Title: A METHOD OF CONTENT AUTHENTICATION INSIDE A SEALED BOX USING SPECIAL LABELS

Abstract: This invention proposes a content verification and authentication method inside a sealed box, which transits between point-of-packaging and point-of-delivery through a logistics supply-chain on per-hop basis. This method is about tagging each item with a label containing internal layering of radio-opaque material randomly oriented. Externally all labels/tags look symmetrical and hence even if an insider replaces the original item and tags with genuine labels on fake item, still this gets detected as original reference imaging signature will have different orientation. Every-time these labels are reused they auto-acquire their imaging credential. This method also mitigates false alarm after ensuring that imaging has changed only due to horizontal movement of items inside the box and not because of rotation. Method has inherent capability to resolve count-deficiency due to pattern overlap. For accelerated direction-agnostic scanning in high volume logistics industry for box level authentication, two labels with covert pattern is highly useful. Labels with covert pattern is again based on orientation, which is not known by insiders and credential is acquired only at time of application of labels. This method can also be used as covert anti-counterfeiting mechanism by associating imaging of random covert patterns with overt feature of unique-alpha-numeric per-piece id.
Description

Title of Invention: A METHOD OF CONTENT AUTHENTICATION INSIDE A SEALED BOX USING SPECIAL LABELS

Claim of Priority:

This application claims the priority benefit of Indian Provisional Patent Application No. 625/CHE/2010, filed with the Government of India, Patent Office Chennai on March 10, 2010, and entitled 'X-ray image based item counter'.

DESCRIPTION: The following specification describes the nature of this invention:

Technical field of invention

This invention belongs to the field of content verification in terms of count and originality inside a sealed container as it transits between point-of-packaging and point-of-delivery. Today customer can track & trace their consignment but this invention enables them to monitor and verify the content at each point during transit. Direct benefit is that if item gets stolen and replaced with fake item of same shape, size and weight tagged with genuine labels, then point-of-intrusion is identified and logistics companies can investigate the matter with precise information. Thus it installs accountability at each point of transit.

Background & prior art

There are known methods to prevent item theft like RF-ID tag. While RF-ID tagging is an excellent solution for inventory management and tracking it is not a dependable technology to prevent item theft/replacement and concealed loss in supply-chain. Major limitation comes from the fact that RF-ID reader counts the RF-ID labels and not the actual item. It implies that somebody can take item out and put RF-ID labels back in box and still count will be shown correct. If the genuine RF-ID label is applied on fake item replacing original item, then there is no differentiation and checks and balances. Further if RF-ID tags do not auto-acquire their credential every time they are re-used.

Core purpose of this invention is to detect those kind of intrusions which results in concealed loss and remain un-detectable and un-traceable and only gets exposed at point-of-delivery after box is opened. This method is just not about item count but also detects if items are reshuffled or replaced with fake item of same shape, size and weight. Disclosed is an improved and stronger method of item theft/replacement detection technology that is even insider threat protected.

Summary of invention:

The following description describes methods and design of invention.

This invention proposes special-purpose labels with internal layering of radio-opaque
material aligned randomly and embedded inside. For human eye all labels look symmetrical in shape size and application. These labels are to be tagged item-wise or box-wise at a designated place. While externally all tags look similar on human visual inspection but internally they have radio-opaque layering done in random orientation. After tagging items are stacked in box in multiple layers arranged in row and column. X-ray imaging of box should show the row-wise and column-wise matrix of tagging. If any item is stolen then overlapped imaging will be different. Assuming replacement with fake item even tagged with label at designated place still orientation will be different and imaging comparison module will catch this.

In another embodiment these labels can have randomly printed patterns with invisible ink and can be scanned by special purpose camera. If invisible ink is difficult to use then these labels with black pattern can be hidden from human vision by placing them under a red and blue colour screen. This embodiment is only establishes that box has not been opened in transit channel and repackaged with genuinely looking tapes.

Niche attributes are listed below.

- Content verification at each point of transit
- 360 degree accountability and audit-ability for insiders as well
- Detection of unauthorized opening of box and reshuffling of items
- Detection of replacement of original item with fake items
- Enables content monitoring in usual track-trace for consumer satisfaction while sending valuable or sensitive consignments
- Evidences are tangible and hence legally admissible

Brief description of the drawings

The invention described herein is illustrated by way of example and not by way of limitation in the accompanying figures. For simplicity and clarity of illustration, elements illustrated in the figures are not necessarily drawn to scale. For example, the dimensions of some elements may be exaggerated relative to other elements for clarity.

Diagram 1: Diagram of tagging with internal layering of radio-opaque material.
Diagram 2: Diagram of internals of tagging showing radio-opaque layering done in random orientation but externally to human eye all tags appear symmetric.
Diagram 3: Diagram of item tagged on two different sides of the box.
Diagram 4: Diagram showing x-ray imaging of items stacked in box after they are tagged with labels having different orientation of radio-opaque layering request. (004) and (005) are X-ray images from two different sides of the box.
Diagram 5: Diagram showing x-ray imaging after one item is taken out.
Diagram 6: Diagram showing x-ray imaging after one item is replaced with fake item but tagged with similar labels.
Diagram 7: Diagram showing top face of items tagged with labels which are
symmetric in imaging with all item intact inside container.

Diagram 8: Diagram showing top face of items tagged with labels which are symmetric in imaging, wherein imaging showing inter-pattern distance changed due to one item has been taken out of container.

Diagram 9: Diagram showing side face x-ray of 5 items stacked depth-wise and each tagged with labels showing only 4 patterns at a given row and column as one pattern is hidden due to overlap.

Diagram 10: Diagram showing side face x-ray of 5 items stacked depth-wise and each tagged with labels showing all 5 patterns at a given row and column as angular x-ray exposes hidden pattern.

Diagram 11: Diagram showing two labels with invisible ink pattern wherein the one label has reference pattern and another label has actual comparison pattern and both reference line and comparison pattern are printed on label from inks. These are invisible to human eye and can only be digitally scanned by appropriate infrared camera.

Diagram 12: Diagram showing another type of two labels wherein Reference circular adhesive label has two circles printed by invisible ink. Another circle is on base tape. Angle with respect to base adhesive tape is calculated using image processing which depends on orientation of circular adhesive tape. These adhesive tapes are self-destroyable to prevent re-use.

Diagram 13: Diagram showing an embodiment of randomly oriented radio-opaque label wherein, radio-opaque material layering which is non-visible is in form of small circle randomly embedded anywhere within the larger circular radio-transparent label and depending on orientation of larger circular label unique imaging signature is auto-acquired.

Diagram 14: Diagram showing x-ray imaging of box with bundle of currency bills with 4 bundles length-wise, 5 bundles height-wise and 5 bundles depth-wise and each bundle is tagged with smart labels.

Diagram 15: Diagram showing x-ray imaging of box padded with thermocol block to ensure radio-transparent media in path of x-ray beam with two circular labels under plastic strapping such that any pilferage requires tampering with plastic strapping and that will change the orientation of labels.

Diagram 16: Diagram showing 360 degree scanning of trapezoidal shaped box, wherein scanning includes all faces and edges of box by using a image acquisition platform with two cameras.

**Detailed specification of the invention**

The following description describes methods and apparatus for x-ray imaging based technology of item loss/theft/replacement. In the following description, numerous
specific details such as implementations, types and interrelationships of system components, are set forth in order to provide a more thorough understanding of the present invention. It will be appreciated, however, by one skilled in the art that the invention may be practiced without such specific details. Various low level details which are not directly related to invention or full instruction sequence have not been shown in detail in order not to obscure the invention. Those of ordinary skill in the art, with the included descriptions, will be able to implement appropriate functionality without undue experimentation.

References in the specification to ‘embodiment’, indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure or characteristic in connection with other embodiments whether or not explicitly described.

In the following description and claims, the term ‘radio-opaque layering’ inside the tag has been shown as straight line, triangles or circles, but this should not be understood to be a specific shape as it can be manufactured any different random shapes. How the labels are applied item-wise inside the box OR outside of box will depend on exact customized requirements of specific deployment. Similarly this invention proposes use of circular labels for best level of security but it can be of any other shape as well.

Embodiments of the invention is described below,

**Tagging with labels embedded with randomly oriented Radio-opaque layering:**

Each item needs to be tagged with a special-purpose label. In diagram 1, the label as appears to human eye (001) and with embedded radio-opaque layer (002) is shown. Externally to human eye all tags look symmetrical but internally they have random orientation of radio-opaque layering as in diagram 2. Another format of labels is shown in diagram 13 wherein symmetrically looking circular labels has internal layer of radio opaque material (018). In usual cases each box is tagged with one label. But the box can be tagged with more than one label (003) as in diagram 3. These labels acquire their credential only at time of application and they auto-acquire their new credential on each re-use. In second embodiment which will be external scanning solution without using xray labels will have invisible patterns and can be digitally scanned by special purpose camera and auto-acquires its credential, which is determined by orientation of invisible pattern with respect to pattern on reference label.

**Reference X-ray imaging:** This imaging has to be done at point-of-packaging in
high physical security and surveillance area. The images of sealed box are to be taken from two different sides of the box such that overlapped orientation (004) and individual orientation (005) are received as in diagram 4. Once box is sealed, internal imaging (004) and (005) is done and reference imaging will show the overlapped imaging of randomly orientated radio-opaque layering from different tags in stacked item. Reference image indexed with unique-ID of box is sent to central server after digitally signing.

[39] **Transit and delivery point X-ray imaging:** X-ray imaging of box at each transit and delivery point is compared with reference images showing the matrix of labels wherein x-ray imaging of randomly orientated radio-opaque layering will be overlapped. If anybody reshuffles the items, steals the item or replaces with fake item the imaging comparison module will catch it during comparison with reference images of that particular box.

[40] **Item loss/theft detection:** If any of the item is lost or have been stolen the overlapped imaging from stacked item from that particular row or column will be significantly different (006) and (007) and image comparison module will catch and raise the alert.

[41] **Item replacement detection:** If any of the item is replaced with fake item of similar shape size and weight, still the overlapped imaging (008) and (009) will be different for stacked item in that particular row or column. Image comparison module will catch and raise the alert.

[42] **Item resshuffle detection:** If position of two similar items is inter-changed then also the overlapped imaging will be different for stacked item in that particular row or column. Image comparison module will catch and raise the alert.

[43] **False alarm mitigation:** Even due to unintentional human mistake one of item is not tagged the reference image will capture this and thus this is not raised as false alarm.

[44] **Corner possibility of same orientation of labels on stacked item:** By any chance if two items have got exactly same orientation then the loss or theft might not get detected. Replacement will still get detected as replaced item will not have same orientation again for all practical purpose. However even to mitigate this corner possibility two tags can be used such that this scenario is effectively ruled out by combining mathematical probability of exact overlapping.

[45] **Image indexing at central server:** During reference imaging each box is assigned a randomly generated unique-ID which is pasted on box preferably on same side on which the reference imaging has been taken. Unique reference imaging of each box is digitally signed and during comparison reference image is fetched indexed with unique-ID of box. All subsequent imaging needs to be taken from same side on which the reference imaging was taken. For added protection of network channel fetching
reference imaging can be crypto-protected using known protocols like IPSEC/SSL.

**Image normalization:** Perfect comparison requires cleaning-up the x-ray imaging. Wooden or corrugated box might have metallic parts like nails. So each time the x-ray imaging is taken it has to be subtracted with x-ray imaging of standard empty boxes.

**Item horizontal movement detection:** Once image capture module concludes the difference between normalized reference image and normalized current-hop captured image, it further examines whether difference is on account of slight horizontal movement of items during transit. Full imaging of box is cropped in multiple portions length-wise and height-wise wherein, each cropped portion represents items stacked depth-wise. Horizontal movement detection is done by subtracting of cropped portion from respective cropped portion from reference image and second subtraction of cropped portion from reference image from respective cropped portion from recently captured image. After these two subtractions each pixel can be verified for a horizontal shift. If it is not a genuine horizontal movement then number of pixels with horizontal shift will be minimal.

**Size based analysis for item count:** This mode is used to count the number of items. In this case all labels will have symmetrical and identical layering of radio-opaque material and not randomly oriented layering. Example sake if tags are circular then radio-opaque layering will also be same sized circle. These tags are applied on top face of each item at a place which is radio-transparent in direction of x-ray beam. In x-ray imaging wherein x-ray beam is downward to upward the size of label closest to flat panel detector will be larger. In case of any item is taken out depending on largest size of circle in x-ray imaging pattern it can be calculated number of item taken out of box. If no items are taken out then all circle (010) in x-ray imaging are of same size as shown in diagram 7. Amount of size variation (011) as in diagram 8, will depend on how many items are taken out. This method will work best on flat panel detector x-ray machines and if all items within box are of standard size and shape and some benchmarking is known beforehand.

**Alternative absolute count method without dual beam x-ray imaging to resolve count-deficiency due to overlapped patterns:** Size based analysis described earlier, requires additional top x-ray imaging and also use of additional labels which are symmetrical in imaging irrespective of their orientation. An alternative method is proposed which does not requires additional top x-ray imaging and also utilizes same labels for both image comparison and absolute count of items as well. These labels have mini-circle or mini-square (only for illustration) kind of pattern of radio-opaque material. Imaging software simply counts the number of mini-patterns for every row and every column in side face x-ray imaging. Count of mini-patterns at a given row and given column gives the number of items stacked depth-wise. However there can be count
conflict if one or more pattern exactly or partially overlaps one behind another. This count conflict can be resolved by angular x-ray which is achieved by simply rotating the box at a prescribed angle on conveyor belt of x-ray machinery. In angular x-ray hidden pattern gets exposed. For illustration, as shown in diagram 9, assuming there are five items stacked depth-wise, (012) shows only 4 mini-circles 'A', 'B', 'C' and 'D' as one pattern is hidden due to overlap. After box is rotated fifth pattern 'E' gets exposed (013) in angular x-ray, as shown in diagram 10. It is shown that an area of 1 inch x 1 inch is cropped from full box imaging, which represents imaging of five items stack depth-wise at given row and column. In angular x-ray an elongated area 1 inch x 1.5 inch is cropped, wherein hidden pattern 'E' is exposed and this information is digitally recorded during reference imaging itself and can be verified at point-of-delivery.

[50] Count of partially overlapped circular pattern in x-ray imaging: This method is only applicable to partially overlapped and if patterns are circular. This method exploits the fact that as circle is traversed along its circumference, then aggregated value of absolute difference (whether positive or negative) of both x-coordinate and y-coordinate between two equidistant points on circumference remains same. If two or more circles are partially overlapping then the periphery will not be geometrically circular and in that case aggregated value of absolute difference of x-coordinate and y-coordinate will not remain same for same distance parsed along the edge of overlapped pattern. Every time the aggregated value of absolute differences in x-coordinate and y-coordinate changes, the count of overlapped pattern is increased, and this traversal continues till original start point on periphery of pattern is reached.

[51] Covert feature for anti-counterfeiting associated with overt feature: Often there is need of covert feature of anti-counterfeiting. In this feature of the invention the authentication of the box is described. Once the box is sealed labels with invisible patterns printed on it is applied on to the box. Noteworthy to mention that in this application labels used are not radio-opaque layered but have invisible patterns printed. Patterns are externally and digitally scanned by special-purpose camera which can scan in non-visible range for human eye. Patterns can be any shape/size or as simple as one line randomly oriented and in that case degree of orientation can be imaging credential. Imaging credential can be associated with a random number printed on packaging and thus becomes a unique signature per-piece which is not re-clonable and non-replaceable even by an insider. A scheme of multi-number random number system for anti-counterfeiting has been disclosed in Indian patent number 41/CHE/2009 and PCT international application PCT/IB20 10/050940. On production-line special-purpose camera image acquisition system scans each packaging externally and associates their imaging credential with unique alpha-numeric credential and this association is
recorded in database. Random pattern can be any shape and size. Reference imaging captured by special cameras like infrared cameras and associating this imaging with unique ID per-piece. At time of verification in field, again imaging is compared programmatically with reference imaging associated with unique-ID.

**Two label approach for external scanning in direction-agnostic manner:** This embodiment is possibly useful for high volume logistics industry, wherein item level tagging with smart labels with internal random radio-opaque layering is not possible and thus only box level authentication is desired and box sizes are different or custom-made. If boxes are of trapezoidal shape then all faces and edges can be scanned with top and bottom scanning. Two labels are used in this embodiment as illustrated in diagram 11. One is base or reference label which gives reference pattern (014). Another comparison label (015) has comparison pattern (016). Imaging of reference pattern is used to determine orientation of comparison pattern image. So irrespective of box scanning direction, image analysis is done based on orientation of comparison image with respect to reference image. Both patterns will be invisible to naked eye (preferably printed from an ink those are non-visible to human eye) but can be digitally scanned by appropriate camera. Preferably these labels should be self destroyable for better security. Comparison label should look symmetrical to human eye in shape, size and application and only differs in terms of pattern's orientation, pattern's shape and pattern's size, which is printed from non-invisible ink to human eye. These labels are to be applied in a manner such that opening point will be sealed. These labels can also be two concentric labels and smaller diameter base label can be applied on top of larger diameter reference label. These labels can bear unique-ID printed by non-visible ink as well to index the images in database. Another embodiment can have two invisible circles on reference label (017) and angle with respect to circle on base label is calculated as shown in diagram 12. If using invisible inks to make patterns is not feasible one can use combination of red and blue screens as adhesive tapes over label, wherein pattern is printed in black colour. Example-sake if, pattern is printed in black on reference label of red background then using a semi-transparent deep blue coloured tape will make pattern invisible but still digitally scan-able by InfraRed camera.

**Internal monitoring at box label:** Sometimes item label tagging is not feasible and still internal monitoring is needed. Challenges are that box can contain any item that may be metallic or non-metallic. Box is padded and strapped along thermocol block or any other radio-transparent material. Thermocol block padding is suitable for flat panel x-ray detectors however in case of normal baggage scanning x-ray machines thermocol block might not be needed and in exceptional cases wherein the x-ray imaging of metallic content inside the box overlaps with imaging of smart-labels, the internal metallic content might need to be rearranged a bit. Before plastic strapping two labels
are placed on thermocol block and after tight strapping these labels auto-acquires their imaging credential. For illustration, as shown in diagram 15, credential can be relative orientation (019) and (020) but not limited to this. This box is placed inside larger container and x-ray imaging is used to validate credentials. Any intrusion that will undetectable requires strapping to be cut and thus labels will change their orientation and imaging credential will change automatically.
Claims

1. A method of content count and authentication inside a sealed box wherein, labels randomly embedding radio-opaque material layering are used to tag consignment, each of labels being externally symmetrical to the human eye but creates unique imaging signature due to the random orientation of the internal radio-opaque layering on the labels, detectable only in x-ray imaging of the label and auto-acquires their fresh imaging credential either at time of first application or reuse.

2. A method of count and authentication as said in claim 1 wherein the labels can be of any shape and preferably circular for highest security.

3. A method of content count and authentication as in claim 1 wherein, item loss, theft, reshuffling or replacement is detected by comparing overlapped x-ray imaging of labels containing randomly oriented radio-opaque material with that of row-wise and column-wise cropped portion of reference image.

4. A method of content count and authentication as in claim 1 wherein, false alarm for item loss or theft or replacement is determined by horizontal movement detection of items stacked along direction of x-ray beam at a given row and column position within box during transit, by monitoring differential between row-wise and column-wise cropped portion from reference imaging and respective cropped portion from recently acquired imaging.

5. A method of content count and authentication as in claim 1 wherein, imaging of the container with each item’s top face tagged with internally symmetric radio opaque layering labels can be taken and size analysis between x-ray imaging of labels can be used to detect missing items in container.

6. A method of content count and authentication as in claim 1, wherein, arithmetic count of items stacked depth-wise is done by counting the number of patterns in x-ray imaging, due to random orientation of each circular labels auto-acquire their imaging credential only at time of tagging.

7. A method of content count and authentication as in claim 6, wherein, count deficiency due to partial or exact overlap of patterns is resolved by rotating box on conveyor belt of x-ray machine by certain degree, which exposes the hidden patterns.

8. A method of content count and authentication as in claim 1, wherein
partially overlapped circular pattern are detected by observing aggregated value of absolute differences in both $x$-coordinate and $y$-coordinate for same distance parsed along the edge of overlapped pattern, and every time this aggregated value will change for same distance parsed along the edge, an overlapping circle is recorded for count purpose.

A method of content authentication wherein, box-authentication by internal scanning is achieved by strapping the box along with radio-transparent thermocol block and within strapping belt, labels embedding internal layering of randomly oriented radio-opaque material is placed such that labels auto-acquire their imaging credential while strapping is tightened and whole box can be placed inside a larger container and per-hop x-ray imaging validates the credential.

10. A method of covert anti-counterfeiting wherein, a pattern randomly sized, shape and orientation printed by ink, not visible to naked eye is printed on packaging and per-piece reference imaging captured by special cameras is indexed with unique-id per piece in database as covert anti-counterfeiting implementation.

A method of content authentication by external scanning wherein, patterns on reference label are made invisible, without using invisible ink and still digitally scan-able by using semi-transparent deep blue coloured adhesive tape over reference label which has red background with pattern printed in black.

12 A method of content authentication by external scanning, wherein, box authentication through external direction-agnostic image scanning is achieved by applying two labels on opening edge of box namely comparison-label and reference-label, wherein patterns in both labels are printed using ink non-visible to human eye, and acquired imaging is analysed for orientation of pattern on comparison label with respect to pattern on reference-label and the same is recorded as unique credential, using a special camera and associated with per-box unique-id in database.

13. A method of content authentication as said in claim 12, wherein the reference-labels used are of any shape and preferably circular for highest security.

14. A method of content authentication by external scanning as said in claim 12, wherein 360 degree scanning of all sides and edges of box to detect any hidden intrusion is done by using trapezoidal shaped box
stationed on a transparent shelf in a platform mounting two special-purpose cameras, one scanning from top view and another from bottom view.
Diagram 6
5/10

Diagram 7

Diagram 8
Diagram 11

Reference label with invisible triangular pattern

Invisible marking on base label seals the logical opening edge of box

Diagram 12

Base adhesive tape applied along logical opening edge of box over circular reference label

Circular reference label, which is visible only by IntraRed scanner and depending on orientation of application the imaging credential is auto-acquired. Unique-ID visible with infrared scanner is also printed on label.
Diagram 13

Internal layering of Radio-opaque material randomly embedded within circular label and can only be seen in XARY imaging and Auto-acquires its imaging credential depending on orientation of circular label, which is always symmetrical to human.

Diagram 14
Diagram 15

Thermocol Block padding on Box (in Case the box is fully stuffed with items and items are radio opaque) ensures radio-transparent media in path of X-ray beam and thus imaging of labels with internal layering of radio-opaque material is acquired as unique credential of box.
Diagram 16

Top and bottom image acquisition for 360 degree scanning of all faces and edges for trapezoidal shaped box with its logical opening edge sealed by base and reference labels those are not visible by naked eye.