A BAGGAGE SCANNER

FIELD OF INVENTION

The present invention relates to a baggage scanner. More particularly, the present invention relates to a standalone baggage scanner for security screening.

BACKGROUND OF THE INVENTION

A baggage scanner in security screening is used to scan a piece of luggage by emitting X-ray radiation to produce X-ray images of the content of the luggage. Security personnel visually inspect the X-ray images for prohibited items such as weapons, explosives, liquid, aerosol, or contraband. Typically, the baggage scanner includes a conveyor belt, an inspection tunnel, and a display monitor. The conveyor belt extends through the inspection tunnel so as to feed the luggage through the inspection tunnel at a consistent speed for scanning. The inspection tunnel houses one or more thermionic X-ray tubes and X-ray detectors. The thermionic X-ray tubes generate and emit X-ray radiation, which is captured by the X-ray detectors to produce the X-ray images shown on the display monitor.

An example of the baggage scanner is disclosed in Malaysian Patent Application No. PI2024000581 which relates to a system and method for inspecting luggage. The system is configured for non-intrusive scanning of the luggage content for specific materials or substances. The scanning of the luggage is based on multiple energy bands detection of radiation. The system may be used at an airport, seaport, post office or any other place which requires luggage to be scanned for contraband items such as drugs, explosives, and weapons. The system comprises a radiation source module, a radiation detection module, a controller module, a cooling module, and a computing module.

Another example of the baggage scanner is disclosed in a PCT Publication No. WO/2009/143169 which discloses an array CT scanner system for X-ray scanning objects (e.g., scanning airline baggage, packages, and cargo). The array CT scanner system includes a conveyor configured to transport baggage through a tunnel, a bottom mounted x-ray source configured to provide five fan beams through the tunnel, a side mounted x-ray source disposed at a height higher than the conveyor and configured to provide a fan beam through the tunnel, and a

plurality of detectors disposed across the arcs of each of the fan beams. The scanner system also includes an image processing system configured to provide 3D type images of a scanned bag as a function of the information received from the detectors. An operator can manipulate the image data and partially rotate the bag to discern objects located within. A side tray is provided to allow an operator to remove a suspect bag from an operational flow of bags. Image information can be stored for subsequent review. Multiple scanners can be networked together such that image and passenger information can be transferred to other workstations.

A further example of the baggage scanner is disclosed in a US Patent No. 5,818,897 which discloses a quadrature transverse CT detection system. The detector system includes a two-dimensional array of detectors for use in generating a volumetric scan of objects moving through a scanner. The array can comprise rows and columns of square detectors, or alternatively at least two types of detectors, one for providing high image resolution in a direction parallel to or within a plane containing the X- and Y-axes of a CT scanner, and the other for providing high image resolution e direction of the Z-axis of the scanner. Preferably, a first set of detectors is oriented in one direction and a second set of detectors is oriented in a different direction. The detector system may be used in connection with CT scanners and, in particular, with CT baggage scanners and is particularly useful for detecting the presence of thin objects such as sheet explosives within scanned baggage. An improved method of scanning baggage is provided by using the one set of detectors to generate CT image information and the other set of detectors to generate at least one sinogram.

However, there are several drawbacks associated with the existing baggage scanners. The use of thermionic X-ray tubes in the existing baggage scanners requires specialised cooling systems to dissipate the heat generated by their heated filaments. This contributes to a higher operational energy consumption of the baggage scanner. The constant heating of the heated filaments also accelerates the degradation of the filament electrodes, consequently reducing the lifespan of the thermionic X-ray tube and necessitating frequent replacements.

The X-ray radiation emitted from the thermionic X-ray tubes is either in the form of a fan beam or a cone beam. For thermionic X-ray tubes that emit X-ray

radiation in fan beam, the fan beam only covers a slice of a bag at any given moment and thus, such baggage scanner is reliant on the conveyor belt to move the bag through the baggage scanner to capture the entire bag in line-by-line images. As for thermionic X-ray tubes that emit X-ray radiation in cone beam, a larger distance between the thermionic X-ray tubes and the bag captures a wider field of view in a single exposure. However, increasing the distance reduces the intensity of the radiation reaching the X-ray detectors due to beam divergence and attenuation that may potentially impact the image quality and require higher X-ray power. Conversely, positioning the thermionic X-ray tubes closer to the bag reduces the field of view but necessitates the use of the conveyor belt to move the bag through the cone beam for sequential scanning of different sections of the bag.

Some of the existing baggage scanners adopt computed tomography technology to provide 3D imaging of scanned baggage. A slip ring is a critical component that enables the continuous rotation of the thermionic X-ray tubes, X-ray detectors or both around the bag. It provides a mechanism to electrically connect stationary components of the baggage scanner to the rotating components which may include the thermionic X-ray tubes and detectors. However, the slip ring is susceptible to wear and tear due to constant rotation that could lead to maintenance issues and potential data transmission failures as data is transmitted through it.

Hence, there is a need to develop a baggage scanner that addresses the abovementioned drawbacks.

SUMMARY OF INVENTION

According to a first aspect of the present invention, a baggage scanner (**1000**) for scanning at least one piece of luggage is provided. The baggage scanner (**1000**) comprises an X-ray source module (**1200**) configured to produce and emit at least one X-ray beam; an X-ray detector module (**1300**) configured to capture and measure transmitted X-ray beam, wherein the transmitted X-ray beam is the at least one X-ray beam emitted by the X-ray source module (**1200**) that may interact with the at least one piece of luggage, wherein the X-ray detector module (**1300**) includes at least one X-ray detector; a control panel (**1600**) configured to facilitate user input and display information related to the operation of the baggage scanner (**1000**); a power

source module (**1500**) configured to supply and manage electrical power required for the baggage scanner (**1000**), wherein power source module (**1500**) is connected to the X-ray source module (**1200**), X-ray detector module (**1300**), and control panel (**1600**); and a processing module (**1400**) configured to manage the operation of the baggage scanner (**1000**) and generate at least one X-ray image, wherein the processing module (**1400**) is connected to the X-ray source module (**1200**), X-ray detector module (**1300**), power source module (**1500**), and control panel (**1600**). Moreover, the baggage scanner (**1000**) is characterised in that the baggage scanner (**1000**) further includes a housing (**1100**) for integrating and supporting the X-ray source module (**1200**), the X-ray detector module (**1300**), the processing module (**1400**), the power source module (**1500**), and the control panel (**1600**), wherein the housing (**1100**) includes a cavity (**1110**) configured to accommodate the at least one piece of luggage for scanning, wherein the cavity (**1110**) is defined by a base of the housing (**1100**) at its bottom, a sidewall of the housing (**1100**) at its first side, a rear wall of the housing (**1100**) at its second side, an opening enclosable by an access door (**1130**) at its third side and a connection to the component compartment (**1120**) at its fourth side, and a component compartment (**1120**) used to house the X-ray source module (**1200**), the processing module (**1400**) and the power source module (**1500**); and the X-ray source module (**1200**) includes at least one X-ray tube (**1220**) connected to at least one mono-block generator (**1210**), wherein the at least one mono-block generator (**1210**) configured to convert electrical power supplied from the power source module (**1500**) into a high-voltage output for operating the at least one X-ray tube (**1220**), wherein the at least one X-ray tube (**1220**) is a cold cathode X-ray tube.

Preferably, the at least one X-ray tube (**1220**) is a carbon nanotube X-ray tube.

Preferably, the X-ray source module (**1200**) further includes a switching unit (**1240**) connected between the at least one X-ray tube (**1220**), the at least one mono-block generator (**1210**), wherein switching unit (**1240**) is configured to alternate the supply of the high-voltage output from the at least one mono-block generator (**1210**) to multiple X-ray tubes (**1220**), wherein the switching unit (**1240**) is connected and controlled by the processing module (**1400**).

Preferably, the at least one X-ray tube (**1220**) is attached to a vertical support structure, wherein the vertical support structure (**1230**) is mounted to the base of the housing (**1100**) and located within the component compartment (**1120**) near the cavity (**1110**). The vertical support structure is suitably equipped with a linear actuator assembly to allow vertical movement of the at least one X-ray tube (**1220**) during scanning, wherein the linear actuator assembly is electrically controlled by the processing module (**1400**).

Preferably, the X-ray detector is a flat panel detector.

Preferably, the processing module (**1400**) includes a controller unit (**1410**) connected to the X-ray source module (**1200**), the X-ray detector module (**1300**), the power source module (**1500**), the control panel (**1600**), and an image processing unit (**1420**), wherein the controller unit (**1410**) is configured to control and synchronise an activation and deactivation of the X-ray source module (**1200**) and X-ray detector module (**1300**), activate and deactivate the at least one X-ray tube (**1220**) at different emission intervals, process user input from the control panel (**1600**), and display the at least one X-ray image on the control panel (**1600**); and the image processing unit (**1420**) configured to generate the at least one X-ray image from at least one X-ray raw data obtained from the X-ray detector module (**1300**). The at least one X-ray image suitably includes either at least one projection image, a volumetric image, at least one sum grayscale image, at least one material-discriminated image, at least one object-stripped image or at least one material-separated image, wherein each projection image is a planar X-ray image of the at least one piece of luggage captured from a specific angular position and the volumetric image is a three-dimensional or 3D X-ray image of the at least one piece of luggage. The controller unit (**1410**) is suitably connected to a remote monitoring device to transmit the at least one X-ray image. The controller unit (**1410**) is suitably configured to actuate the access door (**1130**) for closing and opening the cavity (**1110**). The image processing unit (**1420**) is suitably configured to perform image pre-processing on the at least one X-ray raw data from the X-ray detector module (**1300**). Moreover, the image processing unit (**1420**) is suitably configured to recognise and detect any prohibited items from the at least one X-ray image.

Preferably, the baggage scanner (**1000**) further includes a rotary platform (**1700**) configured for rotational positioning of the at least one piece of luggage placed in the cavity (**1110**), wherein the rotary platform (**1700**) is controlled by the processing module (**1400**).

Preferably, the control panel (**1600**) includes a display unit configured to present visual information to a user; a touchscreen overlay integrated with the display unit configured to allows touch-based input from the user corresponding to the visual information displayed by the display unit; and at least one input button used to receive tactile input from the user.

Preferably, the baggage scanner (**1000**) is configured as a standalone device.

Preferably, the baggage scanner (**1000**) is configured as a compact device.

According to a second aspect of the present invention, a method for scanning at least one piece of luggage is provided. The method is characterised by the steps of placing at least one piece of luggage into a cavity (**1110**) of a housing (**1100**) of a baggage scanner (**1000**); closing an access door (**1130**) of the baggage scanner (**1000**); checking a current state of the access door (**1130**); if the current state of the access door (**1130**) is closed, activating an X-ray source module (**1200**), an X-ray detector module (**1300**), and a rotary platform (**1700**) by the processing module (**1400**) of the baggage scanner (**1000**); transmitting at least one X-ray raw data from the X-ray detector module (**1300**) to a processing module (**1400**) of the baggage scanner (**1000**), wherein each X-ray raw data corresponds to a particular angular position of the at least on piece of luggage and a specific energy level of at least one X-ray beam emitted by the X-ray source module (**1200**); performing image pre-processing on the at least one X-ray raw data; generating at least one X-ray image, wherein the at least one X-ray image includes either at least one projection image, a volumetric image, at least one sum grayscale image, at least one material-discriminated image, at least one object-stripped image or at least one material-separated image, wherein each projection image is a planar X-ray image of the at least one piece of luggage captured from a specific angular position and the volumetric image is a three-dimensional or 3D X-ray image of the at least one piece

of luggage; and displaying the at least one X-ray images generated at a control panel (**1600**) of the baggage scanner (**1000**).

Preferably, the method includes sending an alert notification at a control panel (**1600**) of the baggage scanner (**1000**) by the processing module (**1400**) of the baggage scanner (**1000**) if the current state of the access door (**1130**) is open.

Preferably, the step of activating the X-ray source module (**1200**), the X-ray detector module (**1300**), and the rotary platform (**1700**) includes emitting the at least one X-ray beam towards the at least one piece of luggage within the cavity (**1110**) at different emission intervals as the rotary platform (**1700**) rotates the at least one piece of luggage; capturing and measuring at least one transmitted X-ray beam, wherein the at least one transmitted X-ray beam is the at least one X-ray beam emitted that may interact with the at least one piece of luggage in the cavity (**1110**); and converting the at least one transmitted X-ray beam into the at least one X-ray raw data.

Preferably, the method further includes transmitting the at least one X-ray image to a remote monitoring device.

According to a third aspect of the present invention, a method for scanning at least one piece of luggage is provided. The method is characterised by the steps of placing at least one piece of luggage into a cavity (**1110**) of a housing (**1100**) of a baggage scanner (**1000**); closing an access door (**1130**) of the baggage scanner (**1000**); checking a current state of the access door (**1130**); if the current state of the access door (**1130**) is closed, activating an X-ray source module (**1200**), an X-ray detector module (**1300**), and a rotary platform (**1700**) by the processing module (**1400**) of the baggage scanner (**1000**); transmitting at least one X-ray raw data from the X-ray detector module (**1300**) to a processing module (**1400**) of the baggage scanner (**1000**), wherein each X-ray raw data corresponds to a particular angular position of the at least on piece of luggage and a specific energy level of at least one X-ray beam emitted by the X-ray source module (**1200**); performing image pre-processing on the at least one X-ray raw data; generating a plurality of material-discriminated images, wherein a material-discriminated image is generated for each angular position of the at least one piece of luggage captured by the X-ray detector

module (**1300**); reconstructing a volumetric image of the at least one piece of luggage from the plurality of material discrimination images; recognising and detecting any prohibited items in the at least one piece of luggage based on either the volumetric image or the plurality of material discrimination images by the processing module (**1400**); and sending an alert notification if there are any prohibited items recognised and detected by the processing module (**1400**).

Preferably, the method includes sending an alert notification at a control panel (**1600**) of the baggage scanner (**1000**) by the processing module (**1400**) of the baggage scanner (**1000**) if the current state of the access door (**1130**) is open.

Preferably, the step of activating the X-ray source module (**1200**), the X-ray detector module (**1300**), and the rotary platform (**1700**) includes emitting the at least one X-ray beam towards the at least one piece of luggage within the cavity (**1110**) at different emission intervals as the rotary platform (**1700**) rotates the at least one piece of luggage; capturing and measuring at least one transmitted X-ray beam, wherein the at least one transmitted X-ray beam is the at least one X-ray beam emitted that may interact with the at least one piece of luggage in the cavity (**1110**); and converting the at least one transmitted X-ray beam into the at least one X-ray raw data.

Preferably, the step of recognising and detecting any prohibited items in the at least one piece of luggage includes extracting at least one key feature from the volumetric image or each material discrimination image to identify each item in the at least one piece of luggage; and determining whether the shape profile and material type of each identified items are associated with any prohibited items.

Preferably, the method includes sending a notification to a user through a control panel (**1600**) stating that the at least one piece of luggage has passed security screening if there are no prohibited items recognised and detected by the processing module (**1400**).

Preferably, the method further includes transmitting the volumetric image or the plurality of material discrimination images to a remote monitoring device.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

FIGS. 1(a-c) illustrates a baggage scanner (**1000**) according to an embodiment of the present invention.

FIG. 2 illustrates a cross-sectional view of the baggage scanner (**1000**) of **FIGS. 1(a-c)**.

FIG. 3 illustrates a block diagram of the baggage scanner (**1000**) of **FIGS. 1(a-c)**.

FIG. 4 illustrates a cross-sectional view of an X-ray tube (**1220**) of the baggage scanner (**1000**) of **FIGS. 1(a-c)**.

FIGS. 5(a-b) illustrate a first configuration of an X-ray source module (**1200**) of the baggage scanner (**1000**) of **FIGS. 1(a-c)**.

FIGS. 6(a-c) illustrate a second configuration of an X-ray source module (**1200**) of the baggage scanner (**1000**) of **FIGS. 1(a-c)**.

FIG. 7 illustrates a flowchart of a method for scanning at least one piece of luggage according to a first embodiment of the present invention.

FIG. 8 illustrates a flowchart of a method for scanning at least one piece of luggage according to a second embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the description with unnecessary detail.

Referring to **FIGS. 1(a-c)**, there are illustrated a baggage scanner (**1000**) according to an embodiment of the present invention. The baggage scanner (**1000**) is configured to scan at least one piece of luggage using X-ray radiation to generate one or more X-ray images of the luggage, wherein the X-ray images may either include at least one projection image which is a planar X-ray image of the luggage captured from a specific angular position, a volumetric image which is a three-dimensional or 3D X-ray image of the scanned luggage, at least one sum grayscale image, at least one material-discriminated image, at least one object-stripped image or at least one material-separated image. The X-ray images display the content of the at least one piece of luggage for security screening. The baggage scanner (**1000**) is configured as a standalone device that does not rely on a conveyor belt to move the luggage through for scanning the entire luggage. Instead, the luggage is loaded and remain contained in the baggage scanner (**1000**) to scan through the entire luggage.

Although it has been described that the baggage scanner (**1000**) is configured to scan the at least one piece of luggage such as bag, suitcase and the like, the baggage scanner (**1000**) may also be used to scan packages, parcels or any other types of containers.

FIG. 2 illustrates a cross-sectional view of the baggage scanner (**1000**) while **FIG. 3** illustrates a block diagram of the baggage scanner (**1000**). The baggage scanner (**1000**) comprises a housing (**1100**), an X-ray source module (**1200**), an X-ray detector module (**1300**), a processing module (**1400**), a power source module (**1500**), a control panel (**1600**) and a rotary platform (**1700**). The processing module (**1400**) preferably includes a controller unit (**1410**) and an image processing unit (**1420**). The X-ray source module (**1200**), X-ray detector module (**1300**), control panel (**1600**) and rotary platform (**1700**) are electrically connected to both processing module (**1400**) and power source module (**1500**), wherein those connections to the processing module (**1400**) are suitably for data transmission and control while those connections to the power source module (**1500**) are suitably for electrical power supply.

The housing (**1100**) is a structural enclosure designed to integrate and support all functional components of the baggage scanner (**1000**). Moreover, the

housing (**1100**) is also designed to contain the X-ray radiation and thus, preventing radiation leakage to its surrounding environment. Suitably, the housing (**1100**) incorporates a radiation shielding material to contain the X-ray radiation within it. The internal structure of the housing (**1100**) is constructed to include a cavity (**1110**) and a component compartment (**1120**). The cavity (**1110**) and the component compartment (**1120**) are functionally distinct spaces within the housing that may optionally be separated by a partition or integrated into a contiguous space to form an interconnected internal structure. Suitably, the housing (**1100**) is equipped with an access door (**1130**) that is either integrated into or operatively attached to the housing (**1100**). The access door (**1130**) is used to provide access to the cavity (**1110**) for placing the luggage inside and to enclose the cavity (**1110**) during scanning. **FIG. 1c** illustrates the baggage scanner (**1000**) having its access door (**1130**) opened to provide access to the cavity (**1110**). The access door (**1130**) may be a hinged or sliding door assembly, wherein the sliding door assembly could be an automated sliding door assembly with the actuation of the sliding door assembly controlled by the controller unit (**1410**) of the processing module (**1400**). Additionally, the access door (**1130**) may be equipped with a door sensor to detect a current state of the access door (**1130**), whether it is open or closed. The door sensor is connected to the controller unit (**1410**) to indicate the current state of the access door (**1130**).

The cavity (**1110**) is configured to accommodate luggage for scanning. The cavity (**1110**) is defined by a base (**1140**) of the housing (**1100**) at its bottom, a sidewall of the housing (**1100**) at its first side, a rear wall of the housing (**1100**) at its second side, an opening enclosable by the access door (**1130**) at its third side and a connection to the component compartment (**1120**) at its fourth side. The second side of the cavity (**1110**) may be a rear side of the cavity (**1110**) while the third side of the cavity (**1110**) may be a front side of the cavity (**1110**).

The component compartment (**1120**) is used to house certain functional components of the baggage scanner (**1000**). Preferably, the component compartment (**1120**) is used to house the X-ray source module (**1200**), the processing module (**1400**) and the power source module (**1500**). The component compartment (**1120**) may also include ventilation and cooling module so as to

dissipate heat generated during operation of those functional components in the component compartment (**1120**).

The X-ray source module (**1200**) is configured to produce and emit at least one X-ray beam at one or multiple energies for scanning the luggage placed in the cavity (**1110**) of the baggage scanner (**1000**). Preferably, the at least one X-ray beam is emitted in a cone shaped beam. The X-ray source module (**1200**) is connected to the processing module (**1400**), wherein the controller unit (**1410**) of the processing module (**1400**) controls the emission of the at least one X-ray beam. For the emission of X-ray beam at multiple energies, the controller unit (**1410**) suitably alternates the emission of X-ray beam at different energies during specified emission intervals.

The X-ray source module (**1200**) includes at least one mono-block generator and at least one X-ray tube. For the X-ray source module (**1200**) having the number of mono-block generators less than the number of the X-ray tubes, the X-ray source module (**1200**) may further include a switching unit.

The mono-block generator is configured to convert electrical power supplied from the power source module (**1500**) into a high-voltage output necessary for operating the X-ray tube. Additionally, the mono-block generator regulates the high-voltage output to ensure stable and precise energy delivery for producing X-ray radiation by the X-ray tube. The mono-block generator is controlled by the controller unit (**1410**) of the processing module (**1400**). The mono-block generator is connected to the controller unit (**1410**) and the power source module (**1500**).

The at least one X-ray tube is a cold cathode X-ray tube, preferably a carbon nanotube X-ray tube. The cold cathode X-ray tube is a type of X-ray generation device that uses a cathode to emit a stream of electrons without heating, whereby the emitted electrons are accelerated toward a target material to produce an X-ray radiation beam. Thus, the use of the cold cathode X-ray source eliminates the need for a cooling system or module to dissipate the heat from a heated filament. Preferably, the cold cathode X-ray tube utilises field emission to produce the stream of electrons.

FIG. 4 illustrates a cross-sectional view of the X-ray tube (**1220**), wherein the X-ray tube (**1220**) includes a vacuum envelope (**1221**) housing an electron-emitting cathode (**1222**) at one end and a target anode (**1223**) at the opposite end. The electron-emitting cathode (**1222**) includes a field emitter layer (**1224**) deposited on a substrate (**1225**), wherein the field emitter layer (**1224**) is composed of carbon nanotube, diamond-like carbon, tungsten or any other low-work-function materials. Preferably, the field emitter layer (**1224**) is composed of carbon nanotubes. The target anode (**1223**) is made of a high atomic number material, such as tungsten and molybdenum. The surface of the target anode (**1223**) is tilted at an angle to direct X-ray radiation toward an output window (**1226**) of the vacuum envelope (**1221**), wherein the output window (**1226**) is suitably provided with a collimator to shape and direct the X-ray radiation into a cone-shaped X-ray beam. The electron-emitting cathode (**1222**) is electrically connected to a negative terminal of the mono-block generator while the target anode (**1223**) is electrically connected to a positive terminal of the mono-block generator, wherein either of those connections may be a direct connection or an indirect connection. When a high voltage is applied between the electron-emitting cathode (**1222**) and the target anode (**1223**) by the mono-block generator, a strong electric field causes a stream of electrons to be emitted and accelerated from the field emitter layer (**1224**) towards the target anode (**1223**), where they collide and produce bremsstrahlung radiation or X-ray radiation. The electric field reduces the potential barrier between the surface of the field emitter layer (**1224**) and vacuum, allowing electrons to be emitted without the need for heat. The X-ray radiation produced in the X-ray tube (**1220**) is directed through the output window (**1226**), forming an X-ray beam.

Additionally, the vacuum envelope (**1221**) is preferably incorporated with a focusing electrode and a grid electrode positioned between the electron-emitting cathode (**1222**) and the target anode (**1223**). The focusing electrode is used to concentrate the stream of electrons emitted by the electron-emitting cathode (**1222**) onto a focal spot of the target anode (**1223**). The grid electrode is used control or filter the flow of electrons to reduce the impact of scattered electrons. Advantageously, the incorporation of the focusing electrode and grid electrode improves the control and focusing of the stream of electrons, resulting in a more condensed and directional X-ray beam.

Described herein below the different configurations that may be adapted for the X-ray source module (**1200**). According to a first configuration of the X-ray source module (**1200**), the X-ray source module (**1200**) includes one X-ray tube (**1220**) and one mono-block generator (**1210**), wherein the X-ray tube (**1220**) is electrically connected to the mono-block generator (**1210**) as illustrated in **FIG. 5a**. The X-ray tube (**1210**) and the mono-block generator (**1210**) are attached to a vertical support structure (**1230**) as illustrated in **FIG. 5b**. Suitably, the X-ray tube (**1220**) is attached to the vertical support structure (**1230**) at a height that optimises the coverage of the emitted X-ray beam (**20**) to the luggage (**10**). The vertical support structure (**1230**) is mounted to the base (**1140**) of the housing (**1100**) and located within the component compartment (**1120**) near the cavity (**1110**). This is so that the X-ray beam (**20**) emitted from the X-ray tube (**1220**) can be directed towards the luggage (**10**) in the cavity (**1110**) without obstruction or interference. Additionally, the vertical support structure (**1230**) may be equipped with a linear actuator assembly to allow vertical movement of the X-ray tube (**1220**) during scanning, wherein the linear actuator assembly is electrically controlled by the processing module (**1400**). With the vertical movement of the X-ray tube (**1220**), a wider coverage area of the X-ray beam can be attained by the single X-ray tube (**1220**). For instance, the X-ray tube (**1220**) can be moved upwards to emit the X-ray beam covering an upper portion of the luggage and then, it can be moved downwards to emit the X-ray beam covering a lower portion of the luggage.

According to a second configuration of the X-ray source module (**1200**), the X-ray source module (**1200**) includes six X-ray tubes (**1220a–1220f**), a switching unit (**1240**) and one mono-block generator (**1210**). **FIG. 6a** shows a block diagram of the X-ray source module (**1200**) according to the second configuration. The switching unit (**1240**) is connected to each X-ray tube (**1220a–1220f**), the mono-block generator (**1210**) and the processing module (**1400**).

The switching unit (**1240**) manages the high voltage supply from the mono-block generator (**1210**) to multiple X-ray tubes (**1220a–1220f**). The switching unit (**1240**) is controlled by the processing module (**1400**). The switching unit (**1240**) is configured to alternate the high-voltage supply between the X-ray tubes (**1220a–1220f**). This is so that each X-ray tube (**1220a–1220f**) emits its X-ray beam at a specific time interval. It may also be configured for a pair of X-ray tubes (**1220a–**

1220f) to emit their X-ray beams at a specific time interval. Suitably, the switching unit (**1240**) may comprise a combination of electronic switches, wherein these switches selectively direct the high-voltage output from the mono-block generator (**1210**) to one or more desired X-ray tubes (**1220**). The switching unit (**1240**) may also include isolation circuitry to prevent interference or backflow of voltage between inactive X-ray tubes, as well as a protective circuitry to safeguard against overvoltage or misalignment during switching. The isolation circuitry and protective circuitry are suitably connected to each output of the electronic switches.

Each X-ray tube (**1220a–1220f**), the mono-block generator (**1210**), and the switching unit (**1240**) are mounted to a vertical support structure (**1230**) as illustrated in **FIGS. 6(b-c)**. A pair of X-ray tubes (**1220a–1220f**) is mounted at each height level of the vertical support structure (**1230**), wherein a first X-ray tube (**1220a**) is mounted at a same height level as a second X-ray tube (**1220b**), a third X-ray tube (**1220c**) is mounted at a same height level as a fourth X-ray tube (**1220d**), and a fifth X-ray tube (**1220e**) is mounted at a same height level as a sixth X-ray tube (**1220f**). The vertical support structure (**1230**) is mounted to the base (**1140**) of the housing (**1100**) and located within the component compartment (**1120**) near the cavity (**1110**). This is so that the X-ray beams emitted from the X-ray tubes (**1220a–1220f**) can be directed towards the luggage (**10**) in the cavity (**1110**) without obstruction or interference.

According to a third configuration, the number of X-ray tube (**1220**) is the same as the number of mono-block generators (**1210**). Each mono-block generator (**1210**) is dedicated to one X-ray tube (**1220**), wherein each mono-block generator (**1210**) is controlled by the processing module (**1400**) for the emission interval of each X-ray tube (**1220**). The X-ray tubes (**1220**) and/or mono-block generators (**1210**) are mounted to a vertical support structure mounted to the base of the housing (**1100**). Preferably, a pair of X-ray tube is mounted at each height level of the vertical support structure similar to the arrangement of the second configuration of the X-ray source module (**1200**). The vertical support structure is located within the component compartment (**1120**) near the cavity (**1110**).

The X-ray detector module (**1300**) is configured to capture and measure the transmitted X-ray beam. The transmitted X-ray beam is the X-ray beam emitted by the X-ray source module (**1200**) that may interact with the luggage being scanned.

The X-ray detector module (**1300**) converts the transmitted X-ray beam into one or more X-ray raw data which correlates with the transmittance and attenuation characteristics of the transmitted X-ray beam, wherein each X-ray raw data corresponds to a particular angular position and a specific energy level of the emitted X-ray beam. The X-ray raw data refers to a collection of data points representing the intensity measurement of the transmitted X-ray beam detected at corresponding spatial positions. The X-ray detector module (**1300**) is connected to the processing module (**1400**) to transmit the X-ray raw data. The X-ray detector module (**1300**) includes at least one X-ray detector such as a flat panel detector, a charge-coupled device or CCD detector, complementary metal-oxide semiconductor or CMOS detector, photodiode detector, scintillator detector or any other types of X-ray detectors. Preferably, the X-ray detector is a flat panel detector.

The X-ray detector module (**1300**) is suitably integrated into or attached to the inner sidewall of the housing (**1100**) that defines the first side of the cavity (**1110**). Thus, the X-ray detector module (**1300**) is located at an opposing side of the X-ray source module (**1200**) so as to effectively capture and measure the transmitted X-ray beam. In a configuration whereby the X-ray detector module (**1300**) includes multiple X-ray detectors, a first X-ray detector is positioned above a second X-ray detector. This is so that the arrangement of the multiple X-ray detectors covers a wider area to capture the transmitted X-ray beam.

The processing module (**1400**) is configured to manage the operation of the baggage scanner (**1000**) and generate at least one X-ray image based on the captured radiation from the X-ray detector. The at least one X-ray image may include at least one projection image which is a planar X-ray image of the luggage captured from a specific angular position, a volumetric image which is a three-dimensional or 3D X-ray image of the scanned luggage, at least one sum grayscale image, at least one material-discriminated image, at least one object-stripped image or at least one material-separated image. The processing module is electrically connected to the X-ray source module (**1200**), X-ray detector module (**1300**), power source module (**1500**), control panel (**1600**) and rotary platform (**1700**), wherein these connections facilitate data control and transmission for managing the operations of the baggage scanner (**1000**) and generating the at least one X-ray image. The processing module (**1400**) suitably includes the controller unit (**1410**) and the image processing unit

(**1420**), wherein the controller unit (**1410**) is connected to the image processing unit (**1420**). The processing module (**1400**) may also include other necessary components essential for its operation, such as a memory unit for data storage, a communication interface for connectivity, and etc. Although the processing module (**1400**) is described as comprising the controller unit (**1410**) and image processing unit (**1420**), it is appreciated that the controller unit (**1410**) and the image processing unit (**1420**) may be combined as a single integrated unit or component.

The controller unit (**1410**) is configured to manage and coordinate the operational functions of the baggage scanner (**1000**), wherein the controller unit (**1410**) is connected to the X-ray source module (**1200**), X-ray detector module (**1300**), power source module (**1500**), control panel (**1600**), rotary platform (**1700**) and image processing unit (**1420**) for data transmission and control.

Particularly, the controller unit (**1410**) is configured to control and synchronise the activation and deactivation of the X-ray source module (**1200**) and X-ray detector module (**1300**). This is to ensure that the X-ray detector module (**1300**) is active and ready to capture the transmitted X-ray beam when the X-ray source module (**1200**) emits the X-ray beam. The controller unit (**1410**) is also configured to activate and deactivate the X-ray tube (**1220**) of the X-ray source module (**1200**) at different emission interval. This allows the X-ray detector module (**1300**) to distinguish between the transmitted X-ray beams at different angular positions of the luggage and thereby, producing multiple X-ray raw data at various angular positions of the luggage. For the configuration of the X-ray source module (**1200**) having multiple X-ray tubes (**1220**), the controller unit (**1410**) also activates and deactivates one or more X-ray tubes (**1220**) at different emission intervals. This is to prevent overlapping or conflicting beams that could compromise the accuracy and quality of the X-ray image.

The controller unit (**1410**) is also configured to display the at least one X-ray image on the control panel (**1600**), wherein the X-ray image is obtained from the image processing unit (**1420**). The controller unit (**1410**) may also be connected to a remote monitoring device to transmit the X-ray image, wherein the remote monitoring device may either be a server, a computer, a laptop, or any other suitable computing entity. The connection between the controller unit (**1410**) and the remote monitoring

device may either be through a wireless or wired network. The controller unit (**1410**) may also transmit current operating condition of the baggage scanner (**1000**) and alerts to the remote monitoring device.

The controller unit (**1410**) is also configured to process user input from the control panel (**1600**), with the specific processing depending on the type of user input provided through the control panel (**1600**). The controller unit (**1410**) processes user input by interpreting commands from the control panel (**1600**) and converting the commands into actionable instructions for the baggage scanner (**1600**). As an example, when a user inputs to stop scanning through the control panel (**1600**), the controller unit (**1410**) sends a command signal to the X-ray source module (**1200**) and the X-ray detector module (**1300**) to stop emitting and capturing the X-ray beam. As another example, when a user inputs to start scanning through the control panel (**1600**), the controller unit (**1410**) sends a command signal to actuate the access door (**1130**) to close and the controller unit also sends another command signal to the X-ray source module (**1200**) and the X-ray detector module (**1300**) to start scanning once the access door (**11300**) is closed.

The controller unit (**1410**) may also be configured to control and monitor the power supply of the baggage scanner (**1000**) through its connection with the power source module (**1500**). The controller unit (**1410**) may send command signals to the power source module (**1500**) to start or stop the supply of electrical power. Moreover, the controller unit (**1410**) may obtain one or more parameters such as temperature, voltage, current and power levels from the power source module (**1500**) to ensure that the baggage scanner (**1000**) is operating within safe limits. The controller unit (**1410**) may trigger an alert through the control panel (**1600**) if the controller unit (**1410**) determines one or more parameters obtained exceed or fall below normal operating thresholds.

The controller unit (**1410**) may also be configured to control the rotation motion of the rotary platform (**1700**). Specifically, the controller unit (**1410**) sends electrical or digital control signals to the rotary platform (**1700**) resulting in the rotational motion of the luggage in the cavity (**1110**). Additionally, the controller unit (**1410**) is also configured to synchronise the rotation speed of the rotary platform (**1700**) with the activation of the X-ray source module (**1200**) and the X-ray detector

module (**1300**). This is so that the X-ray detector module (**1300**) captures the transmitted X-ray beam at specific angular positions and specific emission intervals as the rotary platform (**1700**) rotates the luggage. The controller unit tracks the angular positions from the rotary platform (**1700**) to ensure that a full or partial rotation has been completed.

The controller unit (**1410**) may also be configured to actuate the access door (**1130**) for closing and opening the cavity (**1110**). Moreover, the controller unit (**1410**) may also detect whether the access door (**1130**) is close or open through the door sensor. The controller unit (**1410**) does not activate the X-ray source module (**1200**) to emit its X-ray beam unless the access door (**1130**) is closed. If the controller unit (**1410**) detects that the access door (**1130**) is opened during scanning, the controller unit (**1410**) deactivates the X-ray source module (**1200**) to stop emitting X-ray beam. This is to ensure that the X-ray source module (**1200**) does not emit the X-ray beam whenever the access door (**1130**) is left open.

The image processing unit (**1420**) is configured to generate one or more X-ray images from the X-ray raw data, wherein the X-ray images may include the at least one projection image, the volumetric image, the at least one sum grayscale image, the at least one material-discriminated image, the at least one object-stripped image or the at least one material-separated image. Prior to generating the X-ray images, the image processing unit (**1420**) is suitably configured to perform image pre-processing on the X-ray raw data. The image pre-processing may include one or more computational tasks such as noise reduction, edge enhancement, contrast enhancement, geometric calibration, distortion correction, scatter correction, flat-field correction or any other pre-processing tasks.

The image processing unit (**1420**) may generate one or more projection images by converting the X-ray raw data into an image format, wherein each projection image refers to a planar X-ray image of the luggage captured from a specific angular position. After generating the projection images, the image processing unit (**1420**) may generate one or more sum grayscale images by registering and summing the grayscale values at corresponding pixel positions across multiple projection images of the similar angular position but at varying energy levels of the emitted X-ray beams.

The image processing unit (**1420**) may generate one or more material-discriminated images, wherein each material-discriminated image is suitably generated by computing a ratio between attenuation values at different energy levels for each corresponding data point at the same spatial position across multiple X-ray raw data from the same angular position, wherein each X-ray raw data corresponds to the X-ray beam emitted at a specific energy level; comparing each computed ratio to one or more material classification curves and their interpolated ranges, and classifying each corresponding data point as a particular material type if its computed ratio corresponds to the material classification curve or its interpolated range associated with the particular material type; and converting the X-ray raw data, with one or more material types attributed to corresponding data points, into the material-discriminated image for a specific angular position. After generating the material-discriminated images, the image processing unit (**1420**) may further generate one or more object-stripped images by identifying and isolating one or more objects of interest through the suppression or removal of non-relevant background data and unwanted objects within the material-discriminated images. Each object-stripped image corresponds to a specific angular position of the luggage. Additionally, the image processing unit (**1420**) may also generate the at least one material-stripped image by computationally removing or suppressing unwanted materials while retaining one or more specific materials of interest in the material-discriminated images. Each material-stripped image corresponds to a specific angular position of the luggage.

Preferably, the image processing unit (**1420**) generates or reconstructs the volumetric image of the luggage from multiple projection images or the material-discriminated images at different angular positions of the luggage. The volumetric image is a three-dimensional or 3D X-ray image of the luggage. By applying a computational reconstruction technique such as filtered back-projection, iterative reconstruction, and algebraic reconstruction technique, the image processing unit (**1420**) combines multiple projection images or material-discriminated images of the luggage at various angular positions to reconstruct the volumetric image of the luggage.

Additionally, the image processing unit (**1420**) may be equipped with an Artificial Intelligence or AI model so that the image processing unit (**1420**) is suitably configured to automatically recognise and detect any prohibited items such as a weapon, an explosive, liquid, aerosol, or contraband from either the volumetric image or the material discrimination images. The AI model recognises and detects any prohibited items based on shape profile and material type of prohibited items. The AI model may include Convolutional Neural Network or CNN, Region-based CNN, You Only Look Once or YOLO, Single Shot Multi-Box Detector or SSD, Generative Adversarial Network or GAN, or any other suitable AI models. The AI model is suitably pre-trained with datasets containing shape profiles and material composition of both general and prohibited items.

The image processing unit (**1420**) is connected to the controller unit (**1410**) to transmit the X-ray images generated for display. The X-ray images may include the the at least one projection image, the volumetric image, the at least one sum grayscale image, the at least one material-discriminated image, the at least one object-stripped image or the at least one material-separated image.

The power source module (**1500**) is configured to supply and manage electrical power required for the baggage scanner (**1000**). Preferably, the power source module (**1500**) includes a high-power generator. The high-power generator may source its electrical power from an electrical grid, batteries, or any other energy sources. The electrical power output from the high-power generator is distributed to the X-ray source module (**1200**), the X-ray detector module (**1300**), the processing module (**1400**), the control panel (**1600**) and the rotary platform (**1700**). Additionally, the power source module (**1500**) may suitably include other power management components or circuitry, such as a voltage regulator, a current control circuit, a rectifier circuit, an overload protection unit, circuit breakers, a surge protection unit, and a power distribution unit.

The control panel (**1600**) is configured to facilitate user input and display information related to the operation of the baggage scanner (**1000**). The control panel (**1600**) suitably includes a display unit, a touchscreen overlay integrated with the display unit, and at least one input button. The display unit is configured to present visual information to a user. The visual information that may suitably be displayed by

the display unit includes one or more X-ray images of the scanned luggage, instruction guide, error notification, baggage scanner status and settings. The display unit may be a Liquid Crystal Display, an Organic Light-Emitting Diode or OLED display or any other type of display component. The display unit is electrically connected to the processing module (**1400**) to obtain visual information to be displayed. The touchscreen allows touch-based input from the user corresponding to the visual information displayed by the display unit. The touchscreen is electrically connected to the processing module (**1400**) to transmit the user input from touch interactions. The at least one input button is a tactile switch used to receive tactile input from the user. The at least one button may include a power button, emergency halt button or any additional function keys for various control operations of the baggage scanner (**1000**). The at least one input button is electrically connected to the processing module (**1400**) to transmit the user input when pressed.

The control panel (**1600**) is mounted to at least one dedicated area of the housing (**1100**), with its components positioned to ensure user accessibility and secure integration. The at least one dedicated area may include a designated recess or aperture of the housing. The input button, such as the power button, may be located separately from the display unit and touchscreen so as to prevent inadvertent pressing.

The rotary platform (**1700**) is configured for rotational positioning of the luggage placed in the cavity (**1110**). By rotating the luggage, different views of the luggage could be scanned to generate multiple projection images of the luggage at different angular positions. Preferably, the rotary platform (**1700**) comprises a rotating plate, a drive mechanism, a motor, a motor driver and a position encoder.

The rotating plate is adapted to support the luggage placed in the cavity (**1110**). The rotary plate can be mounted to the bottom surface of the cavity (**1110**). Alternatively, the rotary plate can be constructed as an integral part of the cavity's bottom surface. The rotating plate suitably incorporates an anti-slip feature to prevent displacement of the luggage during rotation. Such anti-slip feature may either be a rubberised coating, a textured surface, raised edge or any other means to secure the luggage during rotation.

The rotating plate is coupled to the drive mechanism, wherein the drive mechanism is used for transmitting rotational force from the motor to the rotating plate. The drive mechanism can be a gear assembly, a shaft assembly, a belt drive or any other suitable means for the transmission of rotational force. The drive mechanism is further coupled to the motor. Optionally, the rotating plate may be coupled directly to the motor, eliminating the need for the drive mechanism.

The motor is the source of rotational motion of the drive mechanism and the rotating plate, wherein the motor converts an electrical energy to rotational motion. The motor may be an alternating current motor, a direct current motor, a stepper motor or any other suitable motor. The motor is electrically connected to the motor driver.

The motor driver is configured to regulate and modulate the electrical energy supplied to the motor to induce the rotational motion. The motor driver is further connected to the controller unit (**1410**) to control the rotation of the rotating plate.

The position encoder is used to provide feedback on the angular position of the rotating plate. The position encoder is coupled to either the drive mechanism, the motor or the rotating plate. Alternatively, the motor may be equipped with the position encoder. The position encoder is electrically connected to the controller unit (**1410**).

In addition to the rotating plate, drive mechanism, motor, motor driver and position encoder, the rotary platform (**1700**) may also include other components such as a support ring that is used to stabilise the rotating plate. Preferably, the drive mechanism, motor, motor driver and position encoder are integrated into the base of the housing (**1100**).

Although it has been described that the baggage scanner (**1000**) includes the rotary platform (**1700**), the rotary platform (**1700**) may be excluded from the baggage scanner (**1000**) without departing from the scope of the invention. The exclusion of the rotary platform (**1700**) would limit the image processing unit (**1420**) to generating only one projection image from the X-ray raw data and thereby, preventing the reconstruction of a volumetric image of the luggage. However, the image processing

unit (**1420**) may still be able to generate a sum grayscale image, a material-discriminated image, an object-stripped image or a material-separated image.

Suitably, the baggage scanner (**1000**) is configured as a compact device. This is due to the use of the cold cathode X-ray tube as the at least one X-ray tube that does not require a cooling system specifically for heated filament. Moreover, the arrangement and integration of the X-ray source module (**1200**), X-ray detector module (**1300**), processing module (**1400**), and power source module (**1500**) within the housing (**1100**) further contributes to the compact form factor of the baggage scanner (**1000**). As a result, the overall footprint of the baggage scanner (**1000**) is reduced compared to a typical baggage scanner, allowing multiple baggage scanners (**1000**) to occupy a space normally required for a single unit of the typical baggage scanner.

Referring to **FIG. 7**, there is illustrated a flowchart of a method for scanning at least one piece of luggage according to a first embodiment of the present invention. The at least one piece of luggage is scanned by using the baggage scanner (**1000**) as illustrated in **FIGS. 1-3**. Initially, the at least one piece of luggage such a bag or a suitcase is placed into the cavity (**1110**) of the housing (**1100**) as in step **2001**. Multiple pieces of luggage may be placed within the cavity provided that they can be contained inside it without causing load imbalance or affecting the operation of the rotary platform (**1700**).

In step **2002**, the access door (**1130**) is closed either manually or automatically from a user input through the control panel (**1600**).

In step **2003**, the controller unit (**1410**) of the processing module (**1400**) checks the current state of the access door (**1130**) from the door sensor. If the current state of the access door (**1130**) is open, the processing module (**1400**) sends an alert notification to the user at the control panel (**1600**) as in decision **2004** and step **2005**. Thereon, the method returns to step **2002**.

If the current state of access door (**1130**) is closed, the processing module (**1400**) activates the X-ray source module (**1200**), X-ray detector module (**1300**), and the rotary platform (**1700**) as in decision **2004** and step **2006**. Thus, the X-ray source

module (**1200**) emits X-ray beam towards the at least one piece of luggage within the cavity (**1110**) at different emission intervals as the rotary platform (**1700**) rotates the at least one piece of luggage. For the configuration of the X-ray source module (**1200**) having multiple X-ray tubes (**1220**), one or more X-ray tubes (**1220**) alternately emits their X-ray beams at different emission intervals, wherein the emission of the X-ray beams are controlled by the controller unit (**1410**) through either the mono-block generator (**1210**) or the switching unit (**1240**).

On the other hand, the X-ray detector module (**1300**) captures and measures the transmitted X-ray beams which are the emitted X-ray beams that may interact with the at least one piece of luggage in the cavity (**1110**). The transmitted X-ray beams are converted into one or more X-ray raw data, wherein each X-ray raw data corresponds to a particular angular position of the at least on piece of luggage and a specific energy level of the emitted X-ray beam. The X-ray raw data is subsequently transmitted to the image processing unit (**1420**) of the processing module (**1400**).

Thereon, the image processing unit (**1420**) performs image pre-processing on each X-ray raw data as in step **2007**. The image pre-processing may include one or more computational tasks such as noise reduction, edge enhancement, contrast enhancement, geometric calibration, distortion correction, scatter correction, flat-field correction or any other pre-processing tasks.

Once the image pre-processing has been performed, the image processing unit (**1420**) generates one or more X-ray images as in step **2008**, wherein the X-ray images may include the at least one projection image, the volumetric image, the at least one sum grayscale image, the at least one material-discriminated image, the at least one object-stripped image or the at least one material-separated image.

The image processing unit (**1420**) suitably generates one or more projection images by converting the X-ray raw data into an image format, wherein each projection image refers to a planar X-ray image of the luggage captured from a specific angular position. After generating the projection images, the image processing unit (**1420**) may generate one or more sum grayscale images by registering and summing the grayscale values at corresponding pixel positions

across multiple projection images of the similar angular position but at varying energy levels of the emitted X-ray beams.

The image processing unit (**1420**) may generate one or more material-discriminated images. Each material-discriminated image is suitably generated by computing a ratio between attenuation values at different energy levels for each corresponding data point at the same spatial position across multiple X-ray raw data from the same angular position, wherein each X-ray raw data corresponds to the X-ray beam emitted at a specific energy level; comparing each computed ratio to one or more material classification curves and their interpolated ranges, and classifying each corresponding data point as a particular material type if its computed ratio corresponds to the material classification curve or its interpolated range associated with the particular material type; and converting the X-ray raw data, with one or more material types attributed to corresponding data points, into the material-discriminated image for a specific angular position.

After generating the material-discriminated images, the image processing unit (**1420**) may further generate one or more object-stripped images by identifying and isolating one or more objects of interest through the suppression or removal of non-relevant background data and unwanted objects within the material-discriminated images. Each object-stripped image corresponds to a specific angular position of the luggage. Additionally, the image processing unit (**1420**) may also generate the material-stripped image by computationally removing or suppressing unwanted materials while retaining one or more specific materials of interest in the material-discriminated images. Each material-stripped image corresponds to a specific angular position of the luggage.

The image processing unit (**1420**) suitably generates or reconstructs the volumetric image of the luggage from multiple projection images or the material-discriminated images. The volumetric image is a three-dimensional or 3D X-ray image of the luggage. Specifically, the image processing unit (**1420**) reconstructs the volumetric image by combining multiple projection images or material-discriminated images of the luggage at various angular positions using a computational reconstruction technique such as filtered back-projection, iterative reconstruction, and algebraic reconstruction technique.

The X-ray images are then transmitted to the controller unit (**1410**). In step **2009**, the controller unit (**1410**) displays the X-ray images generated at the control panel (**1600**). The controller unit (**1410**) may also transmit the X-ray images to a remote monitoring device.

Referring to **FIG. 8**, there is illustrated a flowchart of a method for scanning at least one piece of luggage according to a second embodiment of the present invention. The at least one piece of luggage is scanned suitably by using the baggage scanner (**1000**) as illustrated in **FIGS. 1-3**. Initially, the at least one piece of luggage such a bag or a suitcase is placed into the cavity (**1110**) of the housing (**1100**) as in step **3001**. Multiple pieces of luggage may be placed within the cavity provided that they can be contained inside it without causing load imbalance or affecting the operation of the rotary platform (**1700**).

In step **3002**, the access door (**1130**) is closed manually or automatically from a user input through the control panel (**1600**).

In step **3003**, the controller unit (**1410**) of the processing module (**1400**) checks the current state of the access door (**1130**) from the door sensor. If the current state of the access door (**1130**) is open, the processing module (**1400**) sends an alert notification to the user at the control panel (**1600**) as in decision **3004** and step **3005**. Thereon, the method returns to step **3002**.

If the current state of access door (**1130**) is closed, the processing module (**1400**) activates the X-ray source module (**1200**), X-ray detector module (**1300**), and the rotary platform (**1700**) as in decision **3004** and step **3006**. This causes the X-ray source module (**1200**) to emit one or more X-ray beams towards the at least one piece of luggage within the cavity (**1110**) as the rotary platform (**1700**) rotates the at least one piece of luggage.

For the configuration of the X-ray source module (**1200**) having multiple X-ray tubes (**1220**), one or more X-ray tubes (**1220**) emit their X-ray beams at different energy levels during different emission intervals, wherein the emission of the X-ray beams are controlled by the controller unit (**1410**) through either the mono-block

generator (**1210**) or the switching unit (**1240**). As an example of the second configuration of the X-ray module (**1200**), the controller unit (**1410**) triggers the first and second X-ray tubes (**1220a**, **1220b**) to emit their X-ray beams at a low energy level during a first emission interval, the third and fourth X-ray tubes (**1220c**, **1220d**) to emit their X-ray beams at a low energy level during a second emission interval, the fifth and sixth X-ray tubes (**1220e**, **1220f**) to emit their X-ray beams at a low energy level during a third emission interval, the first and second X-ray tubes (**1220a**, **1220b**) to emit their X-ray beams at a high energy level during a fourth emission interval, the third and fourth X-ray tubes (**1220c**, **1220d**) to emit their X-ray beams at a high energy level during a fifth emission interval, the fifth and sixth X-ray tubes (**1220e**, **1220f**) to emit their X-ray beams at a high energy level during a sixth emission interval. The controller unit (**1410**) triggers the emission of the X-ray beams at low and high energy levels during different emission intervals by controlling the mono-block generator (**1210**) and the switching unit (**1240**). The rotation speed of the rotary platform (**1700**) is synchronised to ensure that all of the X-ray beams are emitted towards the at least one piece of luggage at the same angular position throughout these emission intervals. As the rotary platform (**1700**) rotates, the first until the sixth emission intervals are repeated for different angular positions of the at least one piece of luggage until a full rotation is completed.

Meanwhile, the X-ray detector module (**1300**) captures and measures the transmitted X-ray beams which are the emitted X-ray beams that may interact with the at least one piece of luggage in the cavity (**1110**). The X-ray detector module (**1300**) converts captured and measured the transmitted X-ray beam into multiple X-ray raw data which correlates with the transmittance and attenuation characteristics of the transmitted X-ray beam, wherein each X-ray raw data corresponds to a particular angular position and a specific energy level of the emitted X-ray beam. The X-ray raw data refers to a collection of data points representing the intensity measurement of the transmitted X-ray beam detected at corresponding spatial positions. The X-ray raw data is subsequently transmitted to the image processing unit (**1420**) of the processing module (**1400**).

In step **3007**, the image processing unit (**1420**) performs image pre-processing on each X-ray raw data. The image pre-processing may include one or more computational tasks such as noise reduction, edge enhancement, contrast

enhancement, geometric calibration, distortion correction, scatter correction, flat-field correction or any other pre-processing tasks.

Once the image pre-processing has been performed, the image processing unit (**1420**) generates a material-discriminated image for each angular position of the luggage captured by the X-ray detector module (**1300**) as in step **3008**. Preferably, each material-discriminated image is generated by computing a ratio between attenuation values at different energy levels for each corresponding data point at the same spatial position across multiple X-ray raw data from the same angular position, wherein each X-ray raw data corresponds to the X-ray beam emitted at a specific energy level; comparing each computed ratio to one or more material classification curves and their interpolated ranges, and classifying each corresponding data point as a particular material type if its computed ratio corresponds to the material classification curve or its interpolated range associated with the particular material type; and converting the X-ray raw data, with one or more material types attributed to corresponding data points, into the material-discriminated image for a specific angular position.

In step **3009**, the image processing unit (**1420**) reconstructs a volumetric image of the luggage from the multiple material discrimination images, wherein the volumetric image is a three-dimensional or 3D X-ray image of the luggage. Specifically, the image processing unit (**1420**) reconstructs the volumetric image by combining multiple material discrimination images of the luggage at different angular positions, using a computational reconstruction technique such as filtered back-projection, iterative reconstruction, and algebraic reconstruction technique.

In step **3010**, the image processing unit (**1420**) recognises and detects any prohibited items such as weapons, explosives, liquid, aerosol, or contraband in the at least one piece of luggage based on either the volumetric image or the multiple material discrimination images. Preferably, the image processing unit (**1420**) determines whether there are any prohibited items in the at least one piece of luggage by applying its AI model to the volumetric image or each material discrimination image. The AI model recognises and detects any prohibited items by extracting one or more key features such as edges, curves, textures, and patterns from the volumetric image or each material discrimination image in order to identify

each item in the at least one piece of luggage, determining whether the shape profile and material type of each identified items are associated with any prohibited items. The AI model used may include Convolutional Neural Network or CNN, Region-based CNN, You Only Look Once or YOLO, Single Shot Multi-Box Detector or SSD, Generative Adversarial Network or GAN, or any other suitable AI models; wherein the AI model is suitably pre-trained with datasets containing shape profiles and material composition of both general and prohibited items.

If there are no prohibited items recognised and detected, the image processing unit (**1420**) notifies the controller unit (**1410**) that there are no prohibited items found in the luggage and the controller unit (**1410**) sends a notification to the user through the control panel (**1600**) to state that the at least one piece of luggage has passed the security screening as in decision **3011** and step **3012**. At the same time, the image processing unit (**1420**) may also transmit the volumetric image or the multiple material discrimination images to the controller unit (**1410**) which then relays them to a remote monitoring device. Thereon, the access door (**1130**) is opened for the retrieval of the at least one piece of luggage.

If there are any prohibited items recognised and detected, the image processing unit (**1420**) flags to the controller unit (**1410**) that there are prohibited items found in the luggage and the controller unit (**1410**) sends an alert notification to the user through the control panel (**1600**) to state that the luggage has failed the security screening as in decision **3011** and step **3013**. At the same time, the image processing unit (**1420**) may also transmit the volumetric image or the multiple material discrimination images to the controller unit (**1410**) which then relays them to the remote monitoring device with an alert to notify that one or more prohibited items have been found. Each prohibited item recognised and detected is suitably highlighted in the volumetric image or the multiple material discrimination images transmitted to the remote monitoring device.

While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specifications are words of description rather than limitation and various changes may be made without departing from the scope of the invention.

CLAIMS

1. A baggage scanner (**1000**) for scanning at least one piece of luggage comprising:
    a) an X-ray source module (**1200**) configured to produce and emit at least one X-ray beam,
    b) an X-ray detector module (**1300**) configured to capture and measure transmitted X-ray beam, wherein the transmitted X-ray beam is the at least one X-ray beam emitted by the X-ray source module (**1200**) that may interact with the at least one piece of luggage, wherein the X-ray detector module (**1300**) includes at least one X-ray detector,
    c) a control panel (**1600**) configured to facilitate user input and display information related to the operation of the baggage scanner (**1000**),
    d) a power source module (**1500**) configured to supply and manage electrical power required for the baggage scanner (**1000**), wherein power source module (**1500**) is connected to the X-ray source module (**1200**), X-ray detector module (**1300**), and control panel (**1600**), and
    e) a processing module (**1400**) configured to manage the operation of the baggage scanner (**1000**) and generate at least one X-ray image, wherein the processing module (**1400**) is connected to the X-ray source module (**1200**), X-ray detector module (**1300**), power source module (**1500**), and control panel (**1600**);

characterised in that:

the baggage scanner (**1000**) further includes a housing (**1100**) for integrating and supporting the X-ray source module (**1200**), the X-ray detector module (**1300**), the processing module (**1400**), the power source module (**1500**), and the control panel (**1600**), wherein the housing (**1100**) includes:

i. a cavity (**1110**) configured to accommodate the at least one piece of luggage for scanning, wherein the cavity (**1110**) is defined by a base (**1140**) of the housing (**1100**) at its bottom, a sidewall of the housing (**1100**) at its first side, a rear wall of the housing (**1100**) at its second side, an opening enclosable by an access door (**1130**) at its third side and a connection to the component compartment (**1120**) at its fourth side, and

ii. a component compartment (**1120**) used to house the X-ray source module (**1200**), the processing module (**1400**) and the power source module (**1500**); and

the X-ray source module (**1200**) includes at least one X-ray tube (**1220**) connected to at least one mono-block generator (**1210**), wherein the at least one mono-block generator (**1210**) configured to convert electrical power supplied from the power source module (**1500**) into a high-voltage output for operating the at least one X-ray tube (**1220**), wherein the at least one X-ray tube (**1220**) is a cold cathode X-ray tube.

2. The baggage scanner (**1000**) as claimed in claim **1**, wherein the at least one X-ray tube (**1220**) is a carbon nanotube X-ray tube.

3. The baggage scanner (**1000**) as claimed in claim **1**, wherein the X-ray source module (**1200**) further includes a switching unit (**1240**) connected between the at least one X-ray tube (**1220**), the at least one mono-block generator (**1210**), wherein switching unit (**1240**) is configured to alternate the supply of the high-voltage output from the at least one mono-block generator (**1210**) to multiple X-ray tubes (**1220**), wherein the switching unit (**1240**) is connected and controlled by the processing module (**1400**).

4. The baggage scanner (**1000**) as claimed in claim **1**, wherein the at least one X-ray tube (**1220**) is attached to a vertical support structure, wherein the vertical support structure (**1230**) is mounted to the base (**1140**) of the housing (**1100**) and located within the component compartment (**1120**) near the cavity (**1110**).

5. The baggage scanner (**1000**) as claimed in claim **4**, wherein the vertical support structure is equipped with a linear actuator assembly to allow vertical movement of the at least one X-ray tube (**1220**) during scanning, wherein the linear actuator assembly is electrically controlled by the processing module (**1400**).

6. The baggage scanner (**1000**) as claimed in claim **1**, wherein the X-ray detector is a flat panel detector.

7. The baggage scanner (**1000**) as claimed in claim **1**, wherein the processing module (**1400**) includes:
    a) a controller unit (**1410**) connected to the X-ray source module (**1200**), the X-ray detector module (**1300**), the power source module (**1500**), the control panel (**1600**), and an image processing unit (**1420**), wherein the controller unit (**1410**) is configured to:
        i. control and synchronise an activation and deactivation of the X-ray source module (**1200**) and X-ray detector module (**1300**),
        ii. activate and deactivate the at least one X-ray tube (**1220**) at different emission intervals,
        iii. process user input from the control panel (**1600**), and
        iv. display the at least one X-ray image on the control panel (**1600**); and

    b) the image processing unit (**1420**) configured to generate the at least one X-ray image from at least one X-ray raw data obtained from the X-ray detector module (**1300**).

8. The baggage scanner (**1000**) as claimed in claim **7**, wherein the controller unit (**1410**) is connected to a remote monitoring device to transmit the at least one X-ray image.

9. The baggage scanner (**1000**) as claimed in claim **7**, wherein the controller unit (**1410**) is configured to actuate the access door (**1130**) for closing and opening the cavity (**1110**).

10. The baggage scanner (**1000**) as claimed in claim **7**, wherein the at least one X-ray image includes either at least one projection image, a volumetric image, at least one sum grayscale image, at least one material-discriminated image, at least one object-stripped image or at least one material-separated image, wherein each projection image is a planar X-ray image of the at least one piece of luggage captured from a specific angular position and the volumetric image is a three-dimensional or 3D X-ray image of the at least one piece of luggage.

11. The baggage scanner (**1000**) as claimed in claim **7**, the image processing unit (**1420**) is configured to perform image pre-processing on the at least one X-ray raw data from the X-ray detector module (**1300**).

12. The baggage scanner (**1000**) as claimed in claim **7**, the image processing unit (**1420**) is configured to recognise and detect any prohibited items from the at least one X-ray image.

13. The baggage scanner (**1000**) as claimed in claim **1**, wherein the baggage scanner (**1000**) further includes a rotary platform (**1700**) configured for rotational positioning of the at least one piece of luggage placed in the cavity (**1110**), wherein the rotary platform (**1700**) is controlled by the processing module (**1400**).

14. The baggage scanner (**1000**) as claimed in claim **1**, wherein the control panel (**1600**) includes:
    a) a display unit configured to present visual information to a user;
    b) a touchscreen overlay integrated with the display unit configured to allows touch-based input from the user corresponding to the visual information displayed by the display unit; and
    c) at least one input button used to receive tactile input from the user.

15. The baggage scanner (**1000**) as claimed in claim **1**, wherein the baggage scanner (**1000**) is configured as a standalone device.

16. The baggage scanner (**1000**) as claimed in claim **1**, wherein the baggage scanner (**1000**) is configured as a compact device.

17. A method for scanning at least one piece of luggage is characterised by the steps of:
    a) placing at least one piece of luggage into a cavity (**1110**) of a housing (**1100**) of a baggage scanner (**1000**);
    b) closing an access door (**1130**) of the baggage scanner (**1000**);
    c) checking a current state of the access door (**1130**);

d) if the current state of the access door (**1130**) is closed, activating an X-ray source module (**1200**), an X-ray detector module (**1300**), and a rotary platform (**1700**) by the processing module (**1400**) of the baggage scanner (**1000**);

e) transmitting at least one X-ray raw data from the X-ray detector module (**1300**) to a processing module (**1400**) of the baggage scanner (**1000**), wherein each X-ray raw data corresponds to a particular angular position of the at least on piece of luggage and a specific energy level of at least one X-ray beam emitted by the X-ray source module (**1200**);

f) performing image pre-processing on the at least one X-ray raw data;

g) generating at least one X-ray image, wherein the at least one X-ray image includes either at least one projection image, a volumetric image, at least one sum grayscale image, at least one material-discriminated image, at least one object-stripped image or at least one material-separated image, wherein each projection image is a planar X-ray image of the at least one piece of luggage captured from a specific angular position and the volumetric image is a three-dimensional or 3D X-ray image of the at least one piece of luggage; and

h) displaying the at least one X-ray images generated at a control panel (**1600**) of the baggage scanner (**1000**).

18. The method as claimed in claim **17**, wherein if the current state of the access door (**1130**) is open, sending an alert notification at a control panel (**1600**) of the baggage scanner (**1000**) by the processing module (**1400**) of the baggage scanner (**1000**).

19. The method as claimed in claim **17**, wherein the step of activating the X-ray source module (**1200**), the X-ray detector module (**1300**), and the rotary platform (**1700**) includes:

a) emitting the at least one X-ray beam towards the at least one piece of luggage within the cavity (**1110**) at different emission intervals as the rotary platform (**1700**) rotates the at least one piece of luggage;

b) capturing and measuring at least one transmitted X-ray beam, wherein the at least one transmitted X-ray beam is the at least one X-ray beam emitted that may interact with the at least one piece of luggage in the cavity (**1110**); and

c) converting the at least one transmitted X-ray beam into the at least one X-ray raw data.

20. The method as claimed in claim **17**, wherein the method further includes transmitting the at least one X-ray image to a remote monitoring device.

21. A method for scanning at least one piece of luggage is characterised by the steps of:

a) placing at least one piece of luggage into a cavity (**1110**) of a housing (**1100**) of a baggage scanner (**1000**);

b) closing an access door (**1130**) of the baggage scanner (**1000**);

c) checking a current state of the access door (**1130**);

d) if the current state of the access door (**1130**) is closed, activating an X-ray source module (**1200**), an X-ray detector module (**1300**), and a rotary platform (**1700**) by the processing module (**1400**) of the baggage scanner (**1000**);

e) transmitting at least one X-ray raw data from the X-ray detector module (**1300**) to a processing module (**1400**) of the baggage scanner (**1000**), wherein each X-ray raw data corresponds to a particular angular position of the at least on piece of luggage and a specific energy level of at least one X-ray beam emitted by the X-ray source module (**1200**);

f) performing image pre-processing on the at least one X-ray raw data;

g) generating a plurality of material-discriminated images, wherein a material-discriminated image is generated for each angular position of the at least one piece of luggage captured by the X-ray detector module (**1300**);

h) reconstructing a volumetric image of the at least one piece of luggage from the plurality of material discrimination images;

i) recognising and detecting any prohibited items in the at least one piece of luggage based on either the volumetric image or the plurality

of material discrimination images by the processing module (**1400**); and

j) sending an alert notification if there are any prohibited items recognised and detected by the processing module (**1400**).

22. The method as claimed in claim **21**, wherein if the current state of the access door (**1130**) is open, sending an alert notification at a control panel (**1600**) of the baggage scanner (**1000**) by the processing module (**1400**) of the baggage scanner (**1000**).

23. The method as claimed in claim **21**, wherein the step of activating the X-ray source module (**1200**), the X-ray detector module (**1300**), and the rotary platform (**1700**) includes:

a) emitting the at least one X-ray beam towards the at least one piece of luggage within the cavity (**1110**) at different emission intervals as the rotary platform (**1700**) rotates the at least one piece of luggage;

b) capturing and measuring at least one transmitted X-ray beam, wherein the at least one transmitted X-ray beam is the at least one X-ray beam emitted that may interact with the at least one piece of luggage in the cavity (**1110**); and

c) converting the at least one transmitted X-ray beam into the at least one X-ray raw data.

24. The method as claimed in claim **21**, wherein the step of recognising and detecting any prohibited items in the at least one piece of luggage includes:

a) extracting at least one key feature from the volumetric image or each material discrimination image to identify each item in the at least one piece of luggage; and

b) determining whether the shape profile and material type of each identified items are associated with any prohibited items.

25. The method as claimed in claim **21**, wherein if there are no prohibited items recognised and detected by the processing module (**1400**), sending a notification to a user through a control panel (**1600**) stating that the at least one piece of luggage has passed security screening

26. The method as claimed in claim **21**, wherein the method further includes transmitting the volumetric image or the plurality of material discrimination images to a remote monitoring device.