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SYSTEMS AND METHODS FOR PROVIDING ANALYTICS REGARDING A PLURALITY OF OBJECT PROCESSING SYSTEMS

Abstract

An analytics system is disclosed for providing real time analytical data regarding operational characteristics of a plurality of object processing systems that process objects. The analytics system includes a communication system for accessing the warehouse management system and for obtaining object specific data, a data collection system for receiving real time data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems, an integration system for integrating the real time data with the object assignment data, and a graphic display system for displaying the real time data as associated with the assignment data.

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Background/Summary

PRIORITY [0001] The present application is a continuation of U.S. patent application Ser. No. 17/513,091, filed Oct. 28, 2021, which claims priority to U.S. Provisional Patent Application No. 63/107,324 filed Oct. 29, 2020, the disclosures of which are incorporated by reference in their entireties.

BACKGROUND
[0002] The invention generally relates to object processing systems, and relates in particular to object processing systems such as automated storage and retrieval systems, distribution center systems, and sortation systems that are used for processing a variety of objects.
[0003] Automated storage and retrieval systems (AS/RS), for example, generally include computer controlled systems for automatically storing (placing) and retrieving items from defined storage locations. Traditional AS/RS typically employ totes (or bins), which are the smallest unit of load for the system. In these systems, the totes are brought to people who pick individual items out of the totes. When a person has picked the required number of items out of the tote, the tote is then re-inducted back into the AS/RS.
[0004] In these traditional systems, the totes are brought to a person, and the person may either remove an item from the tote or add an item to the tote. The tote is then returned to the storage location. Such systems, for example, may be used in libraries and warehouse storage facilities. The AS/RS involves no processing of the items in the tote, as a person processes the objects when the tote is brought to the person. This separation of jobs allows any automated transport system to do what it is good at—moving totes—and the person to do what the person is better at—picking items out of cluttered totes. It also means the person may stand in one place while the transport system brings the person totes, which increases the rate at which the person can pick goods.
[0005] There are limits however, on such conventional object processing systems in terms of the time and resources required to move totes toward and then away from each person, as well as how quickly a person can process totes in this fashion in applications where each person may be required to process a large number of totes. There remains a need therefore, for an object processing system that stores and retrieves objects more efficiently and cost effectively, yet also assists in the processing of a wide variety of objects.
SUMMARY
[0006] In accordance with an aspect, the invention provides an analytics system for providing real time analytical data regarding operational characteristics of a plurality of object processing systems that process objects in accordance with a warehouse management system. The analytics system includes a communication system for accessing the warehouse management system and for obtaining object specific data, a data collection system for receiving real time data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems, an integration system for integrating the real time data with the object assignment data, and a graphic display system for displaying the

real time data as associated with the assignment data.
[0007] In accordance with another aspect, the invention provides an analytics system for providing real time analytical data regarding operational characteristics of a plurality of object processing systems connected by at last one conveyor that process objects in accordance with a warehouse management system. The analytics system includes a data collection system for receiving real time data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems, an aggregation system for aggregating and storing aggregated data over a period of time regarding processing at each of the plurality of object processing systems, an integration system for integrating the real time data with the aggregated data, and a conveyor controller for adjusting a speed of the at least one conveyor responsive to the aggregated data.
[0008] In accordance with a further aspect, the invention provides an analytics system for providing real time analytical data regarding operational characteristics of a plurality of object processing systems that process objects in accordance with a warehouse management system using programmable motion devices. The analytics system includes a video data collection system for receiving video data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems, a video tagging system for associating portions of the video data with each of the plurality of objects being processed at each of the plurality of object processing systems, and providing object specific video data, an integration system for integrating the object specific video data with the warehouse management system, and a programmable motion device controller for controlling the operation of at least one of the programmable motion devices responsive to the aggregated data.
[0009] In accordance with a further aspect, the invention provides a method of providing real time analytical data regarding operational characteristics of a plurality of object processing systems connected by at least one conveyor that process objects in accordance with a warehouse management system. The method includes accessing the warehouse management system and for obtaining object specific data, receiving real time data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems, integrating the real time data with the object assignment data, and controlling a speed of the at least one conveyor responsive to the assignment data.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0010] The following description may be further understood with reference to the accompanying drawings in which:
[0011] FIG. **1** shows an illustrative diagrammatic view of an object processing system for use in an analytics system in accordance with an aspect of the present invention;
[0012] FIGS. **2**A-**2**C show illustrative diagrammatic views of a view of a bin in accordance with an aspect of the present invention, showing a camera view (FIG. **2**A), a volumetric scan of the bin (FIG. **2**B), and a 3-D scan using edge detection (FIG. **2**C);
[0013] FIG. **3** shows an illustrative diagrammatic view of a plurality of object processing systems for use in an analytics system in accordance with an aspect of the present invention;
[0014] FIG. **4** shows a dashboard of metrics regarding a plurality of object processing systems for use in an analytics system in accordance with an aspect of the present invention;
[0015] FIG. **5** shows a functional diagram of an analytics system in accordance with an aspect of

the present invention;
[0016] FIGS. **6**A and **6**B show illustrative diagrammatic views of complex processing systems in accordance with an aspect of the present invention, showing operation stations (FIG. **6**A), and showing areas of concern among the operational stations (FIG. **6**B);
[0017] FIGS. **7**A and **7**B show illustrative diagrammatic operational flow diagrams in connection with the analytics system in accordance with an aspect of the present invention;
[0018] FIG. **8** shows a relational data collection diagram used in an analytics system in accordance with an aspect of the present invention; and
[0019] FIG. **9** shows an illustrative diagrammatic view of an analytics system with a plurality of object processing stations in accordance with an aspect of the present invention.
[0020] The drawings are shown for illustrative purposes only.
DETAILED DESCRIPTION
[0021] In accordance with various aspects, the invention provides an analytics system for providing real time analytical data regarding operational characteristics of a plurality of object processing systems that process objects in accordance with a warehouse management system. The analytics system includes a communication system for accessing the warehouse management system and for obtaining object specific data; a data collection system for receiving real time data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems; an integration system for integrating the real time data with the object assignment data; and a graphic display system for displaying the real time data as associated with the assignment data.
[0022] In accordance with another aspect, the invention provides an analytics system that includes an aggregation system for aggregating and storing aggregated data over a period of time regarding processing at each of the plurality of object processing systems; an integration system for integrating the real time data with the aggregated data; and a graphic display system for displaying the real time data together with the aggregated data. In accordance with a further aspect, the analytics system includes a video data collection system for receiving video data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems, and the system further includes a video tagging system for associating portions of the video data with each of the plurality of objects being processed at each of the plurality of object processing systems, and providing object specific video data; an integration system for integrating the object specific video data with the warehouse management system; and a graphic display system for displaying the real time data together with the aggregated data.
[0023] FIG. **1** shows an object processing system **10** that includes an object processing station **14** and a site intake perception system **12**. An infeed conveyor **16** carries infeed bins **18**, and a destination conveyor **20** carries destination containers **22**. The object processing station **14** includes a programmable motion device (e.g., an articulated arm **24**) with an attached end-effector as well as an associated perception system **26**. The perception system **26** is positioned to perceive objects (and/or associated indicia) in selected infeed bins **18**′ that are diverted (selected) by bi-directional conveyors **30** to move onto a selected infeed conveyor section **16**′. The perception system **26** is positioned as well to perceive destination containers **22**′ that are provided on a processing destination conveyor section **22**′ of the destination conveyor **22**, via one or more diverters that selectively divert selected destination containers **22**′ onto the processing destination conveyor section **20**′. Operation of the system is controlled by one or more computer processing systems **100** that communicate with the conveyors and the programmable motion devices disclosed herein (including the end-effector) as well as the perception systems.
[0024] The object processing station **14** includes an infeed conveyor section **16**′ that circulates

selected supply bins **18′** from and back to the infeed conveyor **16** using the diverter bi-directional conveyors **30**. The end-effector of the programmable motion device **24** is programmed to grasp an object from the supply bin **18′**, and move the object to deliver it to a desired destination bin **22′** on the destination conveyor load area **20′** by placing or dropping the object into a destination container **130′** on the destination conveyor **128′** at the destination conveyor load area. The supply bin **18′** may then be returned to the input conveyor **16** and, optionally, brought to a further processing station. At the processing station **14** therefore, one or more vendor supply bins **18′** are routed to an input area, and the programmable motion device **24** is actuated to grasp an object from a bin **18′**, and to place the object into a selected destination container **22′**. The processed vendor bins **18′** are then returned to the common input stream on the conveyor **16**, and the destination container **22′** is moved further along the destination conveyor **20**.

[0025] The site intake perception system **12** of the system **10** includes one or more perception units **32** located on or near the infeed conveyor **16** for identifying indicia on an exterior of each of the bins **18**, providing perception data from which the contents of the bin may be identified, and then knowing its relative position on the conveyor **16**, track its location. It is assumed, in accordance with an aspect, that the bins of objects are marked in one or more places on their exterior with a visually distinctive mark such as a barcode (e.g., providing a UPC code), QR code, or radio-frequency identification (RFID) tag or mailing label so that they may be sufficiently identified with a scanner for processing. The type of marking depends on the type of scanning system used, but may include 1D or 2D code symbologies. Multiple symbologies or labeling approaches may be employed. The types of scanners employed are assumed to be compatible with the marking approach. The marking, e.g. by barcode, RFID tag, mailing label or other means, encodes an identifying indicia (e.g., a symbol string), which is typically a string of letters and/or numbers. The symbol string uniquely associates the vendor bin with a specific set of homogenous objects. Based on the identified code on an infeed bin **18**, the system may either permit a bin **18** to continue along the infeed conveyor **16**, or may direct the selected bin **18′** onto the selected infeed conveyor **16′**.

[0026] At the object processing station **14**, the perception system **26** assists (using the central control system **100**—e.g., one or more computer processing systems) and the programmable motion device **24** including the end-effector, in locating and grasping an object in the infeed bin **18′**. In accordance with further aspects, each object may also be marked with a visually distinctive mark, again such as a barcode (e.g., providing a UPC code), QR code, or radio-frequency identification (RFID) tag or mailing label so that they may be sufficiently identified with a scanner for processing. The type of marking depends on the type of scanning system used, but may include 1D or 2D code symbologies. Again, multiple symbologies or labeling approaches may be employed on each object.

[0027] The site intake perception system **12** further includes a top perception unit **40** as well as a plurality of perception units **42**, **44**, **46**, **48** that are directed downward onto the one or more objects in each infeed bin **18** on the infeed conveyor **16**, as well as a weight sensing section **34** of the conveyor **16** under the perception system **12**. Further, the weight sensing section **34** may further include a vibratory device **36** for shaking the bin in order to cause objects within the bin to spread apart from one another within the bin as discussed in more detail below. The perception system is mounted above the conveyor into each bin of objects to be processed next looking down into each bin **18**. The perception units, for example, may include, a camera, a depth sensor and lights. A combination of 2D and 3D (depth) data is acquired. The depth sensor may provide depth information that may be used together with the camera image data to determine depth information regarding the various objects in view. The lights may be used to remove shadows and to facilitate the identification of edges of objects, and may be all on during use, or may be illuminated in accordance with a desired sequence to assist in object identification. The system uses this imagery and a variety of algorithms to generate a set of candidate grasp locations for the objects in the bin as discussed in more detail below.

[0028] FIG. **2**A shows a view of a bin **18** from the perception system **12**, which includes perception units **42**, **44**, **46** and **48**. The image view of FIG. **2**A shows the bin **18** (e.g., on the conveyor **16**), and the bin **18** contains objects **50**, **52**, **54**, **56**, **58**. While in certain systems, the objects in each infeed bin may be non-homogenous (multiple SKUs), in other systems, such as shown in FIG. **2**A, the objects may be homogenous (single SKU). The system will identify candidate grasp locations on one or more objects, and may not try to yet identify a grasp location for the object that is partially obscured by other objects. Candidate grasp locations may be indicated using a 3D model of the robot end effector placed in the location where the actual end effector would go to use as a grasp location. Grasp locations may be considered good, for example, if they are close to the center of mass of the object to provide greater stability during grasp and transport, and/or if they avoid places on an object such as caps, seams etc. where a good vacuum seal might not be available. The system may further include a plurality of cameras **11**, **13**, **15**, **17** at the processing station **14** for monitoring the operation of the processing station. In particular, the cameras may be used with the computer processing system (e.g., including the one or more processors **100**) to watch the programmable motion device **24** as it selects, grasps, moves and deposits each object.
[0029] The perception system **12** additionally includes among the perception units **42-48**, scanning and receiving units as well as edge detection units for capturing a variety of characteristics of a selected object of the whole bin. Again, FIG. **2**A shows a view from the capture system, which in accordance with an embodiment, may include a set of similar or dissimilar objects **50**, **52**, **54**, **56**, **58**. The difference in volume, if any, as scanned is shown in FIG. **2**B and compared with recorded data regarding the item that is identified by the identifying indicia as provided by the detection system of the SKU induction system or the recorded object data. In particular, the scanned volume is compared with a volume of the identified SKU multiplied by the number of objects known to be in the bin.
[0030] In accordance with further aspects, the scanning and receiving units may also be employed to determine a density of the collection of objects in the bin, which is compared with a known density of the identified SKU multiplied by the known number of objects in the bin from knowing the object's mass and volume. The volumetric data may be obtained for example, using any of light detection and ranging (LIDAR) scanners, pulsed time of flight cameras, continuous wave time of flight cameras, structured light cameras, or passive stereo cameras.
[0031] In accordance with further aspects, the system may additionally employ edge detection sensors that are employed (again together with the processing system **100**), to detect edges of any objects in a bin, for example using data regarding any of intensity, shadow detection, or echo detection etc., and may be employed for example, to determine any of size, shape and/or contours as shown in FIG. **2**C to aid in confirming a number of objects in the bin. In certain aspects, the system may identify a specific object in the bin and confirm its shape and size through such edge detection. The above system therefore, may be used to confirm a number of objects in a bin, and in certain aspects, to originally estimate a number of (single SKU) objects in a bin, and/or confirm the recorded data for any particular SKU.
[0032] The perception units **62**, **64**, **66**, **68** may also be employed to monitor activity at the object processing station **14**. Such perception units (and associated processing) permits the system to monitor a wide variety of activity at the processing station **14**, as well as infeed supply and output bin flow. Again, the operations of the system described above are coordinated with a central control system **100** that again communicates (e.g., wirelessly) with the articulated arm **24**, the perception systems **32**, **42-48**, **62-68**, as well as in-feed conveyors **16**, **16′**, bi-directional conveyors **30**, destination conveyors **20**, **20′** and any diverters. This system determines from symbol strings the UPC associated with a vendor bin, as well as the outbound destination for each object. The central control system **100** is comprised of one or more workstations or central processing units (CPUs). For example, the correspondence between UPCs or mailing labels, and outbound destinations is maintained by a central control system in a database called a manifest. The central control system

maintains the manifest by communicating with a warehouse management system (WMS). The manifest provides the outbound destination for each in-bound object.

[0033] In accordance with another aspect therefore, the invention provides an analytics system for providing real time analytical data regarding operational characteristics of a plurality of object processing systems that process objects in accordance with a warehouse management system. The analytics system includes a data collection system for receiving real time data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems; an aggregation system for aggregating and storing aggregated data over a period of time regarding processing at each of the plurality of object processing systems; an integration system for integrating the real time data with the aggregated data; and a graphic display system for displaying the real time data together with the aggregated data.

[0034] In accordance with further aspects therefore, the invention provides an analytics system for providing real time analytical data regarding operational characteristics of a plurality of object processing systems that process objects in accordance with a warehouse management system. The analytics system includes a video data collection system for receiving video data regarding processing at each of the plurality of object processing systems, each of the plurality of object processing systems including a programmable motion device that is programmed to process objects independent of other of the plurality of processing systems; a video tagging system for associating portions of the video data with each of the plurality of objects being processed at each of the plurality of object processing systems, and providing object specific video data; an integration system for integrating the object specific video data with the warehouse management system; and a graphic display system for displaying the real time data together with the aggregated data.

[0035] FIG. **3** shows at **110** a system that includes a plurality of object processing systems **112**, **116**, **117**, **118**, **119** as discussed above with reference to system **14** of FIG. **1**, and any one or two or more (e.g., all) such processing systems may include an associated site intake perception system **114**, **115** as also discussed above with reference to the site intake perception system **12** discussed above with reference to FIG. **1**. Each site intake perception system **114**, **115** may provide checks on the totes as they pass through each system **112**, **116**, not only visually and volumetrically checking the contents, but also providing information regarding the weight of the contents of the tote as well as redistributing objects within the tote to facilitate later grasping by a robot. Each object processing system **112**, **116**, **117**, **118**, **119** is in communication with a common in-feed conveyor **94** on which infeed totes **92** are provided, as well as a common output conveyor **98** on which output containers **96** are provided.

[0036] The system may, for example, provide collective data, graphical data and video data regarding the processing of objects at a plurality of object processing stations, including providing data regarding individual processing stations as well as collected data regarding the processing of objects at a plurality of processing stations. For example, FIG. **4** shows at **60** a collective dashboard of a variety of current and collected metrics regarding the processing of multiple programmable motion devices at a plurality of facilities. As shown at the frame of **62** for example, the system may show the sizes of chosen vacuum cups (S-small, M-medium and L-large) averaged over time by any of single processing station, multiple processing stations at a facility or averaged over multiple processing stations. As shown at the dashboard frame of **64**, the system may show current vacuum pressures at a plurality of programmable motion devices as shown at **63** and **65**. The system may, for example, show real time values of the vacuum pressure at each of a plurality of programmable motion devices, and may permit an analyst to select a particular programmable motion device for viewing, or may automatically show each of the programmable motion devices in succession at a facility or at a plurality of facilities.

[0037] With reference to the dashboard frame at **66**, the analytics system may show active data regarding shuttle picks per hour **67** at each of a plurality of programmable motion devices, or picks per hour at each of a plurality of facilities. The dashboard may also show, e.g., at frame **68**, a plurality of sums of pick counts **69** at plurality of facilities, and may show, e.g., at frame **70**, an active live video image of a programmable motion device. The system may, for example, show real time video data of a plurality of programmable motion devices, and may permit an analyst to select a particular programmable motion device for viewing, or may automatically show each of the programmable motion devices in succession at a facility or at a plurality of facilities.

[0038] The analytics system may also monitor the activity of each programmable motion device by assessing the accuracy of placement of the vacuum gripper on objects (for example using the cameras **11**, **13**, **15**, **17**). The monitoring may be collected over time and displayed as averaged over a time period such as each hour, which may even out any variations due to grasp programming that intentionally seeks non-central locations on objects for grasping. For example, if certain objects are chosen for grasping at specific non-central locations (not central to an exposed viewing surface), the averaging over time, even accounting for different orientations of objects presented to the processing system **12**, should balance. A graphical display **73** as shown in the dashboard frame **72** may provide visual data regarding averages of grasps that are not central (represented as the central cross).

[0039] In accordance with further aspects, the dashboard may include a frame **74** that includes data regarding termination error codes presented at each of a plurality of programmable motion devices, for example, showing termination error codes in bar graph format **80**, **82**, **84**, **86** for each of four programmable motion devices. In accordance with a further aspect, each graph format **80**, **82**, **84**, **86** may be compiled as an average of termination error codes over time for each of a plurality of multi-processing facilities. With reference to the dashboard frame **76**, the system may provide real time visual images of entire facilities (or portions thereof), so that an analyst may view each of a plurality of facilities serially over time, again, either by selection, or on a rotating timed bases (e.g., changing the view every 15 seconds). In accordance with further aspects, the dashboard may include a wide variety of further real time and collected (e.g., averaged) data regarding shuttles (sections of processing system facilities), including the number of successful transfers (e.g., all shuttles), successful transfer per shuttle, average picks per tote, multi-pick outcomes (all shuttles), drops into pick (fast number and slow number), cumulative quantity transferred, per shuttle PPM, pick state grasp success counts, put-backs per shuttle, auto-swap counts, robot recoveries, transfer outcomes, non-item picks and non-item transfers.

[0040] In accordance with various aspects, analytical systems may further provide proactive alerting and anomaly detection, which involves the use of early real time analytical data. In an aspect, a system enables proactive alerting for undesired, or anomalous data emitted by the processing system. Examples of this include observed overall system performance degradation, non-standard gripper sensor data falling outside ‘normal’ expectations, and item (SKU) attribute or package changes not reported to the system via warehouse management system.

[0041] In accordance with further aspects, analytical systems may provide starvation or blockage inference, using systems that operate in close, often serial operation, with non-standard or unknown equipment. As a result, the solutions can be affected by starvation, which is the inability to get the necessary inputs to our system, e.g. totes with product. Additionally, this can also happen down-stream to the systems (described as a blockage), which is not allowing for the solutions/systems to generate the expected output in a non-blocked fashion. Both of these can have performance impacts not only on the processing system, but the facility as a whole. Through the analytics data being described here, metrics are provided for quantifying these starvation and blockage events. This can be used to inform customers of bottlenecks, issues, workflow shortcomings in their operation 2D & 3D image data. The object processing system data includes video data, including 2D & 3D image data.

[0042] With reference to FIG. **5**, a system **120** in accordance with an aspect of the invention may include an analytics processing system **122** that is in communication with a warehouse management system (WMS) **126** and a warehouse processing system **128** at a warehouse facility **124**. The analytics processing system **122** is also in communication with an in-feed conveyor controller **150** (that separately controls each of the in-feed conveyor speeds) as well as a destination conveyor controller **151** (that separately controls each of the destination conveyor speeds), as well as the a plurality of object processing systems **132**, **134**, **136**, **138**, each of which includes a data collection unit **142**, **144**, **146**, **148** as well as a programmable motion device **152**, **154**, **156**, **158**. The data collection units provide collective and video data to the analytics processing system **122**, which provides output dashboard interactive display information **160** to an analyst or supervisor.

[0043] In particular, and with reference initially to FIG. **6**A, a facility may include a complex processing system **200** that includes a plurality of processing shuttle sections **202**, **204**, **206**, **208**, each of which includes a plurality of programmable motion devices **224**, as well as infeed conveyors **216** and output conveyors **220**. With reference to FIG. **6**B, the analytics system of certain aspects of the invention, may monitor the system **200** to provide information regarding relative starvation of bins or boxes (as shown at **218**), blockage of bins or boxes (as shown at **226**), elevated levels of compromised grips at a programmable motion device (as shown at **210**), and elevated levels of not being able to recognize objects at a processing station (as shown at **228**). The system may also monitor rates of changes of conveyor speeds, rates of changes of programmable motion device processing rates, and rates of changes of bin completions.

[0044] The process control in a system in accordance with an aspect of the invention may, with reference to FIGS. **7**A and **7**B, involve using the above discussed perception systems (on the conveyors, at the intake perception system and at the processing stations). In particular, the perception systems are used to monitor movement (e.g., conveyor flow as shown in step **1000**) by using motion rate detection where motion detection is employed continuously over standard intervals of time, and a rate of change (motion rate) is continuously determined. Such a detection system may detect changes in motion much smaller than that which may be detected by human personnel, for example, changes of less than 5% of motion speed, and even less than 2% of motion speed. The perception systems may also monitor movement of the programmable motion devices (PMDs) using motion rate detection wherein the movement of the PMD is monitored for rates of speed changes (step **1002**), again less than 5% or even less than 2%. The directions of movement of the PMDs is not as important as the rate of any changes in speed of movement of the PMDs as they move objects between bins and boxes at the processing stations. The system may even directly focus on movement of the PMDs as they are being used to transfer objects (step **1004**) from one container (e.g., bin) to another container (e.g., shipping box) at all of the processing stations, recording instances of any transfer issues.

[0045] At each processing station (step **1006**) the system may then monitor any issues with regard to picking (step **1008**), and may use motion rate detection as discussed above to monitor an down-time (starvation) at each processing station step **1010**), as well as any backlogs (step **1012**) at each processing station. The system may also monitor any instances of items being damaged (step **1014**) as well as any issues with regard to identifying items (step **1016**).

[0046] With further reference to FIG. **7**B, the system may then enable adjustment of all overall processing at the processing stations (step **1018**). The system then conducts an iterative process, while motion rate detection monitors all flows (step **1020**), and the system reroutes bins and boxes to steer them away areas of significant congestion/blockage (step **1022**). More subtly however, the system makes small incremental changes to speeds of conveyors, both incrementally decreasing speeds of some conveyors for areas of blockages (step **1024**), areas of identification issues (step **1026**), areas of gripping issues (step **1028**), and/or incrementally increasing speeds of other conveyors at areas of starvation (step **1030**), all while monitoring by motion rate detection movement of all conveyors and PMDs. Such a system permits the conveyor speeds and the processing at processing stations to be adjusted at very minute levels during MRD monitoring to detect changes (positive and negative) in overall efficiency. Adjustments, for example, of conveyor speeds of less than 1% at different locations may have significantly beneficial results in efficiencies that could not be replicated by human personnel reacting to video monitors or other data.

[0047] With reference to the data collection diagram **300** of FIG. **8**, the analytics system may therefore, receive at a collection data unit **304** inbound (**310**), outbound (**312**), item transfer issue (**314**), robot pick issue (**316**), item damaged during transfer (**318**), unexpected container (**320**) and inventory not arrived for order (**322**) data from the object processing systems, as well as hosted data **302** from the warehouse management system, and provide analytics output to a central analysis unit **306**. The inbound data **310** may include data relating to container no-scan, container ID mismatch, container quantity mismatch, container property mismatch, container/contents damage, container unsafe to transport, container ID lookup failure, and container properties lookup issue. The outbound data **312** may include data relating to container no-scan, container property mismatch, container damage, conveyor issue/blocked, container cannot be further picked, container unsafe to transport and container has mismatched contents. The item transfer issue data may include data relating to still in inbound container, wrong part of inbound container, and insure where ended up. The robot pick issue data may include data relating to blocking container movement, and not blocking container movement. The item damages during transfer data may include data relating to still-in-inbound container, wrong-part of inbound container, and unsure where the item went. The unexpected container data may include data relating to unexpected container at outbound barcode reader, and the inventory not arrive for order data may include data relating to next inventory not available.

[0048] The analytics system may collect data from a plurality of facilities as shown at **400** in FIG. **9**, where facilities **402**, **404**, **406**, **408**, **410** and **412** all provide hosted data to aggregation servers **420** in communication with hosted visualization analytics tools system **422**. A central control system **424** may further communicate with the hosted visualization tools system **422**.

[0049] Real-time analytics options therefore include: 1) facility hosting and central reporting, 2) central hosted and facility managed dashboards, and 3) facility hosted and central curated procedures. The facility hosting and central reporting system provides facility hosted analytics with central reporting, with the facility responsible for hosting and management, creating and managing views/dashboards, and user authentication. The central reporting role involves real-time reporting (piping) of metrics.

[0050] The central hosting and facility managed dashboards involves the facility being responsible for user authentication, with central reporting role to be responsible for hosting and management, creating and managing views/dashboards, and real-time reporting (piping) of metrics. The facility hosted and central curated system provides the central role being responsible for piping metrics and curating dashboards, and creating and managing views, with the facility being responsible for hosting and management, and user authentication. In each of these systems, the dashboard views may provide key metrics & subsystem performance, starvation and statistics for how to fully utilize the BG system (and warehouse as result), and blockages and starvation.

[0051] Non-Real-time Options for reporting include central reports at some frequency, providing central hosted and managed service for data collection enabling analysis (where the facility does not have access), and where the central role creates and provides reports at some frequency to send to the facility/customer. The creating and providing of reports may be manual to some degree, and/or may be automated, and the scope of the reports may vary.

[0052] In accordance with various aspects, the reporting may involve non-metric image/video data, including for example, queryable images of products handled by the central system (returns), and queryable video of products handled by central system (returns). The reporting may also involve real-time anomaly detection, such as SKU changes involving packaging changes: graphics changes, dimensional changes, weight changes, and ganging (attaching other products together). In accordance with further aspects, the systems may provide facility insights (possibly from the WMS

system or central system), and product velocity and destinations. Further variants include metrics such as application metrics, infrastructure (CPU, memory) metrics, and maintenance metrics. Further variants may also include proactive alerting, such as central internal or direct to facility.
[0053] Various aspects of such systems may provide many benefits. The use of comprehensive data and image aggregation may provide information regarding the full range of potential questions about packages and logistics automation equipment. The use of facility or third party agnostic system provides facilitation of faster diagnosis and coordination in multi- facility or multi-vendor environments. The use of storage efficient system provides fast response time and long-term data retention supporting trend analysis. The use of such a scalable system provides a proven ability to handle volumes of very high volume logistical operations. The use of such an extensible system utilizes a robust core that facilitates the adding of new data sources and types. The use of readily customizable dashboards provides the streamlining of the process for generating new reports. The use of current IT standards permits connecting with enterprise security infrastructure, and conforming to IT security and network standards.
[0054] Facility compliance is provided, in part, by capturing label images and data, and sharing the information with each facility to ensure adherence to standards that allow automation equipment to function efficiently. Order fulfillment quality assurance is provided by capturing images of contents and packaged shipments to detect and resolve delivery issues speedily, and to uncover root causes of recurrent problems. Camera and laser tunnel health monitoring provide the capturing of data to better trigger maintenance and isolate root-causes of issues faster, which improves system uptime and facility relations. The providing of planning statistics provides workflow planner with accurate and current data on package size and label integrity. The use of ad hoc queries provides that data and images may be readily pulled for inquiries beyond those anticipated in default dashboards.
[0055] Those skilled in the art will appreciate that numerous modifications and variations may be made to the above disclosed aspects without departing from the spirit and scope of the present invention.

Claims

1.-**63**. (canceled)
64. An object processing system comprising: a programmable motion device with an attached end-effector and an associated perception system; an infeed conveyor including a portion proximal to the programmable motion device; a destination conveyor; the programmable motion device, the associated perception system the infeed conveyor, and the destination conveyor each including a plurality of operational characteristics; and an analytics system providing real time analytical data of the plurality of operational characteristics, the analytics system including: a data collection system for receiving real time data regarding processing at each of the programmable motion device, the associated perception system the infeed conveyor, and the destination conveyor; an aggregation system for aggregating and storing aggregated data over a period of time regarding processing at each of the programmable motion device, the associated perception system, the infeed conveyor, and the destination conveyor; an integration system for integrating the real time data with the aggregated data; and a graphic display system for displaying the real time data together with the aggregated data.
65. The object processing system as claimed in claim 64, wherein the real time data includes data representative of an object being grasped by the end-effector of the programmable motion device.
66. The object processing system as claimed in claim 64, wherein the real time data includes data representative of an object being moved by the infeed conveyor.
67. The object processing system as claimed in claim 64, wherein the real time data includes data representative of an object being moved by the destination conveyor.
68. The object processing system as claimed in claim 64, wherein the aggregated data includes an

average number of objects processed at one of the programmable motion device, the associated perception system the infeed conveyor, and the destination conveyor in a unit of time.
69. The object processing system as claimed in claim 64, wherein the real time data includes an assessment of an accuracy of placement of the end-effector when grasping an object.
70. The object processing system as claimed in claim 64, wherein the real time data includes a vacuum pressure at the programmable motion device.
71. An object processing system within a warehouse management system comprising: a programmable motion device with an attached end-effector and an associated perception system; an infeed conveyor including a portion proximal to the programmable motion device; a destination conveyor; the programmable motion device, the associated perception system, the infeed conveyor, and the destination conveyor each including a plurality of operational characteristics; and an analytics system providing real time data of the plurality of operational characteristics, the analytics system including: a video data collection system for receiving video data regarding processing at each of the programmable motion device, the associated perception system, the infeed conveyor, and the destination conveyor; a video tagging system for associating portions of the video data with each of the plurality of objects being processed at each of the programmable motion device, the associated perception system, the infeed conveyor, and the destination conveyor and for providing object specific video data; an integration system for integrating the object specific video data with the real time data; and a graphic display system for displaying the real time data together with the object-specific video data.
72. The object processing system as claimed in claim 71, wherein the real time data includes data representative of an object being grasped by the end-effector of the programmable motion device.
73. The object processing system as claimed in claim 71, wherein the real time data includes data representative of an object being moved by the infeed conveyor.
74. The object processing system as claimed in claim 71, wherein the real time data includes data representative of an object being moved by the destination conveyor.
75. The object processing system as claimed in claim 71, wherein the video data includes an active live video of the programmable motion device.
76. The object processing system as claimed in claim 71, wherein the real time data includes an assessment of an accuracy of placement of the end-effector when grasping an object.
77. The object processing system as claimed in claim 71, wherein the real time data includes a vacuum pressure at the programmable motion device.
78. A method of operating an object processing system, the method comprising: receiving real time data regarding processing at each of a plurality of processing stations within a warehouse management system, the plurality of processing stations including at least an infeed conveyor, a programmable motion device; and a destination conveyor, the plurality of processing stations cooperatively processing a plurality of objects; receiving video data from at least one of the plurality of processing stations; monitoring the real time data regarding the processing of objects at one or more of the plurality of processing stations; associating portions of the video data with each of the one or more of the plurality of processing stations corresponding to a selected one of the plurality of objects to provide object specific video data; and displaying the real time data regarding the processing of the selected one of the plurality of objects with the object specific video data.
79. The method as claimed in claim 78, wherein the real time data includes data representative of the selected one of the plurality of objects being grasped by the programmable motion device.
80. The method as claimed in claim 79, wherein the real time data includes data representative of an assessment of the grasp of the selected object by the programmable motion device.
81. The method as claimed in claim 78, wherein monitoring real time data further comprises identifying relative changes or anomalies in an operation of any of the plurality of processing stations, and displaying the real time data further comprises displaying the relative changes or

anomalies.
82. The method as claimed in claim 81, wherein the relative changes or anomalies relate to whether any one of the plurality of objects is identified at any one of the plurality of processing stations.
83. The method as claimed in claim 78, wherein the relative changes or anomalies relate to bottlenecks at any one of the plurality of processing stations.