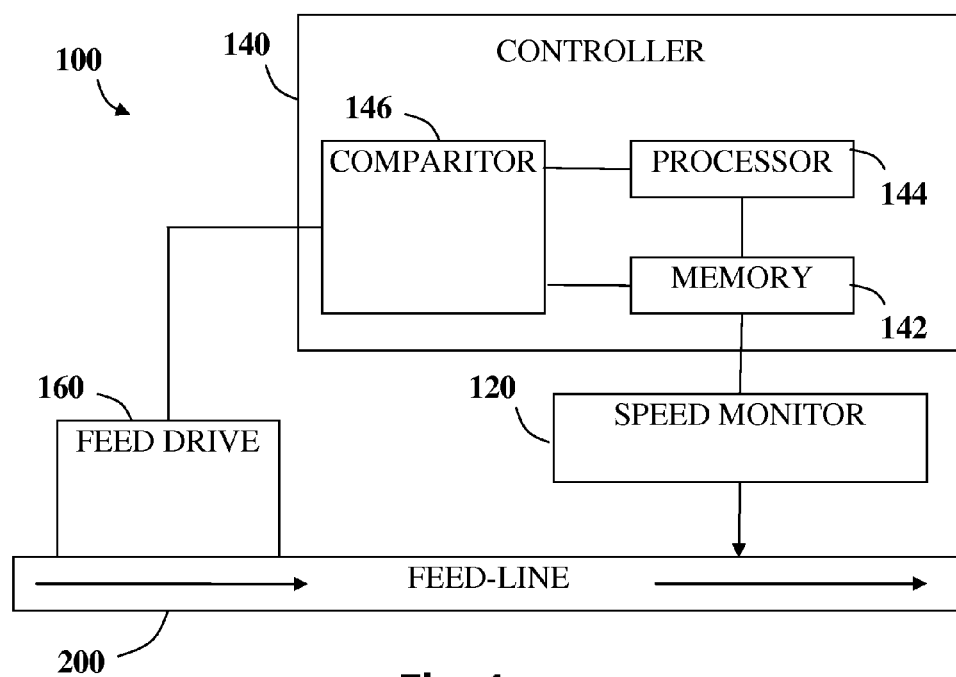


Fig. 1

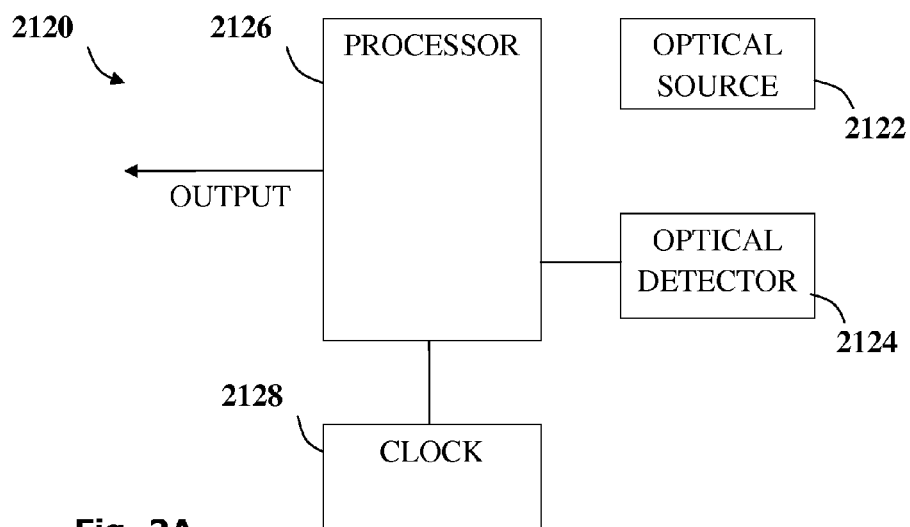


Fig. 2A

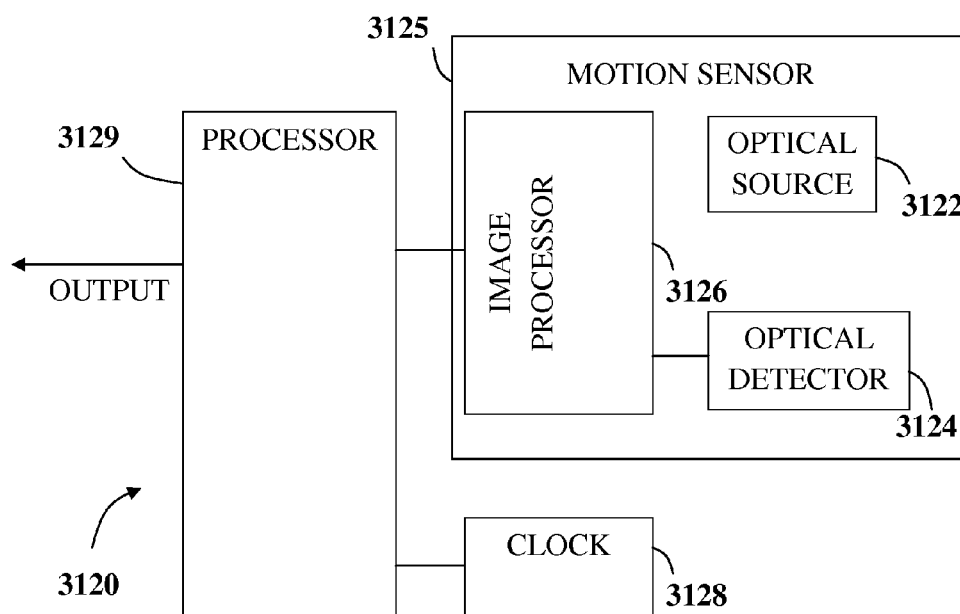


Fig. 2B

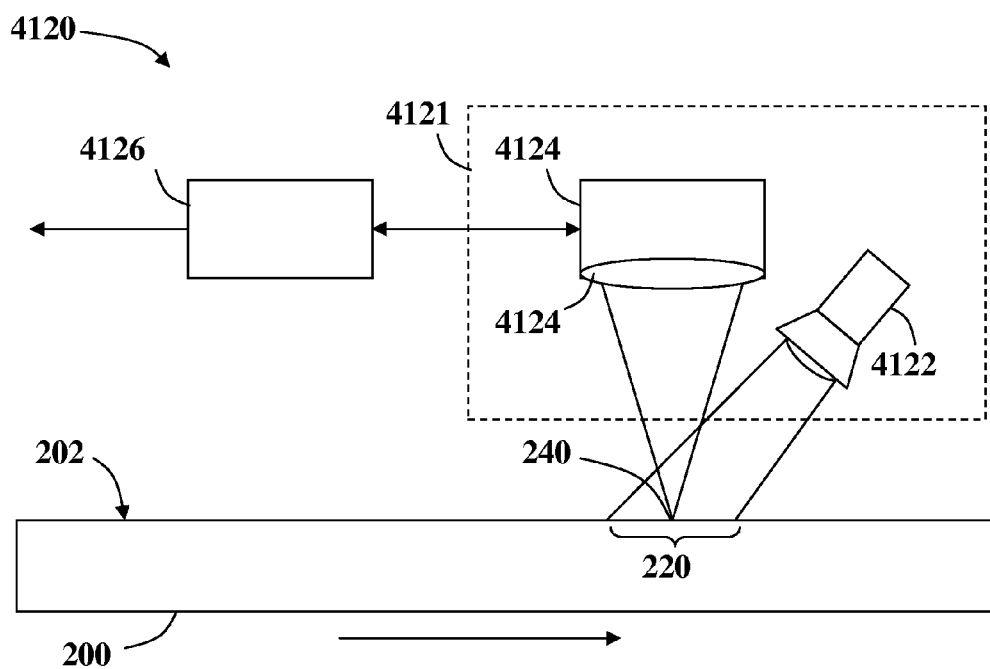


Fig. 3A

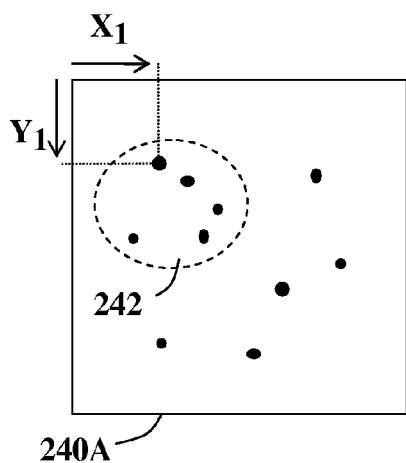


Fig. 3B

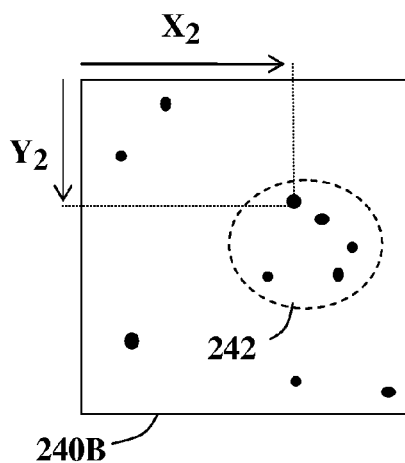


Fig. 3C

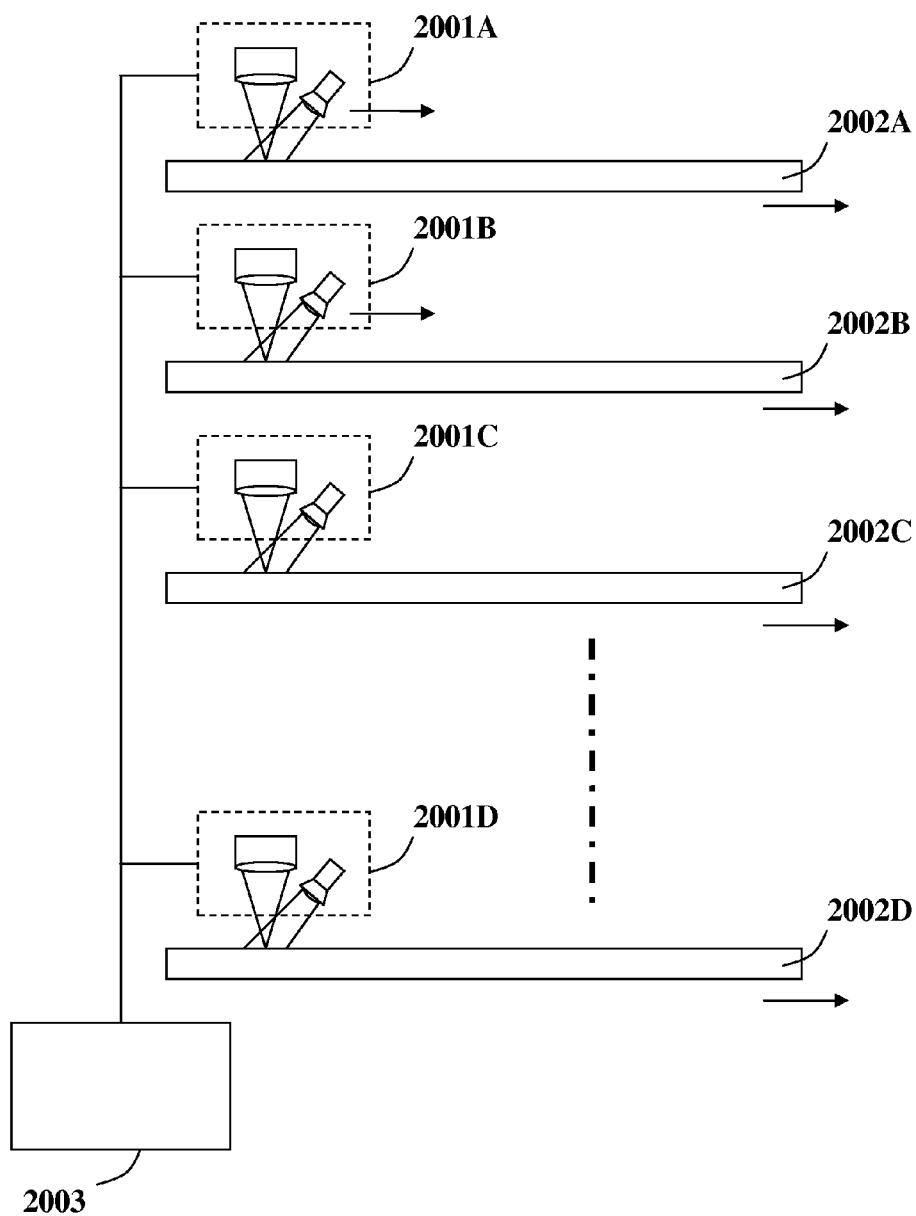
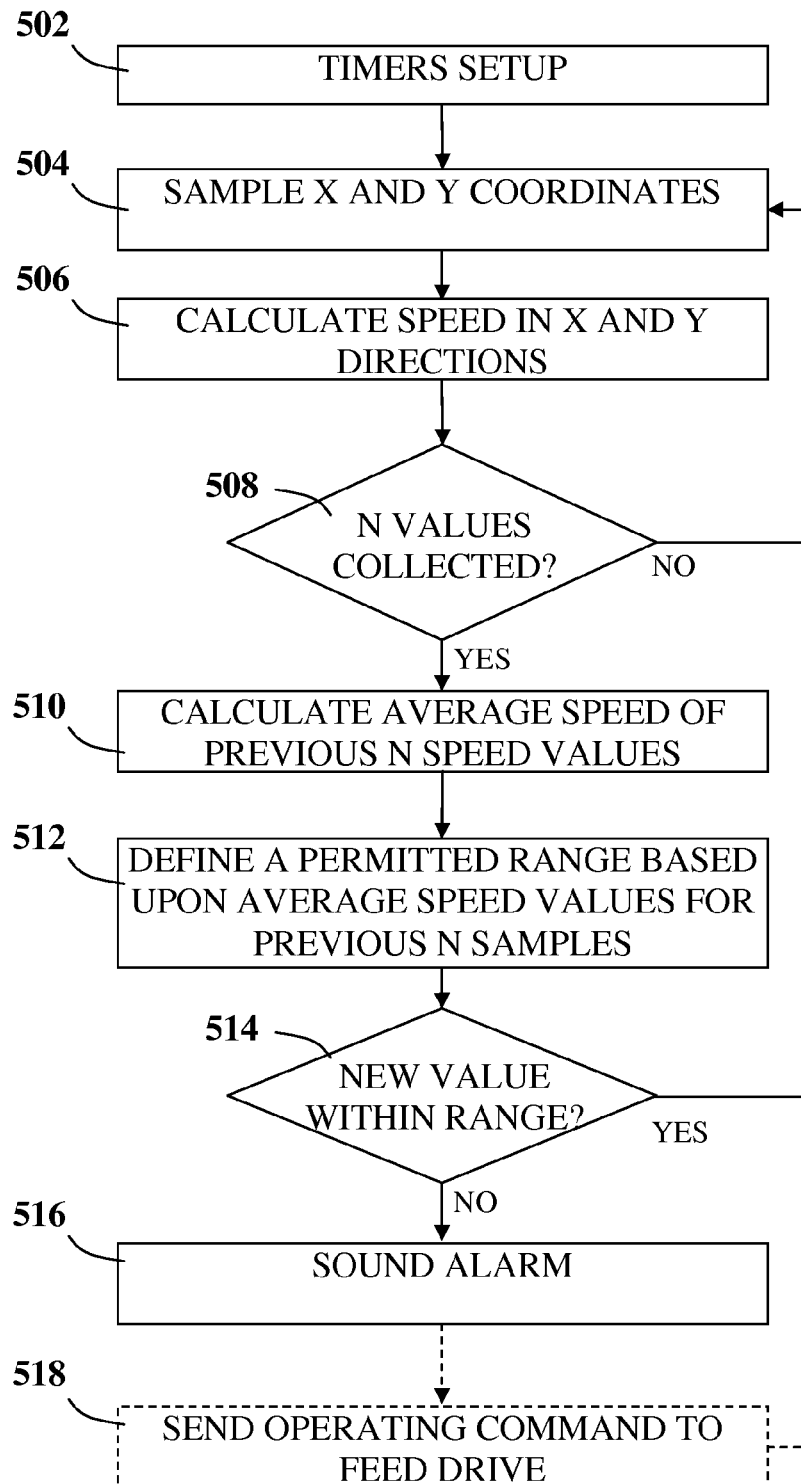
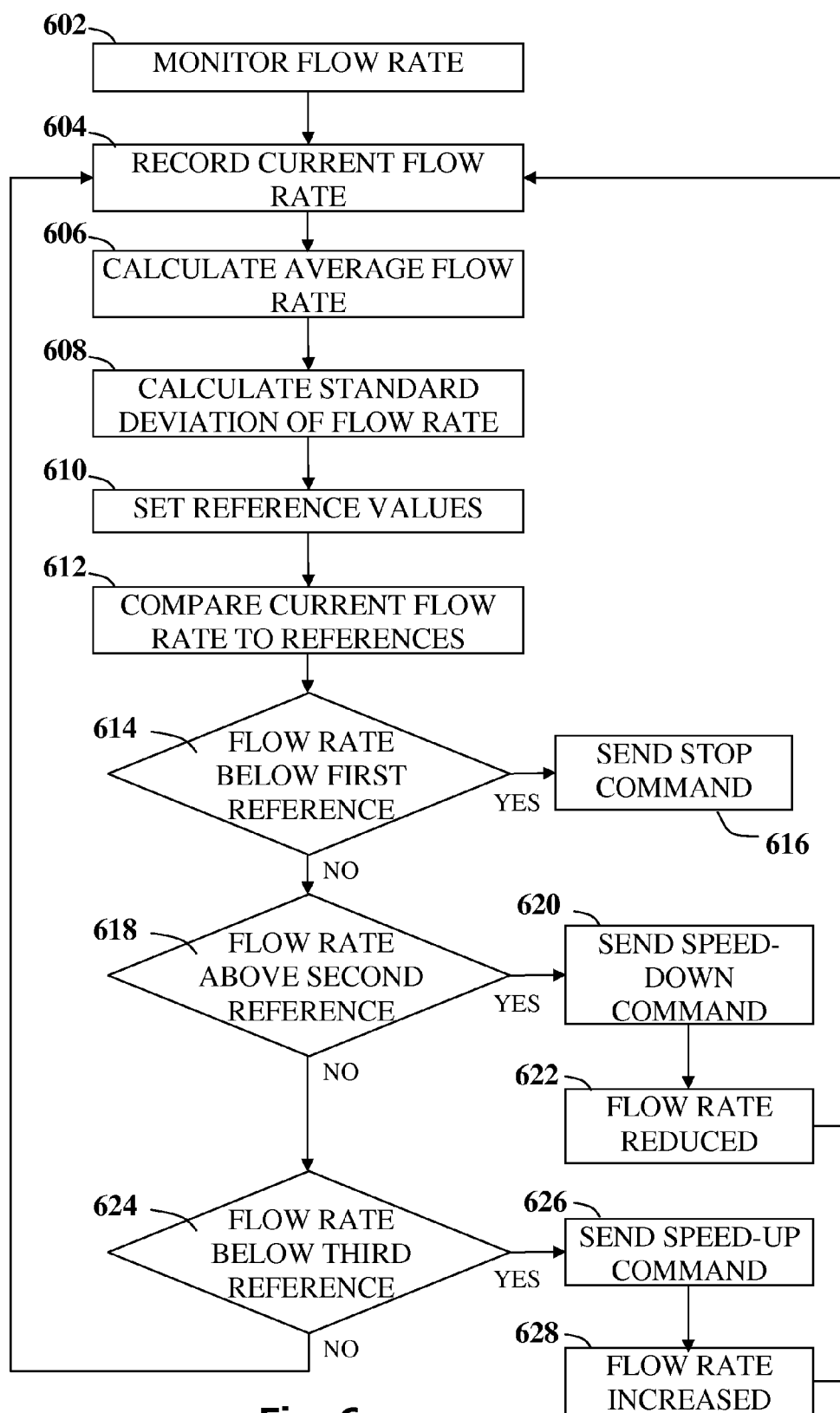


Fig. 4

**Fig. 5**

**Fig. 6**

SYSTEM AND METHOD FOR THE MANAGEMENT OF THE FLOW RATE OF A FEED LINE

FIELD OF THE DISCLOSURE

[0001] The embodiments disclosed herein relate to methods and systems for motion control. In particular the disclosure relates to the management and control of the flow rate of material supplied by a feed line in industrial production systems such as in the textile industry.

BACKGROUND

[0002] Motion control is important for a wide range of industrial applications. Motion control may be used to monitor and regulate the delivery of materials along a feed line to a manufacturing assembly. Such monitoring may provide a greater efficiency of production or higher quality of product.

[0003] By way of example, it is noted that in the textile industry it is often necessary to control the rate of a feeder yarn or other thread being fed to a yarn, tufting machine or the like. Most existing thread control systems are based on tension measurement and generally monitor the physical presence of the thread but do not estimate its motion. Thus, many parameters required for statistical analysis, such as average speed, deviation from average speed, changes in direction of motion and the like, are not readily obtainable using known control systems. Consequently, tension based monitors are of limited use in predictive warning systems as they are not generally capable of recognizing a statistical risk that the thread will break before the tension of thread reaches undesirable values. In order to recognize situations leading to thread-break events, a motion control based on motion measurement is required.

[0004] In other material industrial applications, feed lines may deliver material using conveyer belts, piping, traveling platforms or the like. In another example, a manufacturing system dealing with corrosive, radioactive or easily contaminated raw materials may require management of the flow rates of multiple incoming feed lines of raw materials. In such cases a contactless motion control system may be of particular use as it may avoid cross contamination and possible damage to the apparatus by the raw materials or vice versa.

SUMMARY

[0005] A contactless motion control system may withstand industrial conditions and not to impede operation of the industrial equipment. It will be appreciated therefore that there is a need for an effective contactless motion control system which may be applied in industrial environments. The present disclosure addresses this need.

[0006] In one aspect of the disclosure, a feed-line management system is presented for controlling a flow-rate of at least one material. The system comprises at least one feed driver operable to control the motion of a feed-line comprising the material; at least one optical speed monitor operable to monitor the speed of the feed-line and to output data pertaining to the flow-rate; and at least one controller operable to receive the output data, and to send operating commands to the feed driver. It is noted that the operating commands may be selected in response to statistical analysis of the output data.

[0007] Where appropriate, the optical speed monitor may comprise at least one optical source configured to illuminate a section of the feed-line; at least one optical detector oper-

able to image a series of overlapping frames of the feed-line; and at least one image processor. The image processor may be operable to: receive the frames from the optical detector; identify at least one feature common to a first frame and a second frame; determine the spatial shift between at least one coordinate of the common feature in the first frame and the same coordinate of the common feature in the second frame; and calculate a ratio between the spatial shift and time elapsed between imaging of the at least two frames thereby determining flow-rate of the feed-line in at least one dimension.

[0008] Optionally, the optical speed monitor further comprises a focusing device configured to image microscopic texture of the material upon the optical detector.

[0009] Where appropriate, the image processor may further be operable to determine the spatial shift of the common feature in at least two dimensions.

[0010] Additionally or alternatively, the image processor may further be operable to output a NO-FEED signal when no features are detectable in the frames thereby indicating absence of any feed line.

[0011] In some systems, the at least one controller may comprise a memory configured to store the output data; a processor operable to access the memory and to perform statistical analysis on the output data; and a comparator configured to compare the output data with at least one reference value. Optionally, at least one reference value is calculated by the processor. For example, at least one reference value may be selected from a group consisting of: average speed of the feed-line, average speed plus at least one standard deviations of the speed of the feed-line, the average speed minus at least one standard deviation of the speed of the feed-line. Various, at least one reference value may comprise an upper threshold. Additionally or alternatively at least one reference value may comprise a lower threshold. Generally, the comparator is configured to compare current flow rate to at least one threshold value.

[0012] In certain systems operating commands may be selected from at least one of a group consisting of: a STOP command, a SPEED-DOWN command, a SPEED-UP command and a SET-SPEED command. Accordingly, the feed driver may be operable to: stop the feed-line when a STOP command is received; reduce the flow-rate when a SPEED-DOWN command is received; increase the flow-rate when a SPEED-UP command is received; and set the flow-rate to a defined value when a SET-SPEED command is received.

[0013] The management system of claim 1 configured to control a plurality of feed-lines, the system further comprising at least one central control unit configured to receive output data from a plurality of optical speed monitors and to send operating commands to a plurality of feed drivers.

[0014] In a particular example the management system is configured to monitor a feed-line comprising a yarn.

[0015] Another aspect of the disclosure is to teach a method for controlling flow-rate of at least one material, the method comprising: directing an optical speed monitor towards at least one feed-line; driving the feed-line; monitoring speed of the feed-line; outputting data pertaining to the flow-rate of the feed-line; performing statistical analysis upon the data; and sending operating commands to the feed-line in response to the statistical analysis.

[0016] Optionally, the step of performing statistical analysis comprises calculating an average value of monitored flow-rate.

[0017] Where appropriate the step of performing statistical analysis may comprise calculating a standard deviation value of monitored flow-rate.

[0018] In some methods, the step of sending operating commands may comprise: providing at least one reference flow-rate value; comparing current flow-rate with at least one the reference value; and selecting an operating command. Accordingly, at least one reference flow-rate value may be provided by: calculating an upper threshold value; and calculating a lower threshold value.

[0019] Various, the step of sending operating commands comprises at least one of: sending a STOP command to stop the feed-line; sending a SPEED-DOWN command to reduce the flow-rate; sending a SPEED-UP command to increase the flow-rate; and sending a SET-SPEED command to set the flow-rate to a defined value.

[0020] Accordingly, the operating commands may be selected as follows: sending a STOP command when the monitored flow-rate is below a first threshold value; sending a SPEED-DOWN command when the monitored flow-rate is above a second threshold value; sending a SPEED-UP command when the monitored flow-rate is below a third threshold value; and sending a SET-SPEED command when a used inputs a defined value.

BRIEF DESCRIPTION OF THE FIGURES

[0021] For a better understanding of the embodiments and to show how it may be carried into effect, reference will now be made, purely by way of example, to the accompanying drawings.

[0022] With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of selected embodiments only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects. In this regard, no attempt is made to show structural details in more detail than is necessary for a fundamental understanding; the description taken with the drawings making apparent to those skilled in the art how the several selected embodiments may be put into practice. In the accompanying drawings:

[0023] FIG. 1 is a block diagram representing the main elements of a feed line management system according to one embodiment of the disclosure;

[0024] FIGS. 2A and 2B show block diagrams representing the main element of possible speed monitors for use with a feed line management system;

[0025] FIG. 3A schematically represents how an optical speed monitor may be used to monitor the flow-rate of a feed line;

[0026] FIGS. 3B and 3C represent two frames captured using an optical speed monitor which share some common features;

[0027] FIG. 4 represents a system for the centralized management of multiple feed lines;

[0028] FIG. 5 is a flowchart showing the main stages of a possible method for managing a feed line; and

[0029] FIG. 6 is another flowchart showing a method for controlling the flow-rate of a feed line using a speed monitor.

DETAILED DESCRIPTION

[0030] Reference is now made to the block diagram of FIG. 1 representing the main elements of an example of a feed line management system 100 of the disclosure. The feed-line management system 100 is configured and operable to monitor and control the flow rate of a material.

[0031] The management system 100 may be used to manage the flow rate of feed-lines 200, for example, in industrial manufacturing plants such as feed yarns in looms, raw materials upon conveyor belts, paper being fed into printers or the like.

[0032] The system 100 includes a speed monitor 120, a controller 140 and a feed drive 160. The feed driver 160 may be operable to control the motion of the feed line 200. Various, the feed driver 160 may drive the feed line 200 directly, for example by actuating a roller, pulley or the like. Alternatively, or additionally, the feed driver 160 may control the feed line 200 indirectly, for example by controlling a manufacturing mechanism being supplied by the feed line, such as a loom drawing a yarn.

[0033] The speed monitor 120 may be operable to monitor the speed of the feed-line 200 and to output data pertaining to the flow-rate to the controller 140. The controller 140 is operable to receive the output data from the speed monitor 120 and to send operating commands to the feed driver 160, thereby governing the flow rate.

[0034] It is a particular feature of the disclosure that the controller is further operable to perform statistical analysis upon the output data, such as calculating the mean flow rate, the standard deviation of the flow rate or the like. This analysis may be used to predict potential manufacturing defects resulting from feed line faults.

[0035] The controller 140 includes a memory 142, a processor 144 and a comparator 146. The memory 142 is configured to store output data from the speed monitor. Such data pertains to the flow rate and may be the feed speed, raw coordinates or spatial displacement data from which the flow rate may be calculated. The processor 144 is operable to access data from the memory and to perform statistical analysis thereupon. For example the processor 144 may be configured to calculate the average flow rate of all or some of the stored data. The statistical analysis may be used to select reference values defining a permitted range for monitored flow rate measurements. Where appropriate the average of only the latest records may be considered when calculating reference values. It will be appreciated that limiting the amount of data required for the calculation, memory space may be saved. Alternatively, the monitored flow rate values may be compared to predefined reference values stored in the memory.

[0036] The comparator 146 is configured to compare the current monitored flow rate with the defined reference values. According to the comparator output, operating commands may be selected and sent to the feed drive, thereby controlling the feed line. Various operating commands may be used, these include a STOP command, a SPEED-DOWN command, a SPEED-UP command, a SET-SPEED command or a DESNAG command such as described hereinbelow.

[0037] Referring now to the block diagrams of FIGS. 2A and 2B representing the main element of two possible examples of optical speed monitors 2120, 3120 which may be used with a feed line management system such as described herein.

[0038] In various apparatuses to detect and quantify motion of a body or bodies over small units of time, the data from an optical sensor and clock are processed directly to provide quantified motion information. With particular reference to FIG. 2A, an optical speed monitor 2120 is schematically represented including an optical source 2122, an optical detector 2124, a processor 2126 and a clock 2128.

[0039] The optical source 2122 may be directed towards a feed-line and configured to illuminate at least a section of the surface of the feed-line (not shown). The optical detector 2126 is operable to image a series of overlapping frames of the feed-line and the processor is operable to receive the image data from the optical detector 2126, to communicate with the clock 2128 to determine the time at which each frame is captured, to identify at least one feature common to a first frame and a second frame captured by the optical detector 2126, to determine the spatial shift between at least one coordinate of the common feature in the first frame and the same coordinate of the common feature in the second frame, and to calculate a ratio between the spatial shift and time elapsed between imaging of the at least two frames thereby determining flow-rate of the feed-line in at least one dimension. It is noted that where frames are captured at a known rate, it may be possible to use the regularity of the frames themselves as a clock such that the time elapsed between frames may be determined.

[0040] Where appropriate, the optical detector 2122 may comprise a matrix of light-detecting sensors, for example a 20×20 such sensors in a square grid arrangement. Such a matrix may detect light reflected from the surface of the feed line and produce an image, for example 20×20 pixels. Each pixel of the image may send a separate signal from the light detector and each set of pixel signals representing a frame may receive a timestamp from the clock 2128. The data thus communicated may be stored by the processing unit 2126. Multiple frame data may be collected in this manner.

[0041] The processing unit 2126 may then compare at least two of these sets of image data to find an overlap of the image information. The processor 2126 may then calculate the displacement of the body in at least one direction and then by using the difference between the timestamps, calculate the velocity of the body or bodies being monitored. The processing unit 2126 may be configured to store the most recent time-stamped image until the next one is available. In this way the apparatus 2120 may deliver frequent measurements of the speed of the feed line or other moving body.

[0042] Turning now to the block diagram of FIG. 2B, a schematic representation is presented of another optical speed monitor 3120 which may be able to detect and quantify motion of a body or bodies. The optical speed monitor 3120 includes a motion sensor 3125, a clock 3128, and an external processing unit 3129. The monitor 3120 may be able to determine direction and speed of a moving body or bodies over small intervals of time. It is noted that a motion sensor apparatus 3125 is used in combination with an external processor 3129 which is itself in communication with a clock 3128.

[0043] The motion sensor 3125 may include a light source 3122, a light detector 3124, and an image processing unit 3126. The light source 3122 is configured to illuminate a body or bodies of interest, and the light detector 3124 is configured to detect the returning light and produce an image. Optionally a matrix of light-detecting sensors may be provided to detect

and recorded reflected light from the body. For example a 20×20 matrix of optical sensors may be arranged in a square grid.

[0044] The image processing unit 3126 may be operable to receive pixel signals from the light detector 3124, and to process the images. Pixel-signals from the light detector 3124 may be compared to previously captured set of pixel-signals. If a first set of pixel-signals and a second set of pixel-signals image overlapping regions then the image processing unit 3126 may be used to generate a displacement vector indicating both direction of motion and magnitude of movement in that direction.

[0045] In this example, the displacement data is the output of the motion sensor 3125 which is delivered to the external processing unit 3129 which may then provide a time stamp from the external clock 3128. This displacement data, such as a motion vector, timestamp or the like, may be saved by the processor 3129. When a second set of data comes from the motion sensor 3125 and the clock 3128, the processing unit has enough information to produce a velocity value for the interval between the first and second timestamps. The velocity may be calculated as the displacement increment divided by the incremental time. In this way the apparatus 3120 may generate regular measurements of the speed of moving bodies such as feed lines.

[0046] Referring now to FIG. 3A a schematic representation is presented of a possible optical speed monitor 4120, which may be used to monitor the flow-rate of a feed line 200. The optical speed monitor 4120 may include an image acquisition system 4121 and a digital signal processor 4126. The image acquisition system 4121 may include an optical illuminator 4122 is configured to illuminate an area 220 on the surface of the feed line 200.

[0047] The optical detector 4124 may be provided with a focusing element such as a lens 4125 and may be configured to image a microscopic section 240 of the illuminated surface towards the surface 202 of the feed line 200. Optionally, the optical source may be further provided with a focusing element (NOT SHOWN) so as to illuminate only the small region around the focal section 240 imaged by the optical detector.

[0048] One such optical system may contain an image acquisition system (IAS), a digital signal processor (DSP) and a communication port (NOT SHOWN) for providing a communication channel therebetween. The IAS may acquire microscopic surface images via the lens and illumination system. These images may be processed by the DSP to determine the direction and distance of motion. The DSP may be able to identify texture or other features in the pictures and to track their motion. An example of such a system may be found, for example, in the navigation system of an optical mouse device used with computers.

[0049] Optical navigation systems have been used to monitor their own movement over a stationary extended surface. It will be appreciated that the imaging of a stationary extended surface is relatively simple. Navigation systems have not been considered suitable for imaging of small moving surfaces such as a moving feed line, which may be as narrow as a thread of yarn or even smaller. Nevertheless, it has been surprisingly found that an optical speed monitor may be effectively applied to the monitoring of the surfaces of moving objects, such as thread, yarn or any other kinds of moving objects.

[0050] It is noted that the application of an optical system to the monitoring of feed lines allows significant advances to the management of feed line motion and fulfills a long felt need in the art. In particular, by monitoring such motion it may be possible to track parameters of motion such as speed, direction and acceleration, estimate their values, perform statistical analysis thereupon and to warn whenever a parameter lies outside an expected range.

[0051] An image acquisition system **4121** may include the optical detector **4124**, the imaging lens for optical detector **4125**, the optical source **4122**, such as a Light Emitting Diode (LED), a Laser or the like and an illumination lens (NOT SHOWN). It is noted that although optical systems may operate using visible light, other frequencies of electromagnetic radiation, such as infrared, ultraviolet and the like, may alternatively be used to illuminate the feed line surface.

[0052] The controlled moving surface **202** may be illuminated by the illumination source, optionally through the illumination lens. The moving surface **202** may be located in the focus range of the IAS and is imaged sequentially. Optionally the IAS is operable to capture images at a rate of thousands of frames per second, accordingly, the optical detector **4124** may have a rapid imaging rate.

[0053] The IAS may be operable to capture a sequence of images of the feed line. Thus the IAS may image the moving surface as it moves. The images may be captured at a rate fast enough that sequential image frames overlap. For example the IAS may be configured to capture thousands frames per second or more.

[0054] The sequence of captured images may be sent to the DSP for processing. The DSP may be operable to identify key features in the images and track the motion of these features between frames. It is noted that common features may be identified in two captured images as the imaged surface moves along. By identifying common features in two frames and knowing the time elapsed between the capture of the two frames, the speed of the surface may be determined in at least two dimensions.

[0055] The digital signal processor may analyze the frames thereby generating a value for relative displacement values delta-x and delta-y. These may be converted into signals of specific format, for example, serial communication.

[0056] A microcontroller may be provided to analyze images captured by the image acquisition system, to read the x and y information, calculate speed, speed direction, average speed and speed deviation and optionally send this data to a central control unit **2003** (FIG. 4).

[0057] Reference is now made to FIGS. 3B and 3C representing two frames captured using an optical speed monitor and which share some common features. The frames represent two overlapping microscopic sections **240A**, **240B** of the surface **202** of the feed line **200**.

[0058] A key feature **242** is common to both the two frames **240A**, **240B**. The processor **4216** may be configured to identify the key feature **242** in both frames and to obtain its coordinates in each frame. If the x-coordinate in the first frame X_1 , and the y-coordinate in the first frame Y_1 , as well as the x-coordinate in the second frame X_2 , and the y-coordinate in the second frame Y_2 are all known, then the spatial shift may then be calculated. A value of the spatial shift in the X direction, delta-x may be found from the formula $\text{delta-x} = X_2 - X_1$. Similarly, a value of the spatial shift in the Y direction, delta-y may be found from the formula $\text{delta-y} = Y_2 - Y_1$.

[0059] Accordingly, if the time elapsed between the capture of the two frames is known, the velocity of motion may be calculated for the key feature and therefore for the feed-line as a whole.

[0060] Where no features are detectable in the captured frames, the image processor may be configured and operable to output a NO-FEED signal thereby indicating that no feed line is present. Such an application may be used to monitor faults in the feed line such as yarn breaks, raw material removal or the like.

[0061] In particular embodiments, a method and apparatus for non-contact thread motion recognition may measure a linear velocity of the yarn or thread, store and analyze velocity related data and cumulatively gather statistics. For example the system may record parameters such as the average velocity of a thread, the degree of deviation from the average velocity, the direction of motion and the like. The recorded parameters may be used to provide an assessment of the statistical risk of a thread breaking. Thus a predictive warning may be provided.

[0062] It is particularly noted that where a feeder yarn becomes snagged, its flow rate, or speed of delivery will typically decrease in a predictable manner. The statistical analysis of motion data performed by systems of the present disclosure may allow for such motion to be identified and thereby for the prediction of a possible future thread break event. Accordingly, a loom, tufting machine or other such textile apparatus may be stopped before the break occurs.

[0063] Referring now to FIG. 4, a system **5100** for the centralized management of multiple feed lines **2002A-D** is shown. The system includes at least one central control unit **2003** configured and operable to receive output data from a plurality of speed monitors **2001A-D** and to send operating commands to a plurality of feed drivers (NOT SHOWN).

[0064] A set of the motion sensor apparatuses **2001A-D**, may be installed, each separately monitoring its own feed line, **2002A-D**. The system **5100** may provide updated motion data to a central processing unit **2003**. In an application in the textile industry, the moving bodies **2002A-D** might be thread or yarn going into a loom, and in various permutations of the system, the different yarns might be expected to all move at the same speed, or all move at differing speeds, depending on the specific application. The velocity data from each motion sensing apparatus is fed into a central processing unit **2003** where a variety of processing can be carried out.

[0065] For example, in a system such as a loom multiple feed lines **2002A** may deliver multiple yarns. Feedback information may be provided to a central control unit **2003** which is based upon the analysis of the continually changing motion information gathered by each detector. This data may be used to control the feed lines to ensure uniformity of yarn delivery and thereby to avoid faults and defects in the finished products.

[0066] It may be possible to keep track of the mean velocity of each thread in the system. The mean velocity data may be updated as new data are introduced. Optionally, in order to keep the system response time low, older data may be discarded from the mean calculation. Thus as the system is running, if a motion sensor shows a specific body changing velocity in an exceptional way, this irregularity could indicate an increased risk that a fault may occur.

[0067] In one application, when the velocity deviates by more than two standard deviations or so from the mean updated value, this may indicate that the thread may have

become snagged and that tension may be building to break the thread. In such a case the central processing unit **2003** may be configured and operable to initiate specific action in response to the change. Actions may include, for example, sending an alert to a human supervisor, automatically shutting down the loom, initiating specifically defined unsnagging procedure specific to particular conditions.

[0068] Another possible use for the apparatus might be in a factory handling various conveyor lines of raw materials being directed towards a processing area. It will be appreciated that some raw materials may be corrosive, volatile, fragile or susceptible to contamination, such that a contact-based detection system may be inappropriate to be used. In such cases, the motion sensors may be focused on conveyor lines and may detect the quantities of raw material passing down each feed line. Incorrect amounts or ratios of raw materials entering the processing area may be undesirable or even hazardous, and so the central processing unit **2003** may be designed to take a variety of emergency steps in the event of inappropriate feed speed

[0069] Various methods may be used in order to manage the flow-rate of a material delivered along a feed line. Generally, a speed monitor, such as an optical speed monitor or the like, may be provided to monitor the flow of material along a feed-line. Accordingly, the feed line may be driven and the speed or flow rate of the feed line may be monitored. Data pertaining to the flow rate may be output from the speed monitor to a processor or the like such that statistical analysis may be performed thereupon. Based upon such statistical analysis, operating commands may be selected which may be used to control the motion of the feed-line.

[0070] Various statistical analysis may be performed, for example the mean or other average value as well as the standard deviation of monitored flow-rate may be calculated, possibly in real time. These values may be used to define a permitted range of values for the monitored flow rate, for example by providing upper and lower reference values or flow rate.

[0071] The permitted range may be set to be in keeping with the accepted tolerance for the particular application. In one example, the maximum flow rate may be calculated as the mean plus one standard deviation, alternatively the maximum may be calculated to be mean plus two standard deviations. Similarly, the minimum flow rate may be calculated as the mean minus one standard deviation, alternatively the minimum may be calculated to be mean minus two standard deviations. It will be appreciated that still other tolerances may be used as required.

[0072] Optionally multiple thresholds may be set at which different actions may be taken. For example an alert or warning may be provided at when monitored flow rate exceeds a first threshold, and the system may shut down if the monitored flow rate exceeds a second threshold. Other examples will occur to those skilled in the art.

[0073] Once reference flow-rate values are defined, the current monitored flow-rate may be compared to the reference values and operating commands may be selected accordingly.

[0074] Referring now to the flowchart of FIG. **5**, the main stages are presented of a possible method for managing a feed line. Once the system is powered up, the timers are set up **502**. At least two images are collected and the X and Y coordinates thereof are sampled **504**. The speed in the X and Y directions are then be established **506**. Optionally an initialization procedure may be established during which the first N monitored

values are gathered. Accordingly the system may check if N values have been recorded **508**. If N values have not yet been recorded then more samples may be taken until N values are collected.

[0075] Once the required minimal number N of samples is collected the average speed for the previous N records may be calculated **510**. A permitted range may then be defined based upon this average **512**. The currently monitored flow-rate value is compared to the permitted range **514**. If the monitored flow-rate lies inside the permitted range **514**, then more samples are taken and the procedure continues.

[0076] If the value is outside the range then an alarm may sounded or other alert may be provided **516**. Optionally, operating commands may also be sent to the feed drive to control the flow rate **518** more samples may be taken and the procedure may continue.

[0077] Referring now to the flowchart of FIG. **6**, another method is shown for controlling the flow-rate of a feed line using a speed monitor in which various command signals may be sent to the feed drive to control flow rate.

[0078] The flow rate is monitored **602**, for example using the system described above, and the current flow rate is recorded **604**. The average flow rate may be calculated **606** as well as the standard deviation **608**. Using the statistical values describing the distribution of the flow rate, multiple reference values may be set **610**. The current flow rate **612** may be compared to the reference values.

[0079] If the flow rate is found to be below a first reference value **614** a STOP command may be sent **616** such that the feed drive ceases operation. This may be useful, for example when a yarn becomes snagged in a tufting machine or a loom, as the slowing of a yarn may initiate a shutdown procedure such that the machine is stopped before the yarn breaks.

[0080] If the flow rate is found to be above a second reference value **618** a SPEED-DOWN command may be sent **620** such that the feed drive slows the feed line **622**.

[0081] If the flow rate is found to be below a third reference value **624** a SPEED-UP command may be sent **626** such that the feed drive increases the flow rate of the feed line **628**.

[0082] Other operational commands which may be sent to the feed drive include a SET-SPEED signal to set the flow rate to a predefined value; a DESNAG signal to initiate a desnagging procedure to release a yarn; or other such commands. Still further operational commands may be utilized as required and will occur to those in the art.

[0083] The scope of the disclosed subject matter is defined by the appended claims and includes both combinations and sub combinations of the various features described hereinabove as well as variations and modifications thereof, which would occur to persons skilled in the art upon reading the foregoing description.

[0084] In the claims, the word “comprise”, and variations thereof such as “comprises”, “comprising” and the like indicate that the components listed are included, but not generally to the exclusion of other components.

1. A feed-line management system for controlling a flow-rate of at least one material, the system comprising:

- at least one feed driver operable to control the motion of a feed-line comprising said material;
- at least one optical speed monitor operable to monitor the speed of said feed-line and to output data pertaining to said flow-rate; and
- at least one controller operable to receive said output data, and to send operating commands to said feed driver;

wherein said operating commands are selected in response to statistical analysis of said output data.

2. The management system of claim 1 wherein said optical speed monitor comprises:

- at least one optical source configured to illuminate a section of said feed-line;
- at least one optical detector operable to image a series of overlapping frames of said feed-line; and
- at least one image processor operable to:
 - receive said frames from said optical detector;
 - identify at least one feature common to a first frame and a second frame;
 - determine the spatial shift between at least one coordinate of the common feature in the first frame and the same coordinate of the common feature in the second frame; and
 - calculate a ratio between said spatial shift and time elapsed between imaging of said at least two frames thereby determining flow-rate of said feed-line in at least one dimension.

3. The management system of claim 1 wherein said at least one controller comprises:

- a memory configured to store said output data;
- a processor operable to access said memory and to perform statistical analysis on said output data; and
- a comparator configured to compare said output data with at least one reference value.

4. The management system of claim 3 wherein said at least one reference value is calculated by said processor.

5. The management system of claim 3 wherein at least one reference value is selected from a group consisting of: average speed of said feed-line, average speed plus at least one standard deviations of the speed of said feed-line, the average speed minus at least one standard deviation of the speed of said feed-line.

6. The management system of claim 3 wherein at least one reference value comprises an upper threshold.

7. The management system of claim 3 wherein at least one reference value comprises a lower threshold.

8. The management system of claim 3 wherein said comparator is configured to compare current flow rate to at least one threshold value.

9. The management system of claim 1 wherein said operating commands are selected from at least one of a group consisting of: a STOP command, a SPEED-DOWN command, a SPEED-UP command and a SET-SPEED command.

10. The management system of claim 1 wherein said feed driver is operable to:

- stop said feed-line when a STOP command is received;
- reduce the flow-rate when a SPEED-DOWN command is received;
- increase the flow-rate when a SPEED-UP command is received; and
- set the flow-rate to a defined value when a SET-SPEED command is received.

11. The management system of claim 2 wherein said optical speed monitor further comprises a focusing device configured to image microscopic texture of said material upon said optical detector.

12. The management system of claim 2 wherein said image processor is further operable to determine the spatial shift of said common feature in at least two dimensions.

13. The management system of claim 2 wherein said image processor is further operable to output a NO-FEED signal when no features are detectable is said frames thereby indicating absence of any feed line.

14. The management system of claim 1 configured to control a plurality of feed-lines, said system further comprising at least one central control unit configured to receive output data from a plurality of optical speed monitors and to send operating commands to a plurality of feed drivers.

15. The management system of claim 1 wherein said feed-line comprises a yarn.

16. A method for controlling flow-rate of at least one material, the method comprising:

- directing an optical speed monitor towards at least one feed-line;
- driving said feed-line;
- monitoring speed of said feed-line;
- outputting data pertaining to the flow-rate of said feed-line;
- performing statistical analysis upon said data; and
- sending operating commands to said feed-line in response to said statistical analysis.

17. The method of claim 16 wherein the step of performing statistical analysis comprises calculating an average value of monitored flow-rate.

18. The method of claim 16 wherein the step of performing statistical analysis comprises calculating a standard deviation value of monitored flow-rate.

19. The method of claim 16 wherein the step of sending operating commands comprises:

- providing at least one reference flow-rate value;
- comparing current flow-rate with at least one said reference value; and
- selecting an operating command.

20. The method of claim 19 wherein the step of providing at least one reference flow-rate value comprises at least one of:

- calculating an upper threshold value; and
- calculating a lower threshold value.

21. The method of claim 16 wherein the step of sending operating commands comprises at least one of:

- sending a STOP command to stop the feed-line;
- sending a SPEED-DOWN command to reduce the flow-rate;
- sending a SPEED-UP command to increase the flow-rate; and
- sending a SET-SPEED command to set the flow-rate to a defined value.

22. The method of claim 16 wherein the step of sending operating commands comprises at least one of:

- sending a STOP command when the monitored flow-rate is below a first threshold value;
- sending a SPEED-DOWN command when the monitored flow-rate is above a second threshold value;
- sending a SPEED-UP command when the monitored flow-rate is below a third threshold value; and
- sending a SET-SPEED command when a used inputs a defined value.

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