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Differential Roller Speed Banding for Parcel Singulation

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Abstract

This disclosure describes an arrangement for singulating overlapping parcels on a conveyor system by employing differential roller speeds. Parcels arriving side-by-side or in an overlapped configuration, which prevents individual identification and sorting, are presented to a singulation zone. Within this zone, transport rollers are configured with a speed gradient across the conveying width. This gradient applies differential forces to overlapping parcels, causing them to rotate and separate. The system incorporates mechanisms for gap measurement, handling of excessively wide parcels, and recirculation of items that do not achieve singulation.

1. Technical Field

[0001] The technical field is automated material handling, specifically directed to the singulation of parcels on conveyor systems. This encompasses sorting, identification, and transport applications where individual items must be separated from a group to enable subsequent processing steps.

2. Technical Context

[0002] In automated parcel processing facilities, parcels are frequently introduced onto conveyor systems in a manner that results in them touching, overlapping, or traveling side-by-side. This condition, often referred to as "shingled" or "slugged" flow, presents significant challenges for downstream operations such as automatic identification (e.g., barcode scanning, optical character recognition), weighing, dimensioning, and sortation. For these systems to function accurately and efficiently, parcels must be presented individually, with a sufficient gap between them. Current methods to achieve this often involve manual intervention, which is labor-intensive, or rely on mechanical devices that can be complex, occupy substantial floor space, and may not effectively handle a wide range of parcel sizes, shapes, or weights. The problem specifically arises when parcels occupy more than one logical lane of a conveyor or overlap in their direction of travel, preventing clear separation.

3. System Overview

[0003] The system employs a singulation module (12) integrated into a conveyor line to separate parcels that arrive in an overlapped or side-by-side configuration. As illustrated in FIG. 1, parcels are initially fed from an infeed conveyor (10) into the singulation module (12). This module utilizes a series of independently driven transport rollers (22, 24, 26, 28) arranged with a speed gradient across the conveying width. This gradient applies differential forces to overlapping parcels, causing them to rotate and separate. Following singulation, parcels proceed to a gap creation module (14), which ensures a minimum spacing between items. A verification zone (16) then assesses the effectiveness of the singulation and gapping. If parcels are deemed adequately separated, they continue to downstream sortation (20). If singulation is not achieved, or if a parcel is too wide for effective singulation, it is directed to a recirculation loop (18) for another attempt, returning to the infeed conveyor (10). A control unit (40), depicted in FIG. 3, manages the operation of the various modules based on sensor inputs.

4. Components

[0004] The primary components of the system include:

[0005]

- **Infeed Conveyor (10):** A standard belt or roller conveyor system that introduces parcels into the singulation module. It is sized to deliver a continuous flow of parcels.
- **Singulation Module (12):** This module contains an array of parallel transport rollers (22, 24, 26, 28) spanning the width of the conveyor. Each roller is typically cylindrical, with a diameter that may range from 50 mm to 100 mm. The rollers are arranged with a pitch (P) between their centers, often in the range of 40 mm to 60 mm, as shown in FIG. 2. The surface of these rollers may be smooth or have a high-friction coating. Each roller, or a small group of rollers, is connected to an independent drive motor (30, 32, 34).
- **Drive Motors (30, 32, 34):** These are typically DC brushless motors or geared AC motors, providing variable speed control. They are sized to provide sufficient torque to accelerate and convey parcels up to a maximum design weight, for example, approximately 0.1 kW to 0.5 kW per motor, depending on parcel mass and desired acceleration.
- **Gap Creation Module (14):** This module typically consists of one or more independently driven conveyor belts or roller sections operating at different speeds to create or increase spacing between already separated parcels.
- **Verification Zone (16):** This zone houses a parcel sensor array (36) and a gap measurement sensor (38). The parcel sensor array (36) may comprise multiple photo-eyes or a vision system, spanning the width and length of the conveying surface. The gap measurement sensor (38) is typically a dedicated optical sensor or a laser-based distance sensor.
- **Recirculation Loop (18):** A conveyor path that diverts un-singulated parcels back to the infeed conveyor (10) for another attempt at singulation. This loop includes a divert actuator (44), which could be a pneumatically or electrically actuated arm, a pop-up wheel sorter, or a swing-arm diverter.
- **Downstream Sortation (20):** Represents the subsequent processing stages, such as scanning, weighing, and sorting, which require singulated parcels.
- **Control Unit (40):** An industrial Programmable Logic Controller (PLC) or similar embedded control system that receives input from sensors and sends commands to motor controllers (42) and divert actuators (44).
- **Motor Controllers (42):** Electronic devices that convert control signals from the control unit (40) into power to drive the individual motors (30, 32, 34) in the singulation and gap creation modules.

5. Operation

[0006] The system operates in a continuous sequence to process parcels.

[0007] **Start-up:** Upon system activation, all motors (30, 32, 34) on the infeed conveyor (10), singulation module (12), gap creation module (14), and recirculation loop (18) are brought up to their respective idle or initial operating speeds. The control unit (40) initializes all sensors (36, 38) and actuators (44).

[0008] **Steady Running:**

[0009]

- **Parcel Infeed:** Parcels are transported by the infeed conveyor (10) towards the singulation module (12).
- **Singulation:** As parcels enter the singulation module (12), their presence and approximate dimensions are detected by the parcel sensor array (36). The control unit (40) determines the appropriate speed profile for the individual transport rollers (22, 24, 26, 28) based on the observed parcel arrangement. A speed gradient is applied across the width of the singulation module (12). For example, rollers on the left side of the module might operate at a conveying speed of approximately 1.5 m/s, while rollers on the right side operate at 2.5 m/s, with intermediate rollers presenting a linear or stepped speed increase across the width. An overlapping parcel resting on rollers with different speeds experiences a differential force that causes it to rotate around its vertical axis. This rotation, combined with the forward motion, tends to separate it from adjacent or overlapping parcels. The magnitude of the speed difference between adjacent rollers, for example, 0.1 to 0.5 m/s, influences the rotational force applied. The length of the singulation module is sized to allow sufficient time for this rotation and separation to occur, for instance, a module length of 1.5 to 3.0 meters.
- **Gap Creation:** After passing through the singulation module (12), parcels enter the gap creation module (14). This module typically operates with its downstream section at a higher speed than its upstream section, creating a minimum gap between parcels, for example, 100 mm to 300 mm.
- **Verification:** Parcels then move into the verification zone (16). The gap measurement sensor (38), which might be a laser profiler or an array of photo-eyes, continuously monitors the spacing between parcels. It measures the presence and absence of material to calculate the gap length. For instance, if a parcel is detected, and then a gap of less than a design threshold (e.g., 50 mm) is detected before the next parcel, it indicates a potential failure to singulate or gap effectively. The parcel sensor array (36) also confirms that only one parcel is present across the full conveying width at any given longitudinal position.
- **Diverting and Recirculation:** If the gap measurement sensor (38) or parcel sensor array (36) indicates that singulation was not achieved (e.g., parcels are still overlapping, or the gap is below the minimum threshold), or if a parcel is detected as being excessively wide (e.g., spanning more than 80% of the maximum intended singulation width), the control unit (40) activates the divert actuator (44). This actuator directs the un-singulated parcel(s) onto the recirculation loop (18). The recirculation loop (18) then transports these parcels back to the infeed conveyor (10) for another attempt at singulation. The system is designed to handle multiple recirculation attempts.

[0010] **Fault or Interruption:** In the event of a fault (e.g., motor overload, sensor failure, or a complete stoppage due to a jam), the control unit (40) is designed to halt the affected sections of the conveyor system. An alarm signal may be generated. The system can be configured to either perform an emergency stop of all components or to initiate a controlled shutdown sequence, depending on the severity and type of fault. When a jam is detected, for instance by extended blockage of a sensor, the relevant motors reduce speed or stop to prevent further parcel accumulation.

6. Example Embodiments

[0011] **Embodiment 1** This embodiment utilizes a singulation module (12) with five distinct conveying bands across its width, each band driven by a dedicated drive motor (30, 32, 34). The innermost band operates at a base speed of 1.0 m/s, and each subsequent band outwards from the center increases its speed by 0.3 m/s relative to its inner neighbor. This creates a symmetric speed gradient from the center outwards. The singulation module (12) is 2.0 meters long. Gap measurement is performed by a single laser distance sensor (38) mounted above the conveyor in the verification zone (16), which continuously measures the distance to the conveyor surface, detecting the presence of parcels as deviations from a baseline. Parcels failing singulation are diverted by a pneumatic swing-arm actuator (44).

[0012] **Embodiment 2** In this configuration, the singulation module (12) employs individually driven rollers (22, 24, 26, 28) arranged perpendicular to the direction of travel, with a speed profile that linearly increases from 1.2 m/s on the left side to 2.4 m/s on the right side over a width of 1.0 meter. The module length is 2.5 meters. The parcel sensor array (36) in the verification zone (16) consists of 16 photo-eyes arranged in a transverse line, providing a high-resolution presence detection. A parcel is deemed singulated if all photo-eyes detect an empty gap for a duration corresponding to a minimum 150 mm physical separation. Overly wide parcels are identified if their width, as detected by the photo-eye array, exceeds 900 mm. Recirculation is managed by a pop-up wheel sorter (44) diverting parcels onto an elevated return conveyor.

[0013] **Embodiment 3** This embodiment is optimized for smaller parcels. The singulation module (12) consists of closely spaced, small-diameter rollers (22, 24, 26, 28) with a diameter of 30 mm and a pitch of 35 mm. The speed gradient is designed to be aggressive, with a 1.0 m/s difference between the slowest and fastest rollers across a 600 mm width, achieved over a module length of 1.8 meters. The gap measurement sensor (38) is a vision system, capturing images of the parcel flow and using image processing to determine parcel boundaries and gaps. This allows for detection of subtle overlaps and accurate measurement of small gaps, for example, 30 mm. Parcels that cannot be singulated after two recirculation attempts are diverted to a manual handling station.

7. Alternative Configurations

[0014] Instead of directly driving each roller or band of rollers, a single motor could drive a series of belts, with differential speeds achieved by varying pulley ratios or by using friction-clutched rollers. The speed gradient could be implemented as a stepped increase in speed, rather than a continuous linear gradient, where sections of the conveying surface operate at distinct, increasing speeds. For very delicate parcels, the surface of the singulation rollers (22, 24, 26, 28) might be covered with a softer material, such as a specialized rubber or polyurethane, to reduce the impact of differential forces. The gap creation module (14) could be omitted, relying solely on the singulation module (12) to create sufficient gaps, potentially requiring a longer singulation module or a more aggressive speed gradient. The recirculation loop (18) could include a buffer section to temporarily hold un-singulated parcels, allowing for a more controlled reintroduction to the infeed conveyor (10) rather than immediate re-entry.

8. Parameter Variations

Parameter	Range	Effect of Variation
Roller Diameter	30 mm to 100 mm	Smaller diameters allow for tighter roller pitch, potentially improving control over small parcels, but may reduce parcel contact area. Larger diameters offer more robust support for heavier parcels and can have longer operational life.
Roller Pitch (P)	35 mm to 60 mm	A smaller pitch provides more continuous support for parcels, reducing the chance of parcels dropping between rollers, which is beneficial for small or flexible items. A larger pitch reduces the number of rollers and associated drives, potentially lowering component count and cost, but may be less effective for very small or irregular parcels.
Singulation Module Length	1.5 m to 3.0 m	A longer module provides more time and distance for parcels to singulate under the influence of the differential speeds, potentially increasing singulation success rates, especially for complex overlaps or larger parcels. A shorter module reduces footprint and system cost but may require a more aggressive speed gradient to achieve effective singulation within the reduced travel distance.
Speed Gradient (Max ΔV)	0.5 m/s to 2.0 m/s	A larger maximum speed difference across the module width generates stronger rotational forces on overlapping parcels, leading to faster and potentially more effective singulation. However, excessively high gradients can cause parcels to become unstable, shift unpredictably, or even be ejected from the conveyor. A smaller gradient may be gentler but less effective for tightly overlapped or heavy parcels.
Minimum Gap Threshold	50 mm to 300 mm	A smaller minimum gap allows for higher throughput by packing parcels more densely, but may challenge downstream scanning or sorting equipment. A larger gap ensures more robust separation for downstream processes but reduces the overall throughput capacity of the line.
Recirculation Limit	1 to 3 attempts	A higher number of allowed recirculation attempts increases the probability of eventually singulating a challenging parcel, reducing the need for manual intervention. However, it also consumes system capacity and may lead to congestion in the recirculation loop if too many items are repeatedly failed. A lower limit reduces system load but increases the rate of diversion to manual handling.
Parcel Width Tolerance (Max)	70% to 95% of module width	A lower percentage for the maximum allowed parcel width ensures that even the widest acceptable parcels still have sufficient roller contact across the speed gradient to be influenced. A higher percentage allows larger parcels to pass through the singulation zone, but such parcels may be more difficult to singulate as they span a greater proportion of the available roller speeds, potentially reducing the effectiveness of the differential speed mechanism.

9. Additional Implementations

[0016] The control unit (40) can incorporate machine learning algorithms to dynamically adjust the speed gradient and module length parameters based on real-time feedback from the parcel sensor array (36) and gap measurement sensor (38). This adaptive control could optimize singulation effectiveness for varying parcel mixes and flow rates. For parcels exhibiting high coefficients of friction, the roller surface material could be selected to minimize adhesion, or a slight vibratory motion could be introduced to the rollers to aid in separation. For very heavy or rigid parcels, the roller surface could be designed with low-friction elements or a series of segmented belts, each with its own speed, to apply more precise differential forces. The system could be integrated with upstream dimensioning and weighing equipment to pre-sort parcels by size or weight before entering the singulation module (12), allowing for optimized singulation parameters to be applied to specific parcel categories. Furthermore, the divert actuator (44) could be configured to direct parcels to different recirculation loops based on the nature of the singulation failure, for example, one loop for simple overlaps and another for complex shingled arrangements requiring more aggressive processing.

10. Figures

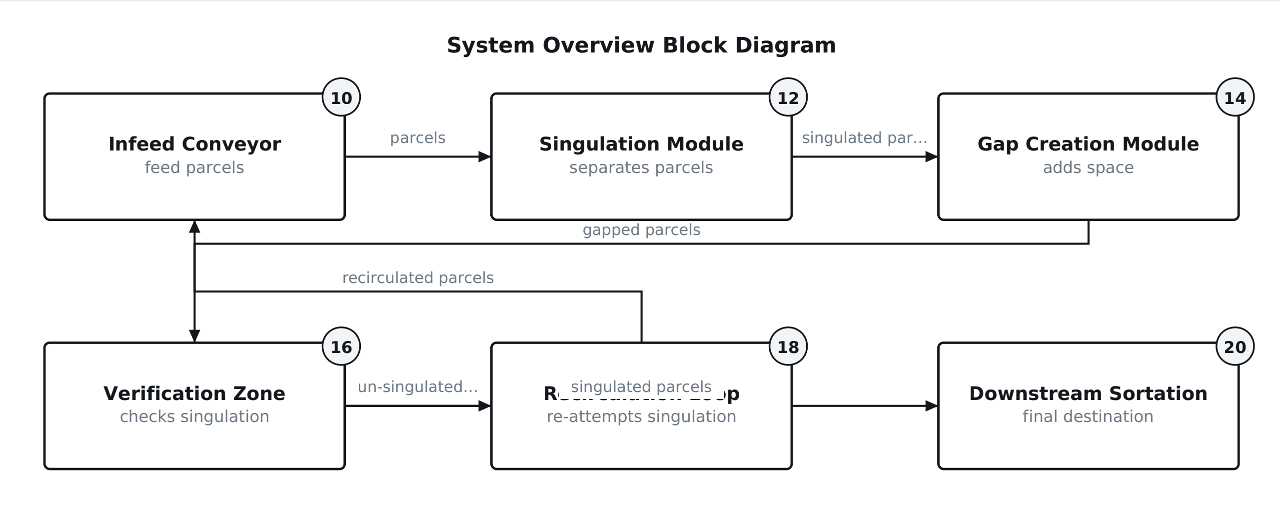

FIG. 1 A block diagram illustrating the main functional stages of the parcel singulation system. PNG

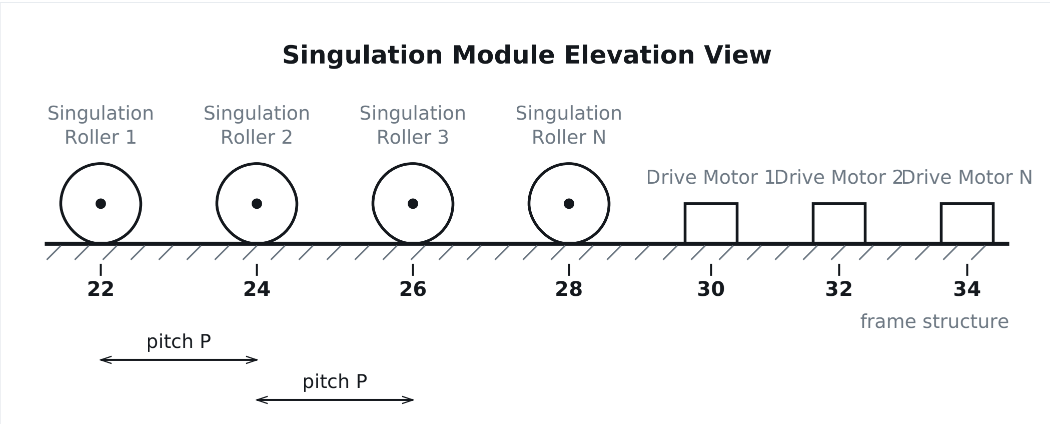

FIG. 2 An elevation view showing the arrangement of rollers within the singulation module. PNG

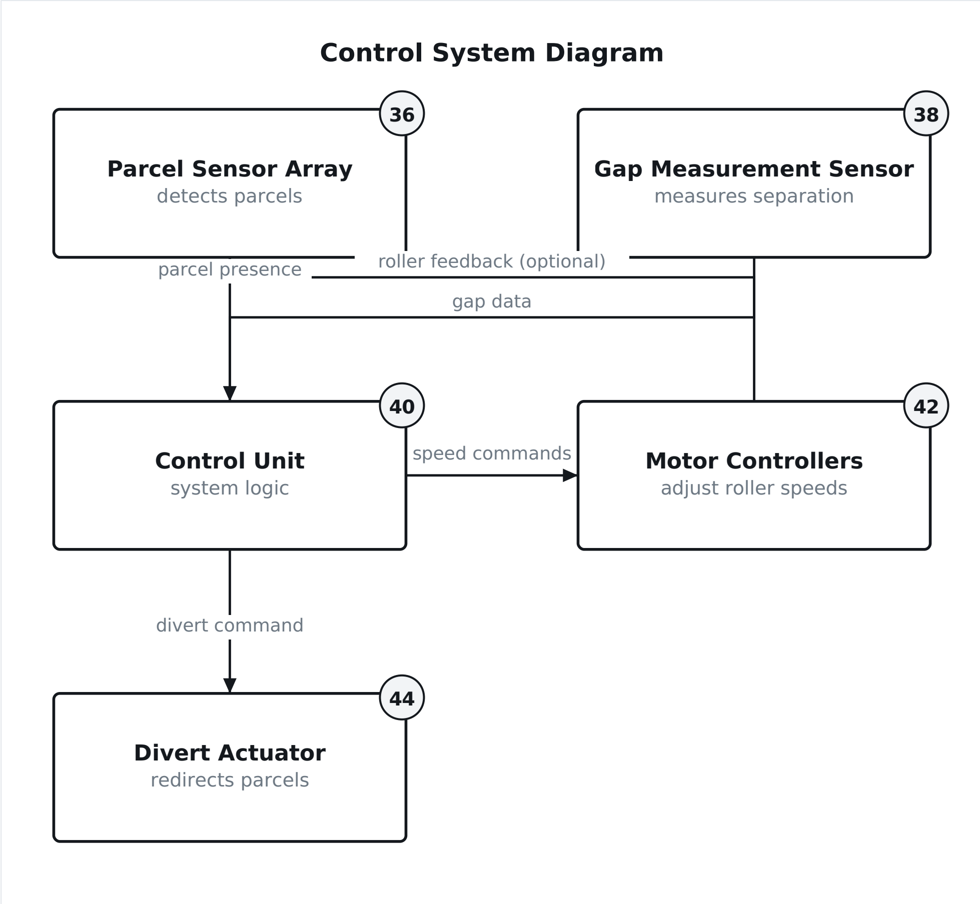

FIG. 3 A block diagram detailing the interaction between sensors, actuators, and the control unit. PNG

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