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(54) **SYSTEM AND METHOD FOR MOBILE DEVICE COSMETIC EVALUATION**

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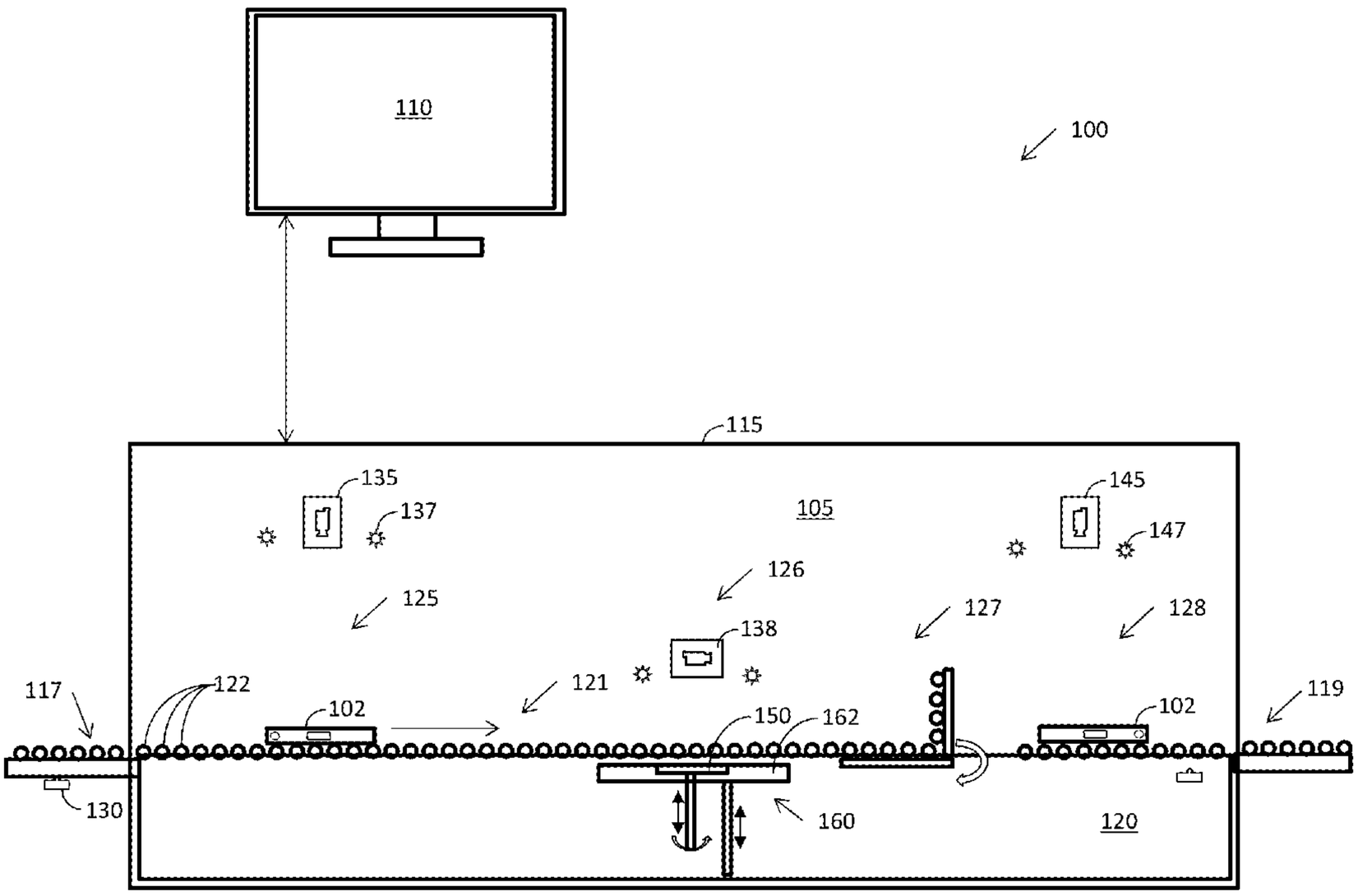
(57) **ABSTRACT**

An automated system which inspects the cosmetic appearance and general physical condition of each mobile device and then assigns a grade. The system inspects for scratches, cracks, dents, bents, dings, etc. The various identified defects are evaluated and receive a grade. All of the independent grades can be used to assign an overall grade.



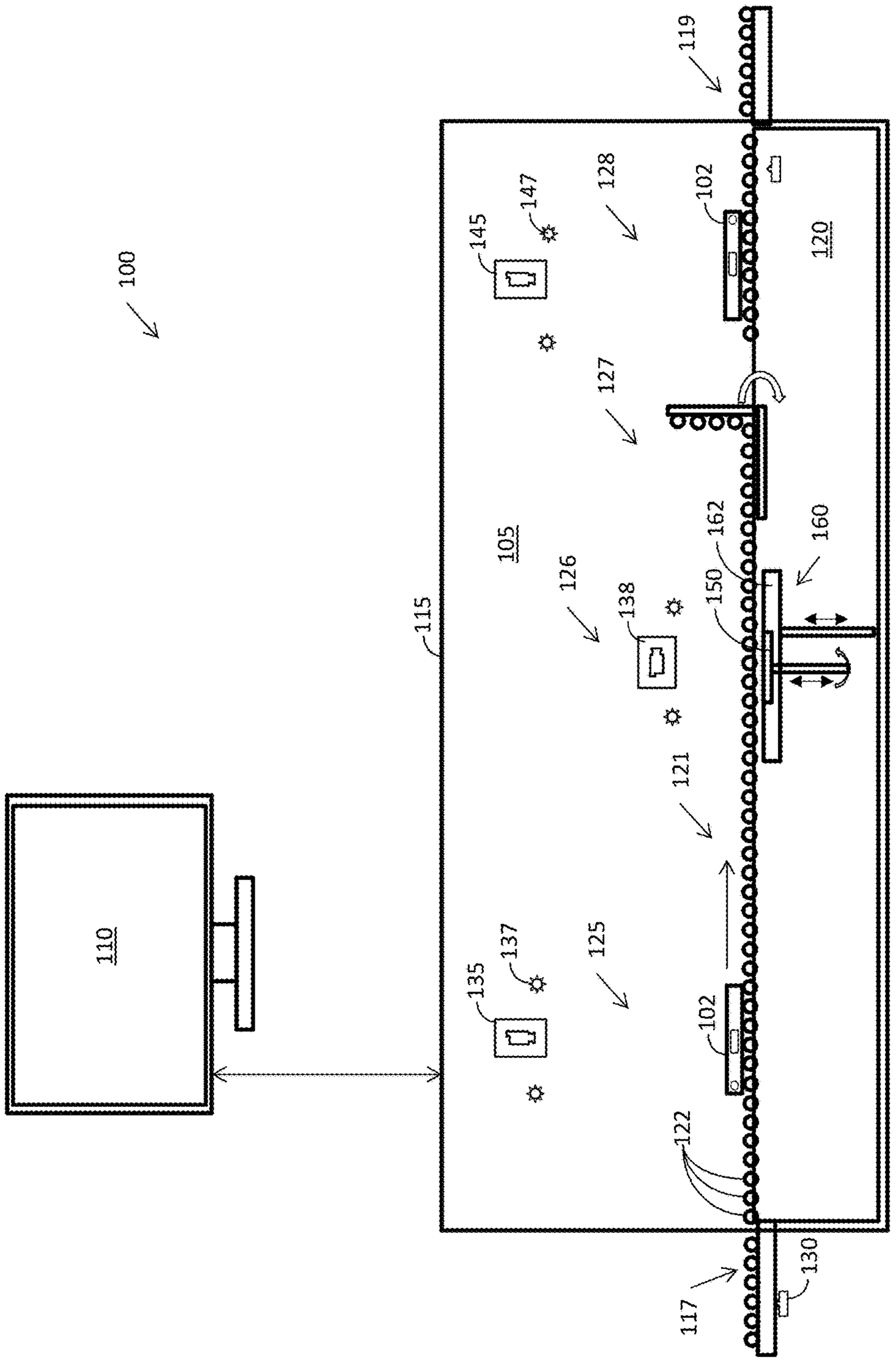

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Figure 1

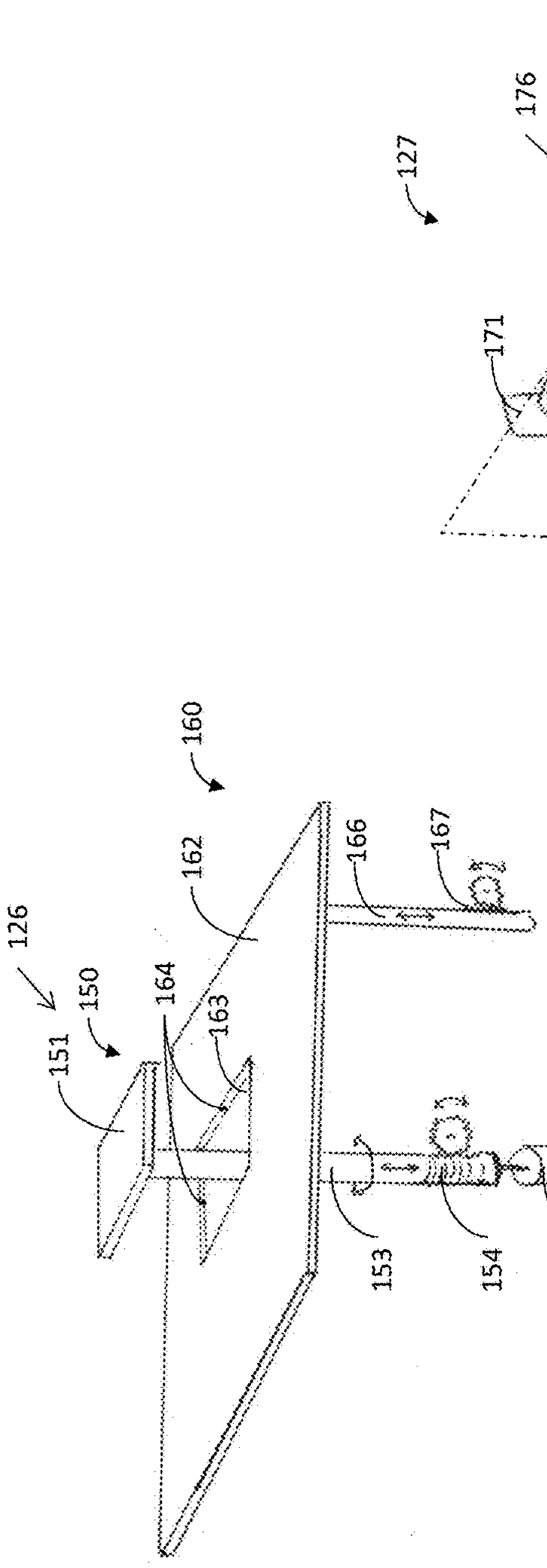

Figure 2

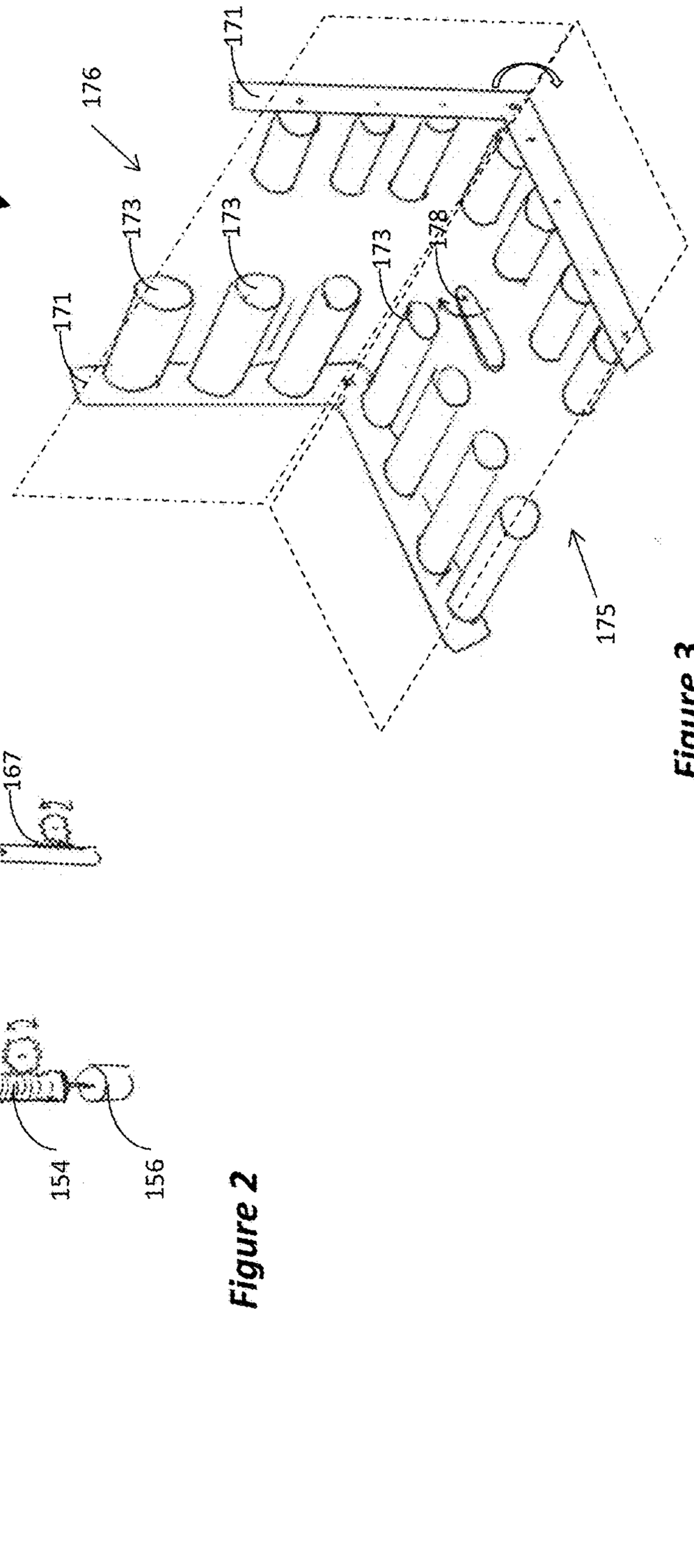

Figure 3

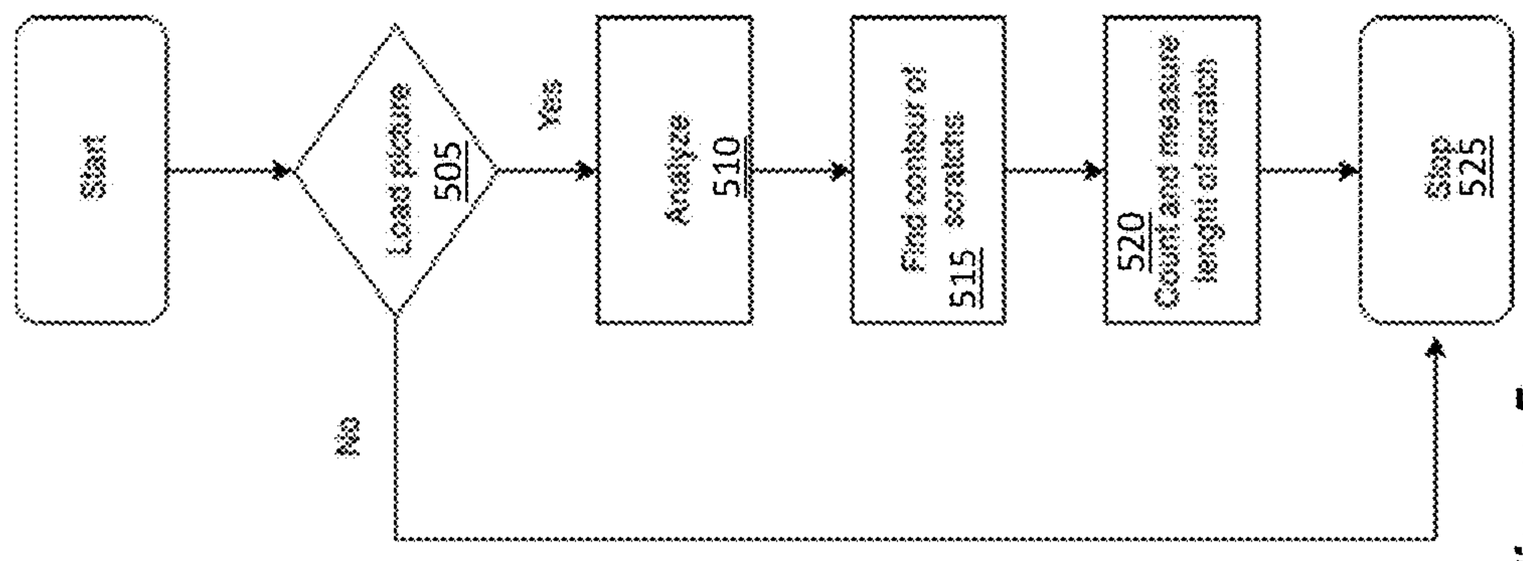

Figure 5

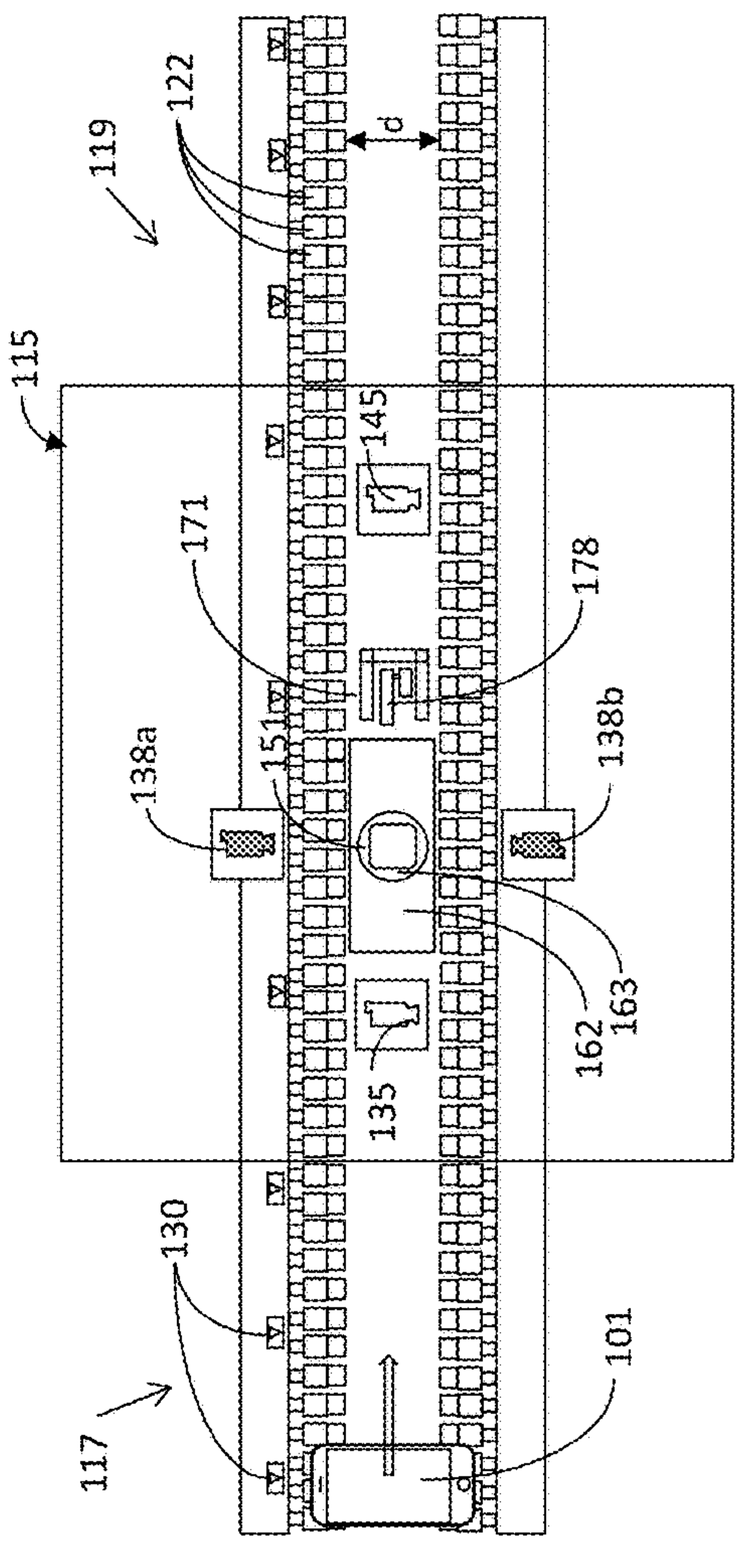

Figure 4

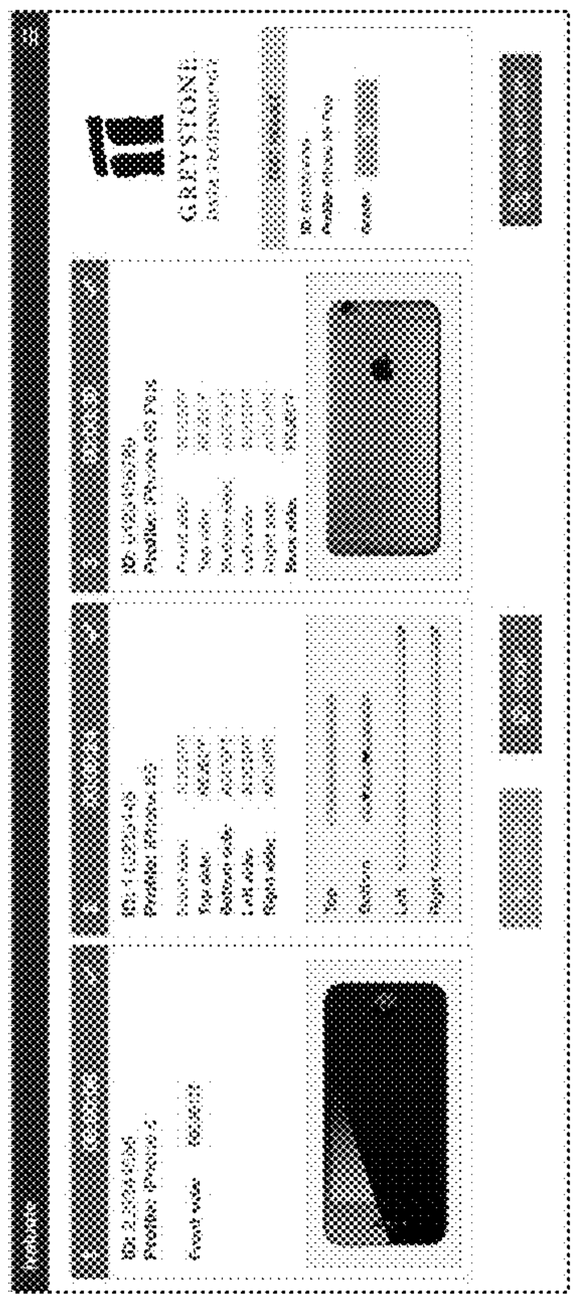

Figure 6

SYSTEM AND METHOD FOR MOBILE DEVICE COSMETIC EVALUATION

RELATED APPLICATION

[0001] This application claims priority benefit from U.S. Provisional Application No. 62/656,917, filed on Apr. 12, 2018, the disclosure of which is hereby incorporated herein by reference in its entirety.

BACKGROUND

1. Field

[0002] This disclosure relates to evaluation of the physical appearance i.e., cosmetic, condition of used mobile devices, and assignment of value grade according to the evaluated condition.

2. Related Arts

[0003] When new mobile devices, such as cellphones, become available, many users opt to upgrade to the new device by surrendering or trading in their old device. Consequently, companies obtain many used devices that they can sell on the used mobile device market. Of course, used devices may be in different cosmetic condition, which directly affect their desirability by purchasers of used devices. Therefore, the pricing should reflect the cosmetic condition of the device.

3. Problem to be Solved

[0004] Currently, the main method is for a seller to manually inspect the used device and assign a price to that device based on somewhat subjective inspection. However, different sellers may ascribe different price according to their subjective valuation criteria. It is therefore desirable to generate a unified method for evaluating the devices and assign a grade which will be easily translated into a selling price.

[0005] Moreover, manual inspection of used devices is time consuming and requires manual labor. Manual inspection also requires training of inspectors to achieve uniformity of inspection standards. Of course, the employment of human inspectors entails the overhead of hiring, training, and retaining a workforce. It is therefore desirable to automate the inspection of used mobile devices, so as to increase the throughput, standardize and unify the grading process, and reduce the headcount of employees dedicated to inspection and sorting of used mobile devices.

[0006] Applicant has previously disclosed systems for evaluation of mobile devices in U.S. patent applications Ser. Nos. 15/097,251 and 15/586,927, the disclosures of which are incorporated herein by reference.

SUMMARY

[0007] The following summary is included in order to provide a basic understanding of some aspects and features of the invention. This summary is not an extensive overview of the invention and as such it is not intended to particularly identify key or critical elements of the invention or to delineate the scope of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is presented below.

[0008] Disclosed herein are embodiments of an automated system which inspects the cosmetic appearance and general physical condition of each mobile device and then assigns a grade. The system inspects for scratches, cracks, dents, bents, dings, etc. The various identified defects are evaluated and receive a grade according to their severity. All of the independent grades for identified defects can be used to assign an overall grade for the device. A weighted system can be implements, e.g., a scratch on the screen of the device may be weighted higher than a scratch on the back of the device.

[0009] Disclosed embodiments provide a system for evaluating cosmetic appearance of mobile devices, comprising: a housing; a transport system for transporting the mobile devices within the housing; a front imaging station having a camera and an illumination source configured to image the front surface of each of the mobile devices; a side imaging station having a camera and an illumination source configured to image four edges of a bezel of each of the mobile devices; a flatness evaluation station configured for evaluating flatness of each of the mobile devices; a back imaging station having a camera and an illumination source configured to image the back surface of each of the mobile devices; a flipper positioned between the front imaging station and the back imaging station; and, a controller evaluating data received from the front imaging station, side imaging station, flatness evaluation station, and back imaging station to identify defect and assign grade to each of the mobile devices.

[0010] According to disclosed embodiments, a method for inspecting cosmetic appearance of a mobile device is provided, comprising: taking a picture of front surface of the mobile device and activating a processor to identify all cosmetic defects presented within the picture and assign a severity score to the cosmetic defects in the front surface; taking a picture of back surface of the mobile device and activating the processor to identify all cosmetic defects presented within the picture and assign a severity score to the cosmetic defects in the back surface; taking pictures of four edges of the mobile device and activating the processor to identify all cosmetic defects presented within the pictures and assign a severity score to the cosmetic defects in the edges; placing the mobile device in a flatness tester and testing the flatness of the mobile device; and, assigning an overall score to the mobile device based on the severity scores and the flatness.

[0011] Other aspects and features of the invention would be apparent from the detailed description, which is made with reference to the following drawings. It should be appreciated that the detailed description and the drawings provides various non-limiting examples of various embodiments of the invention, which is defined by the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The accompanying drawings, which are incorporated in and constitute a part of this specification, exemplify the embodiments of the present invention and, together with the description, serve to explain and illustrate principles of the invention. The drawings are intended to illustrate major features of the exemplary embodiments in a diagrammatic manner. The drawings are not intended to depict every feature of actual embodiments nor relative dimensions of the depicted elements, and are not drawn to scale.

[0013] FIG. **1** is a schematic illustrating an embodiment of the invention.

[0014] FIG. **2** illustrates an example of a bezel imaging with flatness inspection station, according to one embodiment.

[0015] FIG. **3** illustrates an example for a flipper station, according to one embodiment.

[0016] FIG. **4** illustrates a top view of an embodiment of the inventive system.

[0017] FIG. **5** illustrates a flow chart of scratch analysis and grading, according to one embodiment.

[0018] FIG. **6** is an example of a screenshot of a system according to an embodiment, during inspection of three phones.

DETAILED DESCRIPTION

[0019] Embodiments disclosed herein were developed in order to provide automated inspection of the cosmetic appearance of mobile devices and generating grade according to the presence and severity of defects. The disclosed embodiments include various features, not all of which may be implemented in a single system. Rather, disclosed features may be "mixed and matched" in a system according to user's requirements and use cases. Also, while the system can inspect any type of mobile device, for simplicity the explanation below will refer to a smartphone.

System

[0020] The system **100** of the embodiment of FIG. **1** includes a tester **105** and a computer/controller **110**. The computer **110** may run a process that controls the operation of the tester **105**, and the results of the various tests can be fed back to the computer **110**. The computer **110** may then run a process to evaluate the results and assign grades to the defects and to the overall condition of the smartphone. While in FIG. **1** as an example the controller **110** is shown separate from the tester **105**, the controller **110** may be integral to the tester and housed within the tester **105**.

[0021] In the example of FIG. **1**, the tester **105** includes a housing **115**, an entry shelf **117** and an exit shelf **119**. The tester **105** has a transport system **121** for transporting the smartphone from the entry shelf **117** into the tester **105** for testing, and then to the exit shelf **119** once testing has been completed. The operation of the transport system **121**, as well as the other elements of the tester **105**, is controlled by the controller **110**. Also, data collection and analysis is performed by the controller **110**, as indicated by the double-headed arrow.

[0022] In the embodiment of FIG. **1** the transport system **121** comprises a plurality of individually actuated wheels **122**. Since the wheels are actuated individually, each smartphone can be transported and halted at different points, or stations, individually. In general, the transport of each smartphone is halted at four stations during the testing: a front imaging station **125**, an edge/bezel imaging station **126**, a flipper **127**, and a back imaging station **128**. The wheels of the entry shelf **117** may be held motionless until a sensor **130** detects that a mobile device has been placed at the entry. When the sensor **130** detects a device, the wheels of the entry shelf **117** are activated and transport the device into the housing **115**.

[0023] The front imaging station **125** includes a camera **135**, e.g., pointing vertically downwards, and an illumination device **137**. The camera **135** takes images of the front of the device **102**, e.g., smartphone, and sends the images to the controller **110** to analyze the appearance of the front of the smartphone. A similar arrangement is provided at the back imaging station **128**, where camera **145**, e.g., pointing vertically downwards, and illumination device **147** are used to image the backside of the smartphone. To image the backside, the smartphone is flipped by the flipper **127** prior to entering the back imaging station **128**.

[0024] The edge or bezel imaging station **126** includes at least one camera **138**, pointing horizontally, to image the edges, i.e., the bezel or frame, of the smartphone. A lifter **150** is movable vertically and can be rotated. The lifter **150** is used to lift the device to the level of the field of view of the camera **138**. The lifter **150** can also rotate to present different edges of the smartphone to the camera **138**. In this respect, a bezel is generally defined as a grooved ring holding the glass or plastic cover of a watch face or other instrument in position. With respect to smartphones, users sometimes colloquially refer to the areas on the front of the phone that are not occupied by the display as being the "bezel." Such reference is technically incorrect. Instead, in the context of this disclosure, the bezel is the frame that holds the front glass and may also hold the rear cover of the mobile device if it is not integrated with the bezel (e.g., in iPhone 7 the rear cover and the bezel are made integrally as one aluminum piece). In most modern devices the frame also houses the various ports and physical buttons of the device.

[0025] Additionally, a flatness tester **160** is incorporated into the lifter, enabling to identify bows and bends in the body of the smartphone. The flatness tester comprises a flatbed **162** positioned on a z-actuator and having a window in the middle thereof. For flatness testing the z-actuator lifts the flatbed such that the smartphone is lifted by the flatbed. Then a light is turned on to illuminate the smartphone through the window in the middle of the flatbed, and the camera **138** is used to image the interface between the smartphone and the flatbed. If the smartphone is flat, no or little light would be seen in the interface. Conversely, if the smartphone is bowed or bent, light will be seen through the interface and will be captured by camera **138**.

[0026] FIG. **2** illustrates an example of a bezel imaging with flatness inspection station, according to one embodiment. In this particular embodiment, the side or bezel imaging station **126** is nested within the flatness evaluation station **160**, as will become clear from the explanation below. In other embodiments the bezel imaging and the flatness tester can be provided in separate stations. A lifter **150** is formed as a plate **151** attached to a rod **153**. The rod **153** is movable vertically, e.g., using a rack-and-pinion **154**, or any other suitable arrangement. The rod **153** is also rotatable, e.g., via servo motor **156**, or other suitable arrangement. In operation the rod is moved up vertically to lift the phone such that the bezel is in the field of view of the camera. Then, the rod rotates in successive 90° turns to present the next edge of the bezel to the camera for imaging.

[0027] Also shown in FIG. **2** is the flatness tester **160**. In this embodiment the flatness tester includes a flatbed **162**, having a window **163** in the middle thereof. Illumination device, such as, e.g., LED's **164**, can be placed within the window **163**. The window **163** is sized so that the plate **151** can freely pass through the window **163**. The flatbed is sized so as to be at least as large as the largest device to be tested. That is, the flatbed **162** is sized such that when a mobile

device is placed on the flatbed **162**, no part of the mobile device overhangs beyond the flatbed **162**. The flatbed **162** is attached to rod **166** that is movable vertically via, e.g., rack-and-pinion arrangement **167**, or other suitable means. The flatbed **162** can be raised by rod **166** to a level above the vertical level of plate **151**, thereby lifting a mobile device from the plate **151** and placing it on top of the flatbed **162**.

[0028] FIG. **3** illustrates an example for a flipper station **127**, according to one embodiment. The flipper **127** is formed out of a frame that has two arms connected to each other at a right angle, forming a front section **175** and rear section **176**. Each arm has a plurality of mechanized wheels **173**, each of which may be energized independently. Initially, the flipper **127** is positioned such that the front section **175** is horizontal. For flipping a mobile device, the system energizes the proper wheels to transfer the mobile device onto the front section **175**, as shown by the dashed-line rhomboid in FIG. **3**. Then flipper-arm **178** is activated to turn 90°, as shown by the curved arrow. This raises the mobile device and places it against the rear section **176**, in a vertical position, as shown by the dash-dot rhomboid in FIG. **3**. The entire flipper **127** is then rotated 90°, as shown by the curved arrow, such that the rear section **176** becomes horizontal, while the front section vertical. Through these two 90°, turns the mobile device has been turned 180°, and now exits the flipper **127** upside down.

[0029] In the embodiment shown in FIG. **1**, the flipper **127** is situated between the flatness evaluation station **160** and the back imaging station **128**. This implementation has the following advantages. When a device is placed on the entry shelf **117**, it enters the system and then the front, i.e., the side with the touchscreen, is imaged by camera **135**. The device is then moved to the edge imaging station **126** and then lifted by the flatbed of the flatness evaluation station **160**. The flatness evaluation station illuminates the surface of the device and, in this condition it is preferable that the illumination be of the backside, not the touchscreen side, of the device. This avoids various reflections caused by the touchscreen. This is why in the preferred embodiment the mobile device is not flipped until after it has passed the flatness test.

[0030] FIG. **4** is a top-view schematic of an embodiment of the system. A cellphone **101** is shown placed on the wheels **122** at the entrance shelf **117**. A sensor **130** detects the presence of the cellphone **101** and communicates that to the controller, which initiates an examination process for the cellphone **101**. Additional sensors are placed along the conveyor to detect the presence of the cellphone at different stations and send corresponding signals to the controller. Also, note that in this embodiment the conveyor is formed out of two rows of wheels **122**, wherein each row traverses the entire length of the conveyor and the two rows of wheels face each other, but do not traverse the entire width of the conveyor. That is, the two rows of wheels are separated from each other by a given distance d. This arrangement has at least two advantages. First, by creating space d, the lifter **150**, the flatness evaluation station **160**, and the flipper **127** can be placed between the two rows of wheels of the conveyor. The conveyor can thus transport the cellphone over the lifter **150**, the flatness evaluation station **160**, and the flipper **127**, without interruption. A second advantage is coupled with the feature that each of the wheels can be activated independently. As shown in FIG. **4**, one row of wheels is positioned so as to engage the upper area of the cellphone while the second row of wheels is positioned so as to engage the lower area of the cellphone. Therefore, if it is determined by sensor **130** that the cellphone was not placed orthogonally to the direction of travel (indicated by the arrow), the top and bottom wheels can be energized at different speeds so as to rotate the cellphone while transporting it, so that when the cellphone enters the housing **115** it is positioned orthogonally to the direction of travel.

[0031] Also, in the embodiment of FIG. **4** two edge cameras **138**a and **138**b are provided in a position opposing each other. Thus, when the cellphone is lifter by the lifter **150**, two edges can be photographed simultaneously. Thus, the plate **151** of lifter **150** needs only to rotate once 90°, and then the two other edges are photographed simultaneously. Also, if desired, when the cellphone is lifted by the flatbed **162**, both cameras can photograph the interface between the backside of the cellphone and the flatbed **162**, so that if the cellphone is bent in only one side, it can be detected.

Operation

[0032] As a first step, an incoming smartphone is thoroughly cleaned by an operator. Then, a sticker with a barcode, in this example a QR code, is adhered to the smartphone and the data of the smartphone with the respective barcode identity are entered into a database. In this manner, during the inspection the system can individually identify all of the smartphones being inspected.

[0033] Once cleaned and preparation for testing is completed, the smartphone **102** is placed on entry shelf **117**. When the sensor **130** detects that a smartphone **102** has been placed at the entry shelf **117**, the controller **110** energizes the proper wheels **122** to bring the smartphone **102** to the front imaging station **125**, under the camera **135**. The controller **110** activates camera **135** to image the front of the smartphone **102**, and the image from the camera **135** is analyzed by the processor to identify the bar code within the image. If no barcode is identified the controller energizes the wheels to exit the smartphone from the system to either the entry shelf **117** or the exit shelf **119** without inspection. If a barcode is identified, inspection of the smartphone commences.

[0034] As indicated above, in this embodiment camera **135** takes pictures of the front of the smartphone. Therefore, in this embodiment the barcode sticker should be placed on the front of the smartphone without covering any imperfections, so that all imperfections on the front of the smartphone can be seen in the image taken by camera **135**. In this embodiment the processor **110** identifies each imperfection and assigns a grade value to imperfections according to the severity of the imperfections. The processor can also present an image on a monitor, highlighting the location of each imperfection and the corresponding severity or score.

[0035] The smartphone is then transported to the edge imaging station **126**. The lifter **150** then lifts the smartphone to place the edge of the smartphone at the field of view of camera **138**, so that camera **138** can take a picture of one edge of the smartphone's bezel. The lifter than rotates to present the next edge to the camera **138**. Once all the edges have been imaged by the camera **138**, the flatness tester **160** is raised and engages the smartphone **102**, such that the backside of the smartphone rests completely on the flatbed **162**. The light source **164** in window **163** is then energized. Since in this embodiment the smartphone is placed in the system facing up, the light source illuminates the backside of the smartphone through the window **163** in the flatbed

162. The camera then takes another edge image and the interface between the backside of the smartphone and the flatbed **162** is analyzed. If the smartphone is flat, it should contact the entire top surface of the flatbed **162**, such that no or very little light can be seen form the interface. Conversely, if the phone is bent, more light will be seen at the interface. The processor measures the intensity of the light seen at the interface and using the intensity calculates the flatness of the phone and assigns a corresponding score.

[0036] When the flatness analysis is completed, the flatness tester **160** and the lifter **150** are lowered, so that the smartphone rests on the wheels **122** and can be transported to the flipper **127**. The flipper **127** flips the smartphone, such that its backside now faces up. After it is flipped, the smartphone is transported to the back imaging station **128**, where camera **145** takes an image of the back of the phone. The processor analyzes the image to locate all defects and assigns score to indicate the severity of the defects. At this point inspection is completed and the smartphone is transported out of the system.

[0037] FIG. **5** is a flow chart illustrating an example of a process executed by the controller in order to identify and grade defects, e.g., scratches, on the phone. In one embodiment, the process uses functions in the OpenCV libraries on the Ubuntu operating system to process the images. The process synthesizes and classifies the cosmetic level of the phone.

[0038] When a new image is loaded at step **505** the process proceeds to step **510** to analyze the image. In this embodiment, the controller first checks to see that the phone in the image is straight. If not, the image is rotated to have the phone straight. Then the image may be cropped so as to obtain only the areas that need processing. At step **515** the contour of each of the scratches is determined. At step **520** the scratches are counted and the length of each scratch is determined. The results are then stored, to be used by defect classifier.

[0039] According to one embodiment, the processor determines for each of the front imaging station **125**, edge/bezel imaging station **126**, and a back imaging station **128**, whether the defect results resulted in an acceptable or unacceptable score. For example, an acceptable/unacceptable decision can be made for each of: front surface, back surface, top edge, bottom edge, right edge, and left edge. The overall score for the phone can be determined according to the number of unacceptable results. The phone may then be scored on an A-F overall score. Once all the analysis is completed, the processor may display the test result of the phone, including phone ID, phone model, defect count, defects score, and overall grade. The price of the phone can be determined by reference to the overall grade.

[0040] FIG. **6** is an example of a screenshot during inspection of three phones. The top line indicates the time into the testing cycle of each of the phones, while the second line indicates an ID of the phone and the third the model of the phone. As seen in this example, phone number 1 is only six seconds into the cycle and only the front side has been inspected. The grade for the front side is "reject." Phone number 2 is 24 seconds into the test cycle, had its front side graded as "accept," its top side graded as "reject" and its other three sides graded as "accept." Phone number 3 is completed the inspection cycle and had its top side and back side graded as "reject", while the reset graded as "accept." On the right-side of the screen, under the heading "Test Result" the summary for the third phone is provided, with an overall grade of B.

[0041] While the invention has been described with reference to particular embodiments thereof, it is not limited to those embodiments. Specifically, various variations and modifications may be implemented by those of ordinary skill in the art without departing from the invention's spirit and scope, as defined by the appended claims.

1. A system for evaluating cosmetic appearance of mobile devices, comprising:

a housing;

a transport system for transporting the mobile devices within the housing;

a front imaging station positioned within the housing and having a camera and an illumination source configured to image front surface of each of the mobile devices;

an edge imaging station positioned within the housing and having a camera and an illumination source configured to image four edges of a bezel of each of the mobile devices;

a flatness evaluation station positioned within the housing and configured for evaluating flatness of each of the mobile devices;

a back imaging station having a camera and an illumination source configured to image back surface of each of the mobile devices;

a flipper positioned between the front imaging station and the back imaging station; and,

a controller evaluating data received from the front imaging station, edge imaging station, flatness evaluation station, and back imaging station to identify defect and assign grade to each of the mobile devices.

2. The system of claim **1**, wherein the transport system comprises a plurality of individually motorized wheels.

3. The system of claim **1**, wherein the edge imaging station comprises a plate configured to engage a mobile device, the plate being coupled to a z-actuator movable in the vertical direction and rotatable about a rotation axis.

4. The system of claim **1**, wherein the flatness evaluation station comprises a flatbed and an illumination source configured to illuminate a surface of one the mobile devices while resting on the flatbed.

5. The system of claim **3**, wherein the flatness evaluation station comprises a flatbed and an illumination source provided within a window situated in the flatbed.

6. The system of claim **5**, wherein the plate of the edge imaging station is configured to pass through the window in the flatbed.

7. The system of claim **1**, wherein the edge imaging station is nested within the flatness evaluation station.

8. The system of claim **1**, wherein the flipper is positioned between the flatness evaluation station and the back imaging station.

9. The system of claim **1**, further comprising an entry shelf and a sensor for detecting presence of a mobile device on the entry shelf.

10. A method for inspecting cosmetic appearance of a mobile device, comprising:

taking a picture of front surface of the mobile device and activating a processor to identify all cosmetic defects presented within the picture and assign a severity score to the cosmetic defects in the front surface;

taking a picture of back surface of the mobile device and activating the processor to identify all cosmetic defects presented within the picture and assign a severity score to the cosmetic defects in the back surface;

taking pictures of four edges of the mobile device and activating the processor to identify all cosmetic defects presented within the picture and assign a severity score to the cosmetic defects in the edges;

placing the mobile device in a flatness tester and testing the flatness of the mobile device; and,

assigning an overall score to the mobile device based on the severity scores and the flatness.

11. The method of claim **10**, wherein testing the flatness of the mobile device comprises:

placing the mobile device on a flatbed having a window;

illuminating the mobile device through the window;

imaging an interface between the mobile device and the flatbed;

analyzing intensity of light appearing at the interface.

12. The method of claim **10**, wherein taking pictures of four edges of the mobile device comprises:

transporting the mobile device onto a plate;

raising the plate so as to bring a first edge of the mobile device to within a field of view of a side imaging camera;

activating the side imaging camera to take a picture of the first edge;

rotating the plate so as to bring a second edge to within the field of view;

activating the side imaging camera to take a picture of the second edge.

13. The method of claim **10**, wherein between the steps of taking a picture of the front surface and taking a picture of the back surface, the method comprises the steps of:

placing the mobile device on a flipper;

activating the flipper to flip the phone.

14. The method of claim **10**, further comprising assigning weights to the different severity scores.

15. A system for evaluating cosmetic appearance of mobile devices, comprising:

a housing;

at least one camera configured for imaging front, back, and edges of each mobile device;

an illumination source positioned inside the housing and configured to illuminate each of the mobile devices during imaging;

a flatbed having back-illumination and configured to list each mobile device and illuminate the back of each mobile device with the back-side illumination;

a flatness tester configured to measure intensity of light emanating from an interface between the flatbed and a mobile device resting on the flatbed.

16. The system of claim **15**, further comprising a flipper configured to flip each mobile device.

17. The system of claim **16**, wherein the flipper comprises:

two front arms and two back arms, each of the back arms being connected to one of the front arms at a ninety-degree angle;

a plurality of individually motorized wheels distributed along the two front arms and two back arms in a facing relationship;

a holding arm configured to rotate ninety degrees so as to assume a first position in parallel with the front arms and a second position parallel with the back arms.

18. The system of claim **17**, wherein the arrangement of two front arms and two back arms is configured to rotate ninety degrees.

19. The system of claim **15**, further comprising a z-lifter and wherein the flatbed is attached to the z-lifter.

20. The system of claim **15**, further comprising a lifting plate attached to a rotatable lift and configured to lift a mobile device rotate the mobile device is successive ninety-degrees rotations.

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