FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

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COMPLETE SPECIFICATION

(See sections 10; rule 13)

TITLE OF THE INVENTION

A SYSTEM, A DETECTION SYSTEM FOR DETECTING A FOREIGN OBJECT ON A RUNWAY AND A METHOD OF THE SYSTEM

APPLICANTS

1) NAME : Rong-Jie, David, CHEW
   NATIONALITY : SINGAPORE
   ADDRESS : 131 Lorong 1, Realty Park, Parkwood Collection
   Singapore 533807, SINGAPORE

2) NAME : Rong-Qi, Phoebe, CHEW
   NATIONALITY : SINGAPORE
   ADDRESS : 131 Lorong 1, Realty Park, Parkwood Collection
   Singapore 533807, SINGAPORE

PREAMBLE TO THE DESCRIPTION:

The following description particularly describes the invention and the manner in which it is to be performed.

A SYSTEM, A DETECTION SYSTEM FOR DETECTING A FOREIGN OBJECT ON A RUNWAY AND A METHOD OF THE SYSTEM

Cross-Reference to Related Applications

[0001] The present application claims the benefit of Singapore Patent Application No. 10202009789R filed on 1 October 2020, which is incorporated by reference herein.

Technical Field

[0002] The present invention relates to a system, a detection system for detecting a foreign object on a runway and a method of the system.

BACKGROUND

[0003] Foreign objects and debris (FOD) on an airport runway pose a hazard to aircraft landing and taking-off thereon. There are FOD detection systems using visible light spectrum cameras to perform reliable FOD detection under normal clear weather conditions. Under normal clear weather conditions, e.g. in the absence of any fog, the FOD detection system will be able to capture high resolution images of any FOD and process them for the detection of the FOD with high accuracy. FOD may include engine and aircraft parts, tools, construction debris, rubber materials, natural materials, etc.

[0004] However, during adverse weather conditions, especially under foggy weather conditions, the performance of the FOD detection system could be adversely impacted and compromised. The FOD detection system may not be able to reliably detect an FOD under foggy weather conditions, i.e. poor visibility conditions, as it operates only in the visible light spectrum. Hence, it will not be able to "see" the FOD under such conditions, e.g. through fog, which typically reduces visibility along the runway to less than 1 km. The visibility conditions may be categorised into different categories. For example, Cat II represents standard operations with associated Runway Visual Range (RVR) ranging from 550m (1,800 feet) to 300m (1,000 feet), Cat IIIa represents a precision instrument approach and landing operation with RVR not less than 175m (600 feet), Cat IIIb represents a precision instrument approach and landing

operation with RVR less than 175m (600 feet) but not less than 50m (200 feet), Cat IIIc represents a precision instrument approach and landing operation with no RVR limitations, i.e. even zero visibility. Depending on the geographical location of the airports, the visibility of the runways at airports may vary and are categorised accordingly. While most FOD detection systems are able to detect FOD for airports with Cat II visibility, they are not able to be used for airport that experience Cat IIIa, Cat IIIb and Cat IIIc visibility.

[0005] Further, the FOD detection system often generates invalid alerts or false positive alarms. The invalid alerts may be due to some phenomena, mainly light reflections, e.g. from artificial light sources originating from nearby buildings or runway edge lights, etc. These artificial lights reflecting off the smooth runway surface or reflecting off water puddles or ponding on the runway surface may cause the FOD detection system to identify it as a FOD and hence result in invalid alerts. The number of such invalid alerts due to reflections would typically increase significantly after a rainfall when water puddles or ponding are prevalent on the runway pavement surface. Though such reflections do occur during the daytime, they are much more prevalent at night and during the periods of dawn and dusk of the day.

[0006] Therefore, it is important to provide a solution that enables the detection of FOD during poor visibility conditions, e.g. adverse weather conditions, and prevent or minimise false detection of the FOD.

SUMMARY

[0007] According to various embodiments, a method for detecting a foreign object on a runway is provided. The method includes capturing a thermal image of an area of interest on the runway, capturing a visible light image of the area of interest on the runway, detecting a thermal object image in the thermal image, detecting a visible light object image in the visible light image, and determining that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively.

[0008] According to various embodiments, determining the foreign object may include generating at least one attribute of the foreign object in each of the thermal object image and

visible light object image, comparing the at least one attribute of the foreign object in the thermal object image and the visible light object image, such that the foreign object is detected when the at least one attribute of the foreign object in thermal object image and the visible light object image are the same.

[0009] According to various embodiments, the at least one attribute of the foreign object may include the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image.

[0010] According to various embodiments, the at least one attribute of the foreign object in thermal object image and the visible light object image are the same when the distance between the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image is within a position parameter.

[0011] According to various embodiments, the at least one attribute of the foreign object may include the size of the thermal object image and visible light object image.

[0012] According to various embodiments, the at least one attribute of the foreign object in the thermal object image and visible light object image are the same when the difference in the size of the thermal object image in the thermal image and the size of the visible light object image in the visible light image is within a size parameter.

[0013] According to various embodiments, the method may further include obtaining an enlarged thermal object image and an enlarged visible light object image when the foreign object is detected.

[0014] According to various embodiments, the method may further include identifying an object category of the foreign object in the thermal image, such that identifying the object category may include, segmenting the thermal image into a plurality of thermal image regions, assigning a feature vector to each of the plurality of thermal image regions, comparing the feature vector to a plurality of reference feature vectors, such that each of the plurality of reference feature vectors represents an object category, identifying the reference feature vector closest to the feature vector and its object category.

[0015] According to various embodiments, segmenting the thermal image may include labelling each pixel in the thermal image and grouping the labelled pixels with the same characteristic into a plurality of groups to form the plurality of thermal image regions.

[0016] According to various embodiments, the method may further include identifying an object category of the foreign object in the visible light image, such that identifying the object category may include, segmenting the visible light image into a plurality of visible light image regions, assigning a feature vector to each of the plurality of visible light image regions, comparing the feature vector to a plurality of reference feature vectors, such that each of the plurality of reference feature vectors represents an object category, and identifying the reference feature vector closest to the feature vector and its object category.

[0017] According to various embodiments, segmenting the visible light image may include labelling each pixel in the visible light image and grouping the labelled pixels with the same characteristic into a plurality of groups to form the plurality of visible light image regions.

[0018] According to various embodiments, the method may further include training the thermal camera to detect the foreign object based on the visible light images from the visible light camera.

[0019] According to various embodiments, training the thermal camera may include determining a relationship between the object category of the foreign object in the visible light image and the temperature of the foreign object in the thermal image.

[0020] According to various embodiments, a system for detecting a foreign object on a runway is provided. The system includes a thermal camera having a first field of view and adapted to capture a thermal image of an area of interest on the runway, a visible light camera having a second field of view and adapted to capture a visible light image of the area of interest on the runway, such that the first field of view overlaps the second field of view. The system further includes a processor in communication with the thermal camera and the visible light camera, a memory in communication with the processor for storing instructions executable by the processor, such that the processor is configured to detect a thermal object image in the thermal

image, detect a visible light object image in the visible light image, and determine that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively.

[0021] According to various embodiments, to determine the foreign object, the processor may be configured to generate at least one attribute of the foreign object in each of the thermal object image and visible light object image, compare the at least one attribute of the foreign object in the thermal object image and the visible light object image, such that the foreign object is detected when the at least one attribute of the foreign object in thermal object image and the visible light object image are the same.

[0022] According to various embodiments, the at least one attribute of the foreign object may include the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image.

[0023] According to various embodiments, the at least one attribute of the foreign object in thermal object image and the visible light object image are the same when the distance between the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image is within a position parameter.

[0024] According to various embodiments, the at least one attribute of the foreign object may include the size of the thermal object image and visible light object image.

[0025] According to various embodiments, the at least one attribute of the foreign object in the thermal object image and visible light object image are the same when the difference in the size of the thermal object image in the thermal image and the size of the visible light object image in the visible light image is within a size parameter.

[0026] According to various embodiments, the processor may be further configured to zoom in the thermal camera and visible light camera to obtain an enlarged thermal object image and an enlarged visible light object image when the foreign object is detected.

[0027] According to various embodiments, the processor may be configured to identify an object category of the foreign object in the thermal image, such that the processor may be configured to, segment the thermal image into a plurality of thermal image regions, assign a feature vector to each of the plurality of thermal image regions, compare the feature vector to a plurality of reference feature vectors, such that each of the plurality of reference feature vectors represents an object category, identify the reference feature vector closest to the feature vector and its object category.

[0028] According to various embodiments, to segment the thermal image, the processor may be configured to label each pixel in the thermal image and group the labelled pixels with the same characteristic into a plurality of groups to form the plurality of thermal image regions.

[0029] According to various embodiments, the processor may be further configured to identify an object category of the foreign object in the visible light image, such that the processor may be configured to, segment the visible light image into a plurality of visible light image regions, assign a feature vector to each of the plurality of visible light image regions, compare the feature vector to a plurality of reference feature vectors, such that each of the plurality of reference feature vectors represents an object category, identify the reference feature vector closest to the feature vector and its object category.

[0030] According to various embodiments, to segment the visible light image, the processor may be configured to label each pixel in the visible light image and group the labelled pixels with the same characteristic into a plurality of groups to form the plurality of visible light image regions.

[0031] According to various embodiments, the processor may be further configured to train the thermal camera to detect the foreign object based on the visible light images from the visible light camera.

[0032] According to various embodiments, to train the thermal camera, the processor may be configured to determine a relationship between the object category of the foreign object in the visible light image and the temperature of the foreign object in the thermal image.

[0033] According to various embodiments, a detection system for detecting a foreign object on a runway divided into a plurality of sectors is provided, the detection system includes a plurality of sets of cameras spaced apart from each other, each of the plurality of sets of cameras may include a thermal camera includes a first field of view and adapted to capture a thermal image of an area of interest on the runway, a visible light camera includes a second field of view and adapted to capture a visible light image of the area of interest on the runway, such that the first field of view overlaps the second field of view, a processor in communication with the thermal camera and the visible light camera, a memory in communication with the processor for storing instructions executable by the processor, such that the processor may be configured to detect a thermal object image in the thermal image, detect a visible light object image in the visible light image, and determine that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively, such that each of the plurality of sets of cameras may be configured to scan one of the plurality of sectors of the runway.

BRIEF DESCRIPTION OF DRAWINGS

[0034] Fig. 1 shows a schematic diagram of an exemplary embodiment of a system for detecting a foreign object on a runway.

[0035] Fig. 1A shows a schematic diagram of the visible light image with the visible light object image of the foreign object therein and the thermal image with the thermal object image of the foreign object therein.

[0036] Fig. 2A shows an exemplary embodiment of the system.

[0037] Fig. 2B shows the system in Fig. 2A scanning one of the plurality of sectors of the runway.

[0038] Fig. 3 shows an exemplary embodiment of a detection system for detecting a foreign object on a runway divided into a plurality of sectors.

[0039] Fig. 4 shows a flow diagram of an exemplary method for detecting a foreign object on a runway.

[0040] Fig. 5 shows a flow diagram of an exemplary method for detecting the foreign object on a runway.

[0041] Fig. 6 shows a flow diagram of an exemplary method for detecting the foreign object on a runway.

[0042] Fig. 7 shows a flow diagram of an exemplary method for comparing the at least one attribute of the foreign object in the thermal object image and the visible light object image.

[0043] Fig. 8 shows a flow diagram of a method for identifying a foreign object on the runway.

[0044] Fig. 9 shows a flow diagram of a method for identifying a foreign object on the runway.

[0045] Fig. 10 shows a flow diagram of a method for training the image identification module to improve the identification of a foreign object on the runway.

[0046] Fig. 11 shows a flow diagram of a method for detecting a foreign object with a thermal camera.

DETAILED DESCRIPTION

[0047] In the following examples, reference will be made to the figures, in which identical features are designated with like numerals.

[0048] Fig. 1 shows a schematic diagram of an exemplary embodiment of a system 100 for detecting a foreign object 20 on a runway. System 100 includes a thermal camera 110 having a first field of view 110F and adapted to capture a thermal image 110M of an area of interest 112 on the runway, a visible light camera 120 having a second field of view 120F and adapted

to capture a visible light image of the area of interest 112 on the runway, such that the first field of view 110F overlaps the second field of view 120F, a processor 132 in communication with the thermal camera 110M and the visible light camera 120M, a memory 134 in communication with the processor 132 for storing instructions executable by the processor 132, such that the processor 132 is configured to detect a thermal object image in the thermal image, detect a visible light object image in the visible light image, and determine that the foreign object 20 is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively. System 100 may include a server comprising the processor 132, the memory 134, an I/O interface 136 configured to provide an interface between the processor 132 and peripheral interface modules, e.g. keyboard, mouse, touchscreen, display, etc. System 100 may include a communication module 138 configured to facilitate communication, wired or wirelessly, between the system 100 and other user devices, e.g. mobile devices, laptops, via the internet. System 100 may include a storage device 140 configured to store data. System 100 may include a display, e.g. monitor, touchscreen, for displaying signals, e.g. alert signal, to the operator. System 100 is configured to detect a foreign object, debris (FOD), on a runway, a taxiway, aprons, ramps, etc. under both day and night ambient light condition without assisted illumination, e.g. visible spectrum illumination, infrared illumination, laser illumination.

[0049] Fig. 1A shows a schematic diagram of the visible light image 120M with the visible light object image 120B of the foreign object 20 therein and the thermal image 110M with the thermal object image 110B of the foreign object 20 therein.

[0050] System 100 may include an image processing module 134M (see Fig. 1) configured to process images 110T, 120T captured from the thermal camera 110 and visible light camera 120. System 100 may include a thermal camera operating module 134T containing operating parameters of the thermal camera 110 for operating the thermal camera 110. System 100 may include a visible light camera operating module 134V containing operating parameters of the visible light camera 120 for operating the visible light camera 120. The modules 134T, 134V, 134M may be stored in the storage device 140 and loaded into the memory 134 to be processed by the processor 132.

[0051] Upon capturing the thermal image 110M and visible light image 120M, the images 110M, 120M may be transmitted to the processor 132 to be processed. Processor 132 may receive and process the thermal image 110M and the visible light image 120M to detect a foreign object 20 on the runway. System 100 enables detection of a foreign object 20 for airports with Cat II visibility, Cat IIIa visibility, Cat IIIb visibility and Cat IIIc visibility, such that it enables the detection of foreign object during poor visibility conditions, e.g. adverse weather conditions, and prevent or minimise false detection of the foreign object.

[0052] Fig. 2A shows an exemplary embodiment of the system 200. System 200 may include a set of cameras, i.e. the visible light camera 220 and the thermal camera 210. The set of cameras 210S may be mounted rigidly on an actuator 250 adapted to move the set of cameras 210S. Set of cameras 210S may be controlled by the processor 132 to scan a sector of the runway to detect the foreign object 20 on the surface of the runway.

[0053] Actuator 250 may be a pan and tilt unit (PTU) adapted to pan and tilt the set of cameras 210S simultaneously so that the set of cameras 210S are able to have the same field of view and focus on the same area of interest. Actuator 250 may be adapted to pan the set of cameras 210S in the horizontal direction 210H and/or tilt the set of cameras 210S in the vertical direction 210V. Actuator 250 may be in communication with the processor 132 such that the processor 132 may be configured to remotely control the movement of the actuator 250 to pan and tilt the set of cameras 210S to scan the runway. Actuator 250 may be installed on top of a support 252, e.g. a mast structure, which is typically located along the runway. Support may be located at distance of 120m - 350m from the centreline 304 (see Fig. 3) of the runway.

[0054] Fig. 2B shows the system 100 in Fig. 2A scanning one of the plurality of sectors 202S of the runway 202. Each set of cameras 210S may include the thermal camera 210 and the visible light camera 220, each having a field of view 210F, 220F and is adapted to capture an area of interest 212. Field of view 210F of the visible light camera 220 may overlap with the field of view 220F of the thermal camera 210. Both the field of views 210F, 220F of the visible light camera 220 and the thermal camera 210 may cover a specific area of interest 212 within the sector 202S of the runway 202. Hence, as a result of the overlapping field of views 210F,

220F, both the visible light camera 220 and the thermal camera 210 may detect the same foreign object 20 on the sector 202S of the runway at the same time while scanning the sector 202S.

[0055] Fig. 3 shows an exemplary embodiment of a detection system 300 for detecting a foreign object 20 on a runway 302 divided into a plurality of sectors 302S. Detection system 300 includes a plurality of sets of cameras 310S spaced apart from each other. Each of the plurality of sets of cameras 310S includes a thermal camera 210 having a first field of view 210F and adapted to capture a thermal image 110M of an area of interest 212 on the runway 302, a visible light camera 220 having a second field of view 220F and adapted to capture a visible light image 120M of area of interest 212 on the runway 302, such that the first field of view 210F overlaps the second field of view 220F. Detection system 300 further includes a processor, a memory in communication with the processor for storing instructions executable by the processor, such that the processor is configured to detect a thermal object image 110B in the thermal image 110M, detect a visible light object image 120B in the visible light image 120M, and determine that the foreign object 20 is detected when the thermal object image 110B and the visible light object image 120B are detected in the thermal image 110M and the visible light object image 120B respectively, such that each of the plurality of a set of cameras 310S is configured to scan one of the plurality of sectors 302S of the runway 302. As shown in Fig. 3, the runway 302 may be divided into a plurality of sectors 302S. Each of the plurality of sets of cameras 310S may scan one of the plurality of sectors 302S to detect any foreign object 20 on the surface of the respective sector 302S. Each of the plurality of sectors 302S may be further divided into a plurality of subsectors. Each set of cameras 310S may be operable to scan a dedicated sector 302S and scan the sector 302S, subsector by subsector. In this way, when a foreign object 20 is detected, the system 300 is able to identify the sector 302S based on the set of cameras 310S scanning the sector 302S. Set of cameras 310S may scan the sector 302S in a specific typical scan direction, e.g. from the left-most subsector to the right-most subsector or the right-most subsector to the left-most subsector.

[0056] Thermal camera 210 detects foreign object 20 on the runway 302 by detecting the difference in thermal radiation level (or temperature) between the foreground, i.e. foreign object 20, and the background, i.e. the runway surface. Thermal camera 210 operates in the infrared spectrum and does not require any ambient light to enable it to “see” the foreign object 20. Thermal camera 210 may also be commonly known as infrared thermal camera. Thermal

camera 210 may be a Mid Wave Infrared (MWIR) camera or a Long Wave Infrared (LWIR) camera. Thermal camera 210 provides the advantage to detect the foreign object 20 on the runway 302 under very low visibility conditions and even under zero illumination conditions, i.e. total darkness. Hence, the thermal camera 210 provides the advantage of the ability to detect the foreign object 20 on the runway 302 even under foggy weather conditions. Thermal camera 210 may capture and transmit images and video output in monochrome to the processor 132. Thermal camera 210 is entirely passive with no active transmissions or emissions, e.g. radio frequency, microwave, artificial illumination, infrared, laser and LIDAR etc. As such, the thermal camera 210 offers the following advantages, e.g. no interference with existing airport systems/equipment and aircraft systems/equipment, no interference with future airport systems/equipment and aircraft systems/equipment, no licensing and approval of frequency/spectrum required from airport and frequency spectrum regulator.

[0057] Unlike the thermal camera 210, the visible light camera 220 operates within the visible spectrum of light and hence requires some minimum amount of ambient visible spectrum light to enable it to "see" the foreign object 20 on the runway 302. Visible light camera 220 is not able to detect any foreign object 20 when the visibility conditions are too poor or under zero illumination conditions. For example, the visible light camera 220 is also not able to detect the foreign object 20 when the visibility condition (above the runway surface) is very poor or in the presence of fog (above the runway surface). Visible light camera 220 is able to capture and transmit full colour and high-resolution images/video, e.g. Full HD (FHD) or 4K Ultra HD (4K UHD) resolution. The colour images in high resolution enables reliable and accurate visual verification and confirmation of the detected foreign object 20 by an operator, as well as reliable and accurate recognition/classification of the detected foreign object 20 by the system 300. Therefore, the combined use of both the visible light camera 220 and the thermal camera 210 enables the system 300 to operate under very low visibility conditions, e.g. foggy weather conditions, to enable the system 300 to detect foreign object 20 on the runway 302 surface accurately and reliably. Visible light camera 220 is configured to capture and output visible light image 120M in colour and high resolution to the processor 132. Visible light camera 220 does not require any transmission of infrared illumination, visible spectrum illumination or laser illumination to operate. Being passive, the system 300 provides the advantage that it does not pose any hazard or cause any interference to other airport systems and/or aircraft systems, e.g. for aircraft landing/taking-off from the runway 302. System 300 provides the following

advantages, no interference with existing airport systems/equipment and aircraft systems/equipment, no interference with future airport systems/equipment and aircraft systems/equipment, no licensing and approval of frequency/spectrum required from airport and frequency spectrum regulator.

[0058] Fig. 4 shows a flow diagram of an exemplary method 1000 for detecting a foreign object 20 on a runway. Method includes capturing a thermal image 110M of an area of interest 112 on the runway in block 1010, capturing a visible light image 120M of the area of interest 112 on the runway in block 1020, detecting a thermal object image 110B in the thermal image 110M in block 1030, detecting a visible light object image 120B in the visible light image 120M in block 1040, and determining that the foreign object 20 is detected when the thermal object image 110B and the visible light object image 120B are detected in the thermal image 110M and the visible light object image 120B respectively in block 1050. Thermal object image 110B may be a portion of the thermal image 110M representing the foreign object 20 in the thermal image 110M and may be casually known as the foreign object 20 in the thermal image 110M. Visible light object image 120B may be a portion of the visible light image 120M representing the foreign object 20 in the visible light image 120M and may be casually known as the foreign object 20 in the visible light image 120M.

[0059] Before capturing the thermal image 110M and visible light image 120M, the method may include scanning the runway with the thermal camera 110 and the visible light camera 120. As the thermal camera 110 and the visible light camera 120 scan a sector of the runway, the thermal camera 110 and the visible light camera 120 captures thermal images 110M and visible light images 120M of a plurality of area of interests 112 along the sector. To detect the foreign object 20, the image processing module 134M may process the thermal image 110M and the visible light image 120M to determine if the foreign object 20 is present in the thermal image 110M and the visible light image 120M. Upon detecting the foreign object 20, the image processing module 134M may be configured to identify the thermal object image 110B and the visible light object image 120B within the thermal image 110M and the visible light image 120M respectively. Upon identifying the foreign object 20, the system 100 may generate an alert signal.

[0060] To detect the foreign object 20, the method may include generating at least one attribute of the foreign object 20 in each of the thermal object image 110B and visible light object image 120B, comparing the at least one attribute of the foreign object 20 in the thermal object image 110B and the visible light object image 120B, such that the foreign object 20 is detected when the at least one attribute of the foreign object 20 in thermal object image 110B and the visible light object image 120B are the same or within a specified parameter or threshold level. System 100 may be configured to obtain an enlarged thermal object image 110B and an enlarged visible light object image 120B when the foreign object 20 is detected by zooming the visible light camera 120 and thermal camera 110 onto the detected foreign object 20.

[0061] Fig. 5 shows a flow diagram of an exemplary method 2000 for detecting the foreign object 20 on a runway. System 100 may be configured to designate the visible light camera 120 to be a primary detector and the thermal camera 110 to be a secondary detector. Referring to Fig. 5, in block 2110, the visible light camera 120 may be configured to scan one of the plurality of sectors on the runway. Visible light camera 120 may be configured to scan a subsector by subsector of the sector. Visible light camera 120 may capture a plurality of visible light images 120M within each sector. Plurality of visible light images 120M may be processed by the image processing module 134M to detect the foreign object 20. In block 2210, the thermal camera 110 may be configured to scan the same sector on the runway scanned by the visible light camera 120. Thermal camera 110 may be configured to scan a subsector by subsector of the sector. Thermal camera 110 may capture a plurality of thermal image 110Ms within the same sector. Plurality of thermal images 110M may be processed by the image processing module 134M to detect the foreign object 20. Thermal camera 110 and the visible light camera 120 may be configured to scan the sector concurrently. Image processing module 134M for the visible image and thermal image 110M may be separate modules for processing the visible light image 120M and thermal image 110M respectively.

[0062] In block 2120, the system 100 may detect a foreign object 20 after processing the visible light image 120M. System 100 may identify the visible light object image 120B within the visible image. In block 2220, the system 100 may detect a foreign object 20 after processing the thermal image 110M. System 100 may identify the thermal object image 110B within the thermal image 110M. Thermal image 110M and the visible light image 120M may be processed by the processor 132 concurrently. If the system 100 detects a foreign object 20 in the visible

light image 120M, the system 100 may generate a “Suspected FOD” alert signal to inform the operator that a foreign object 20 has been detected in the visible light image 120M in block 2130. Similarly, if the system 100 detects a foreign object 20 in the thermal image 110M, the system 100 may generate a “Suspected FOD” alert signal to inform the operator that a foreign object 20 has been detected in the thermal image 110M in block 2230 as the detection of the foreign object 20 has yet to be verified. The “Suspected FOD” signal may be generated for each of the visible light image 120M and the thermal image 110M. System 100 may display the thermal object image 110B and/or the visible light object image 120B on the display for the operator to view. System 100 may generate at least one attribute of the visible light object image 120B and of the thermal object image 110B. At least one attribute may include the position of the visible light object image 120B in the visible light image 120M, the position of the thermal object image 110B in the thermal image 110M, the size of the visible light object image 120B and/or the size of the thermal object image 110B. For example, the system 100 may generate the position of the visible light object image 120B in the visible light image 120M and the position of the thermal object image 110B in the thermal image 110M and/or the size of the visible light object image 120B and thermal object image 110B. In block 2140, the system 100 may be configured to determine whether the foreign object 20 is detected in the visible light image 120M and the thermal image 110M by comparing the at least one attribute of the visible light object image 120B and the thermal object image 110B. Details of this comparing step may be shown in Fig. 7. If the attributes of the visible light object image 120B and the thermal object image 110B matches in block 2150, the system 100 determines that the foreign object 20 is detected in the visible light image 120M and the thermal image 110M. System 100 may receive an operator verification input via the peripheral interface module to verify the detection of the foreign object 20 after viewing the visible light image 120M and/or thermal image 110M on the display. System 100 may identify the foreign object 20 based on the at least one attributes in block 2160. Once the foreign object 20 has been detected and/or identified, the system 100 may generate an alert signal, e.g. a “Confirmed FOD” signal in block 2170. Otherwise, the system 100 may generate a “No Confirmed FOD” alert signal. System 100 may transmit the alert signal to an operator’s mobile device or display the alert signal on the display for the operator’s viewing. System 100 may generate the alert signal upon receiving the operator verification input that the foreign object 20 is detected.

[0063] Fig. 6 shows a flow diagram of an exemplary method 3000 for detecting the foreign object 20 on a runway. Method 3000 is identical to method 2000 in Fig. 5 except that the system 100 is configured to designate the thermal camera 110 to be a primary detector and the visible light camera 120 to be a secondary detector. Like reference numerals in Fig. 5 and Fig. 6 represent the same steps. Referring to Fig. 6, in block 3110, the thermal camera 110 may be configured to scan one of the plurality of sectors on the runway. Thermal camera 110 may be configured to scan a subsector by subsector of the sector. Thermal camera 110 may capture a plurality of thermal images 110M within each sector. Plurality of thermal images 110M may be processed by the image processing module 134M to detect the foreign object 20. In block 3210, the visible light camera 120 may be configured to scan the same sector on the runway scanned by the thermal camera 110. Visible light camera 120 may be configured to scan a subsector by subsector of the sector. Visible light camera 120 may capture a plurality of visible light images 120M within the sector. Plurality of visible light images 120M may be processed by the image processing module 134M to detect the foreign object 20. Thermal camera 110 and the visible light camera 120 may be configured to scan the sector concurrently. In block 3120, the system 100 may detect a foreign object 20 after processing the thermal image 110M. System 100 may identify the thermal object image 110B within the thermal image 110M. In block 3230, the system 100 may detect a foreign object 20 after processing the visible light image 120M. System 100 may identify the visible light object image 120B within the visible light image 120M. Thermal image 110M and the visible light image 120M may be processed by the processor 132 concurrently. Blocks 3140 to 3170 are identical to blocks 2140 to 2170 in Fig. 5.

[0064] Fig. 7 shows a flow diagram of an exemplary method 4140 for comparing the at least one attribute of the foreign object 20 in the thermal object image 110B and the visible light object image 120B. Method 4140 is used in method 2000 in Fig. 5 and method 3000 in Fig. 6 in block 2140 and block 3140 respectively. At least one attribute of the foreign object 20 may include the position of the thermal object image 110B in the thermal image 110M and the position of the visible light object image 120B in the visible light image 120M. In block 4141, the at least one attribute of the foreign object 20 in thermal object image 110B and the visible light object image 120B may be considered the same when the distance between the position of the thermal object image 110B in the thermal image 110M and the position of the visible light object image 120B in the visible light image 120M is within a position parameter. For

example, the processor 132 identifies the positional difference between the positions of the visible light object image 120B and thermal object image 110B in the visible light image 120M and the thermal image 110M and determines if the positional difference between the positions are within a position parameter, i.e. a pre-defined position threshold level. Position parameter may be determined based on statistical analysis of the detected positions of all the detected foreign object 20 samples. If the positional difference is within the position parameter, the processor 132 may generate a “position match” alert signal in block 4142.

[0065] At least one attribute of the foreign object 20 may include the size of the thermal object image 110B and visible light object image 120B. In block 4143, the at least one attribute of the foreign object 20 in the thermal object image 110B and visible light object image 120B may be considered the same when the difference in the size of the thermal object image 110B in the thermal image 110M and the size of the visible light object image 120B in the visible light image 120M is within a size parameter. For example, the processor 132 identifies the size difference between the sizes of the visible light object image 120B and thermal object image 110B in the visible light image 120M and the thermal image 110M and determines if the size difference between the positions are within a size parameter, i.e. a pre-defined size threshold level. Size parameter may be determined based on statistical analysis of the measured sizes of all the detected foreign object 20 samples. If the size difference is within the size parameter, the processor 132 may generate a “size match” alert signal in block 4144.

[0066] Depending on the configuration of the system 100, the process may detect the foreign object 20 based on the position and/or size of the thermal object image 110B and visible light object image 120B. For example, where both the position and size of the thermal object image 110B and the visible light object image 120B are used, the foreign object 20 is detected when the position and size of the thermal object image 110B and visible light object image 120B are within the position parameter and size parameter respectively, i.e. matched. System 100 may generate an alert signal when the foreign object 20 is detected, e.g. generate an “attribute match” signal when the attributes are matched in block 4145. System 100 may generate the alert signal when the “position match” alert signal and “size match” alert signal is on or generated.

[0067] The exemplary system 100 and methods described above provide a solution that enables the detection of a foreign object 20 during adverse weather conditions and prevent or minimise false detection of the foreign object 20. For example, the reflections from water puddles or ponding after a rainfall, or the reflections on a smooth runway surface occur within the visible spectrum of light. As, the visible light camera 120 operates solely within the visible light spectrum, the system 100 may easily misinterpret these reflections as foreign objects 20, or "Suspected FOD". This would cause the system 100 to generate an invalid alert or false positive alarms. Therefore, by comparing and detecting the foreign object 20 using both the thermal image 110M and visible light image 120M, the system 100 is able to provide a more accurate detection of the foreign object 20 and prevent or minimise false detection of the foreign object 20.

[0068] Referring to the method 2000 in Fig. 5 and method 3000 in Fig. 6. When comparing the at least one attribute of the visible light object image 120B and the thermal object image 110B, the system 100 may determine that the detection of the foreign object 20 is not confirmed, i.e. the at least one attribute in the visible light object image 120B does not match the at least one attribute in the thermal image 110M. System 100 may then generate a "No Confirmed FOD" alert signal. In this situation, as the system 100 "suspected" that a foreign object 20 is detected, but identified that it is not "confirmed", the system 100 may be configured to identify this event as an invalid alert or false positive alert. Hence, the system 100 may be configured to store at least one of: the alert signal, attributes, features and the images of this event into a database, e.g. invalid alert database, for post-mortem analysis and investigation.

[0069] Fig. 8 shows a flow diagram of a method 5000 for identifying a foreign object 20 on the runway. Image processing module 134M may be configured to carry out the method 5000. System 100 may store a plurality of reference feature vectors and an object category associated with each of the plurality of reference feature vectors in a reference feature vector database, which may be stored in the storage device 140. To identify the foreign object 20, the system 100 is configured to identify the object category of the foreign object 20. Referring to Fig. 8, the method may include capturing the visible light image 120M and the thermal image 110M via the visible light camera 120 and the thermal camera 110 in block 5302. To identify an object category of the foreign object 20 in the thermal image 110M, the method includes

segmenting the thermal image 110M into a plurality of thermal image regions in block 5304. Method may include segmenting the visible light image 120M into a plurality of visible light image regions in block 5304. Segmenting the thermal image 110M may include labelling each pixel in the thermal image 110M and grouping the labelled pixels with the same characteristic into a plurality of groups to form the plurality of thermal image regions. Segmenting the visible light image 120M may include labelling each pixel in the visible light image 120M and grouping the labelled pixels with the same characteristic into a plurality of groups to form the plurality of visible light image regions. Processor 132 may be configured to assign a label to each pixel in the thermal image 110M and visible light image 120M such that the pixels with the same label share certain common characteristics or properties. Upon segmentation, the thermal image 110M and the visible light image 120M are made up of a plurality of thermal image regions and a plurality of visible light image regions that collectively cover the respective images. The pixels within each of the plurality of regions are similar with respect to some characteristic, feature or property, such as texture, colour, or intensity. Adjacent regions of the plurality of image regions are significantly different from each other with respect to the same characteristic. The segmented thermal image 110M and visible light image 120M may be used to detect and locate region or regions which may include the suspected foreign object 20 in the images. In block 5306, the method may include detecting and extracting features from the thermal image 110M and visible light image 120M. System 100 may be configured to assign a feature vector to each of the plurality of thermal image regions, e.g. thermal feature vector, and each of the plurality of visible light image regions, e.g. visible light feature vector. A feature may refer to a pattern or distinct structure found in an image, such as a point, blob, small patch, corner, edge. Features are represented by an image region which differs from the image regions in its immediate surroundings, e.g. by texture, colour or intensity. Features may be extracted, grouped and represented by the feature vector. A foreign object 20 may be represented by a group of features, which may be represented by a feature vector.

[0070] In block 5308, the method may include comparing the feature vector to the plurality of reference feature vectors, such that each of the plurality of reference feature vectors is associated to an object category. System 100 may match the feature vector to the plurality of reference feature vectors in block 5308. Each object category, e.g. rubber tire, mechanic's tool, aircraft part, vehicle part etc., may be represented by a specific reference feature vector stored in the reference feature vector database. Each extracted feature vector may be matched against

the plurality of reference feature vectors in the reference feature vector database. In block 5310, the method may include detecting the foreign object 20. If there is a match between the feature vector and one or more of the plurality of reference feature vectors, the system 100 may determine that a foreign object 20 is detected. System 100 may generate a “Suspected FOD” alert signal. In block 2312, the method may include identifying the object category of the foreign object 20. System 100 may be configured to identify the reference feature vector closest to the feature vector and its object category. Based on the matched one or more of the plurality of reference feature vectors, the system 100 may identify or classify the foreign object 20 based on the closest match between the feature vector and the one or more of the plurality of reference feature vectors, e.g. the “shortest distance” between the feature vector and the specific reference feature vector. In addition, the “shortest distance” may be used to determine the match or probability of the foreign object 20 being classified accurately. There could potentially be more than one reference feature vector which may match the feature vector. The matching may be based on fuzzy matching. System 100 may be configured to recognise and classify the foreign object 20 based on the object category. System 100 may identify an object category of the foreign object 20 in the visible light image 120M. Based on the matched reference feature vector, the object category tagged to the matched reference feature vector may be retrieved and the foreign object 20 may be identified or classified. Upon identifying the foreign object 20, the system 100 may generate and transmit an alert signal.

[0071] Fig. 9 shows a flow diagram of a method 6000 for identifying a foreign object 20 on the runway. Method 6000 is identical to method 5000 in Fig. 8 except that the system 100 is configured to automatically detect and extract the features from the thermal image 110M and visible light image 120M, match the feature vector to the plurality of reference feature vectors and detecting the foreign object 20 in block 6306. Like reference numerals in Fig. 8 and Fig. 9 represent the same steps. System 100 may be configured to train the image processing module 134M using deep learning modules and automatically carry out the steps in block 6306.

[0072] Thermal camera 110 is able to detect foreign objects 20 by detecting the difference in the temperature, i.e. the infrared thermal radiation of the foreground, e.g. the foreign object 20, with respect to the background, e.g. the runway 202 surface. Different categories or types of foreign objects 20 are made of different materials, e.g. metallic, rubber, plastic, concrete, etc., and would have different energy absorptivity, reflectivity and emissivity. As such, different

categories of foreign objects 20 would result in different temperature, i.e. different level of infrared thermal radiation with respect to the background, i.e. the runway surface. The difference in temperature between the foreign object 20 and the runway would be detectable by the thermal camera 110.

[0073] Therefore, it is beneficial to "train" the thermal camera 110, or rather the thermal camera operating module 134T, to differentiate the different categories of foreign objects 20 by identifying the type of material which the foreign object 20 is made of, e.g. rubber, metallic, plastic, concrete, asphalt, etc. As foreign objects 20 made of the different types of materials would have different emissivity resulting in different level of temperature and different temperature contrast level with respect to the background, i.e. the runway, the "well-trained" thermal camera 110 would be able to identify a foreign object 20 more accurately.

[0074] To train the thermal camera 110. Under normal clear weather conditions, the thermal camera 110 may be put through an initial period of "training" whereby the thermal camera 110 may operate in "training" mode to enable it to "learn" from the visible light images 120M of the visible light camera 120. After the initial "training", the thermal camera 110 may be adequately "learned" to enable the thermal camera 110 to provide reliable and accurate foreign object 20 detection with relatively high level of accuracy. With a high level of accuracy, it would then be possible to enable a system 100 with a "standalone" thermal camera 110 instead of a set of visible light camera 120 and thermal camera 110. In this way, the system 100 will be applicable under adverse weather conditions and/or very low visibility conditions without the visible light camera 120.

[0075] Fig. 10 shows a flow diagram of a method for training the image processing module 134M to improve the identification of a foreign object 20 on runway. In block 7110, the visible light camera 120 may be configured to scan one of the plurality of sectors on the runway. Visible light camera 120 may be configured to scan a subsector by subsector of the sector. Visible light camera 120 may capture a plurality of visible light images 120M of the sector. Plurality of visible light images 120M may be processed by the image processing module 134M to detect the foreign object 20. In block 7210, the thermal camera 110 may be configured to scan the same sector on the runway scanned by the visible light camera 120. Thermal camera

110 may be configured to scan a subsector by subsector of the sector. Thermal camera 110 may capture a plurality of thermal images 110M of the sector.

[0076] Plurality of thermal images 110M may be processed by the image processing module 134M to detect the foreign object 20. Thermal camera 110 and the visible light camera 120 may be configured to scan the sector concurrently. In block 7120, the system 100 may detect a foreign object 20 after processing the visible light image 120M and identify the visible light object image 120B. In block 7220, the system 100 may detect a foreign object 20 after processing the thermal image 110M and identify the thermal object image 110B. Thermal image 110M and the visible light image 120M may be processed by the processor 132 concurrently. If the system 100 detects a foreign object 20 in the visible light image 120M, the system 100 may generate a "Suspected FOD" alert signal to inform the operator that a foreign object 20 has been detected in the visible light image 120M. Similarly, if the system 100 detects a foreign object 20 in the thermal image 110M, the system 100 may generate a "Suspected FOD" signal to inform the operator that a foreign object 20 has been detected in the thermal image 110M in block 7230 as the detection of the foreign object 20 has yet to be verified. The "Suspected FOD" alert signal may be generated for each of the visible light image 120M and the thermal image 110M. System 100 may display the thermal object image 110B and/or the visible light object image 120B on the display for the operator to view. System 100 may generate at least one attribute of the visible light object image 120B in block 7130 and generate at least one attribute of the thermal object image 110B in block 7230.

[0077] At least one attribute may include the position of the visible light object image 120B in the visible light image 120M, the position of the thermal object image 110B in the thermal image 110M, the size of the visible light object image 120B, the size of the thermal object image 110B and/or the temperature of the thermal object image 110B. For example, the system 100 may generate the position of the visible light object image 120B in the visible light image 120M and/or the size of the visible light object image 120B. For example, the system 100 may generate at least one of the position of the thermal object image 110B in the thermal image 110M, the size of the thermal object image 110B and the temperature of the foreign object 20. System 100 may be configured to store at least one of: the alert signal, attributes, features and the images of this event into the foreign object alert signal and event database 742 in block 7132 and block 7232. In block 7140, the system 100 may be configured to determine whether

the foreign object 20 is present in the visible light image 120M and the thermal image 110M by comparing the at least one attribute of the visible light object image 120B and the thermal object image 110B. The method of comparing the at least one attribute may be shown in method 4140 in Fig. 7. If the attributes of the visible light object image 120B and the thermal object image 110B matches in block 7150, the system 100 determines that the foreign object 20 is detected in the visible light image 120M and the thermal image 110M. If the foreign object 20 has been detected, the system 100 may generate and display an alert signal, e.g. a "Confirmed FOD" alert signal in block 7170. Otherwise, the system 100 may generate and transmit a "No Confirmed FOD" alert signal. System 100 may be configured to store at least one of: the signal, attributes, features and the images into the foreign object alert signal and event database 742 in block 7172. In block 7180, the system 100 may be configured to optimize detection configuration parameters of the thermal camera 110. System 100 may optimize the detection configuration parameters based on the data stored in the foreign object alert signal and event database 742. System 100 may run statistical analysis and/or optimization modules to optimise the detection configuration parameters based on the data. System 100 may use artificial intelligence to optimize the detection configuration parameters based on the data. In block 7182, the system 100 may be configured to store the optimized detection configuration parameters of the thermal camera 110 in a foreign object 20 detection configuration parameters database 744 for the thermal camera 110.

[0078] System 100 may determine the relationship between the object category and the temperature of the foreign object 20 in the thermal image 110M for all the detected/verified foreign object samples. Processor 132 may be further configured to train the thermal camera 110 to detect the foreign object 20 based on the visible light images 120M from the visible light camera 120. As it is substantially easier to identify and categorise a foreign object 20 in visible light image 120M, the system 100 may form a relationship between the object category of the visible light object image 120B obtained from the visible light camera 120 and the temperature of the thermal object image 110B from the thermal camera 110. Hence, with a sufficiently large foreign object sample size, the system 100 would be able to determine the relationship between different foreign object categories, e.g. foreign object made of different materials, such as metal, plastic, rubber, etc. and their corresponding temperatures. System 100 may then be able to build an "FOD Type Thermal Profile Model" which could be used to map the various foreign object types, i.e. made of different materials, to their corresponding

temperature ranges. In this way, the system may be able to identify the foreign object 20 more easily based on the thermal object image 110B thereof.

[0079] The "FOD Type Thermal Profile Model" would enable the system 100 to determine the foreign object category or type, including the specific type of material which the foreign object 20 is made of, such as metal, rubber, plastic, etc. of any detected foreign object 20 based on the temperature of the foreign object 20 detected by the thermal camera 110. The development of the "FOD Type Thermal Profile Model" may be based on mathematical methods and/or statistically methods, such as statistical correlation analysis. Alternatively, the development of the "FOD Type Thermal Profile Model" may be based on artificial intelligence and machine learning technologies. This "FOD Type Thermal Profile Model" may be used to optimize the detection configuration parameters of the thermal camera 110.

[0080] To optimize the performance of the thermal camera 110, it is necessary to optimize the detection configuration parameters of the thermal camera 110. The detection configuration parameters of the thermal camera 110 may be a set of operating parameters pertaining to the thermal camera 110 to enable the thermal camera 110 to detect foreign objects 20 with optimum and high level of accuracy. Operating parameters of the thermal camera 110 may include sensitivity, gain, brightness, contrast, shutter timing settings, etc. In this way, as the system 100 trains the thermal camera operating module 134T, the detection performance of the thermal camera 110 would be improved over time to a level at which it may be able to operate as "standalone" and sole foreign object detector for the system 100, i.e. without the visible light camera 120. The optimized performance thermal camera 110 would be beneficial under adverse weather conditions and/or under very low visibility conditions.

[0081] The various temperature contrast levels due to different types of foreign object materials may be detected by the thermal camera 110. This would enable the thermal camera 110 to detect a foreign object 20 accurately. This may also enable the system 100 to classify or recognise the different categories or types of foreign object 20 based on the different types of materials which the foreign object 20 is made of.

[0082] Database 742 may contain the alert signals, e.g. "Suspected FOD", "Confirmed FOD" and events that took place in the methods for both the visible light camera 120 and the thermal

camera 110. Database 742 may store the detected and/or computed foreign object 20 attributes, e.g. category, size, position, temperature etc.

[0083] Fig. 11 shows a flow diagram of a method 8000 for detecting a foreign object 20 with a thermal camera 110. After the "training", the thermal camera 110 may be able to provide reliable and accurate foreign object 20 detection with relatively high level of accuracy. With a high level of accuracy, it would then be possible for the thermal camera 110 to be used without the visible light camera 120. Referring to Fig. 11, the system 100 may be configured to detect a foreign object 20 by leveraging on optimized detection configuration parameters for the thermal camera 110 stored in the detection configuration parameters database 844 for the thermal camera 110 in block 8402. Thermal camera 110 may be configured as the sole foreign object detector to detect a foreign object 20.

[0084] A skilled person would appreciate that the features described in one example may not be restricted to that example and may be combined with any one of the other examples.

[0085] The present invention relates to a system 100, a detection system 100 for detecting a foreign object on a runway and a method of the system 100 generally as herein described, with reference to and/or illustrated in the accompanying drawings.

CLAIMS

I/We Claim:

1. A method for identifying a foreign object on a runway based on a thermal object image of the foreign object, the method comprising

capturing a thermal image of an area of interest on the runway,

capturing a visible light image of the area of interest on the runway,

detecting a thermal object image in the thermal image, detecting a visible light object image in the visible light image,

determining that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively,

identifying and categorizing the visible light object image into an object category of the foreign object,

determining a relationship between the object category of the foreign object in the visible light image and the thermal object image of the foreign object, wherein when a thermal object image of the foreign object is detected, the foreign object is identified by mapping the object category to the thermal object image based on the relationship.

2. The method according to claim 1, wherein determining the foreign object comprises generating at least one attribute of the foreign object in each of the thermal object image and visible light object image, comparing the at least one attribute of the foreign object in the thermal object image and the visible light object image, wherein the foreign object is detected when the at least one attribute of the foreign object in thermal object image and the visible light object image are the same.

3. The method according to claim 2, wherein the at least one attribute of the foreign object comprises the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image.

4. The method according to claim 3, wherein the at least one attribute of the foreign object in thermal object image and the visible light object image are the same when the distance

between the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image is within a position parameter.

5. The method according to any one of claims 2 to 4, wherein the at least one attribute of the foreign object comprises the size of the thermal object image and visible light object image.

6. The method according to claim 5, wherein the at least one attribute of the foreign object in the thermal object image and visible light object image are the same when the difference in the size of the thermal object image in the thermal image and the size of the visible light object image in the visible light image is within a size parameter.

7. The method according to any one of claims 1 to 6, further comprising obtaining an enlarged thermal object image and an enlarged visible light object image when the foreign object is detected.

8. The method according to any one of claims 1 to 7, further comprising identifying an object category of the foreign object in the thermal image, wherein identifying the object category comprises,

segmenting the thermal image into a plurality of thermal image regions,

assigning a feature vector to each of the plurality of thermal image regions,

comparing the feature vector to a plurality of reference feature vectors, wherein each of the plurality of reference feature vectors represents an object category,

identifying the reference feature vector closest to the feature vector and its object category.

9. The method according to claim 8, wherein segmenting the thermal image comprises labelling each pixel in the thermal image and grouping the labelled pixels with the same characteristic into a plurality of groups to form the plurality of thermal image regions.

10. The method according to any one of claims 1 to 11, wherein identifying the object category comprises,

segmenting the visible light image into a plurality of visible light image regions,

assigning a feature vector to each of the plurality of visible light image regions,

comparing the feature vector to a plurality of reference feature vectors, wherein each of the plurality of reference feature vectors represents an object category, and

identifying the reference feature vector closest to the feature vector and its object category.

11. The method according to claim 10, wherein segmenting the visible light image comprises labelling each pixel in the visible light image and grouping the labelled pixels with the same characteristic into a plurality of groups to form the plurality of visible light image regions.

12. The method according to claim 10 or 11, further comprising training the thermal camera to detect the foreign object based on the visible light images from the visible light camera.

13. The method according to any one of claims 1 to 12, further comprising generating a thermal profile model of the foreign object based on the relationship and optimizing the detection configuration parameters of the thermal camera based on the thermal profile model.

14. A detection system for identifying a foreign object on a runway based on a thermal object image of the foreign object, the system comprising:

a thermal camera comprising a first field of view and adapted to capture a thermal image of an area of interest on the runway,

a visible light camera comprising a second field of view and adapted to capture a visible light image of the area of interest on the runway, wherein the first field of view overlaps the second field of view,

a processor in communication with the thermal camera and the visible light camera,

a memory in communication with the processor for storing instructions executable by the processor, wherein the processor is configured to,

detect a thermal object image in the thermal image,

detect a visible light object image in the visible light image,

determine that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively

identify and categorizing the visible light object image into an object category of the foreign object,

determine a relationship between the object category of the foreign object in the visible light image and the thermal object image of the foreign object,

wherein when a thermal object image of the foreign object is detected, the foreign object is identified by mapping the object category to the thermal object image based on the relationship.

15. The detection system according to claim 14, wherein to determine the foreign object, the processor is configured to generate at least one attribute of the foreign object in each of the thermal object image and visible light object image, compare the at least one attribute of the foreign object in the thermal object image and the visible light object image, wherein the foreign object is detected when the at least one attribute of the foreign object in thermal object image and the visible light object image are the same.

16. The detection system according to claim 15, wherein the at least one attribute of the foreign object comprises the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image.

17. The detection system according to claim 16, wherein the at least one attribute of the foreign object in thermal object image and the visible light object image are the same when the distance between the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image is within a position parameter.

18. The detection system according to any one of claims 15 to 17, wherein the at least one attribute of the foreign object comprises the size of the thermal object image and visible light object image.

19. The detection system according to claim 18, wherein the at least one attribute of the foreign object in the thermal object image and visible light object image are the same when the difference in the size of the thermal object image in the thermal image and the size of the visible light object image in the visible light image is within a size parameter.

20. The detection system according to any one of claims 14 to 19, wherein the processor is further configured to zoom in the thermal camera and visible light camera to obtain an enlarged thermal object image and an enlarged visible light object image when the foreign object is detected.

21. The detection system according to any one of claims 14 to 20, wherein the processor is configured to identify an object category of the foreign object in the thermal image, wherein the processor is configured to,

segment the thermal image into a plurality of thermal image regions,

assign a feature vector to each of the plurality of thermal image regions,

compare the feature vector to a plurality of reference feature vectors, wherein each of the plurality of reference feature vectors represents an object category,

identify the reference feature vector closest to the feature vector and its object category.

22. The detection system according to claim 21, wherein to segment the thermal image, the processor is configured to label each pixel in the thermal image and group the labelled pixels with the same characteristic into a plurality of groups to form the plurality of thermal image regions.

23. The detection system according to any one of claims 14 to 22, wherein to identify an object category of the foreign object in the visible light image, the processor is configured to,

segment the visible light image into a plurality of visible light image regions,

assign a feature vector to each of the plurality of visible light image regions,

compare the feature vector to a plurality of reference feature vectors, wherein each of the plurality of reference feature vectors represents an object category,

identify the reference feature vector closest to the feature vector and its object category.

24. The detection system according to claim 23, wherein to segment the visible light image, the processor is configured to label each pixel in the visible light image and group the labelled

pixels with the same characteristic into a plurality of groups to form the plurality of visible light image regions.

25. The detection system according to any one of claims 23 to 24, wherein the processor is further configured to train the thermal camera to detect the foreign object based on the visible light images from the visible light camera.

26. The detection system according to any one of claims 14 to 22, wherein the process is further configured to generate a thermal profile model of the foreign object and optimizing the detection configuration parameters of the thermal camera based on the thermal profile model.

27. A system for detecting a foreign object on a runway divided into a plurality of sectors, the detection system comprising,

a plurality of sets of cameras spaced apart from each other, each of the plurality of sets of cameras comprises:

a thermal camera comprising a first field of view and adapted to capture a thermal image of an area of interest on the runway,

a visible light camera comprising a second field of view and adapted to capture a visible light image of the area of interest on the runway, wherein the first field of view overlaps the second field of view,

a processor in communication with the plurality of sets of cameras,

a memory in communication with the processor for storing instructions executable by the processor, wherein the processor is configured to:

detect a thermal object image in the thermal image,

detect a visible light object image in the visible light image, and

determine that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively,

identify and categorizing the visible light object image into an object category of the foreign object,

determine a relationship between the object category of the foreign object in the visible light image and the thermal object image of the foreign object,

wherein when a thermal object image of the foreign object is detected, the foreign object is identified by mapping the object category to the thermal object image based on the relationship,

wherein each of the plurality of sets of cameras is configured to scan one of the plurality of sectors of the runway..

Dated this 28th April, 2023

Signature of the Patent Agent:

Arjun Karthik Bala

IN/PA - 1021

ABSTRACT

A SYSTEM, A DETECTION SYSTEM FOR DETECTING A FOREIGN OBJECT ON A RUNWAY AND A METHOD OF THE SYSTEM

The present invention relates to a system for detecting a foreign object on a runway. The system includes a thermal camera having a first field of view and adapted to capture a thermal image of an area of interest on the runway, a visible light camera having a second field of view and adapted to capture a visible light image of the area of interest on the runway, such that the first field of view overlaps the second field of view. The system further includes a processor, a memory in communication with the processor for storing instructions executable by the processor, such that the processor is configured to detect a thermal object image in the thermal image, detect a visible light object image in the visible light image, and determine that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively. The present invention further provides a method thereof and a detection system for detecting the same.

Fig. 1

FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

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The Patent Rules, 2003

COMPLETE SPECIFICATION

(See sections 10 & rule 13)

1. TITLE OF THE INVENTION

A SYNERGISTIC POLY-HERBAL COMPOSITION FOR FATTY LIVER DISEASE

2. APPLICANT (S)

NAME	NATIONALITY	ADDRESS
Dr. Kaliappan Ilango	IN	Department of Pharmaceutical Quality Assurance, SRM College of Pharmacy, SRM Institute of Science and Technology, Kattankulathur- 603 203, Chengalpattu (Dt), Tamilnadu.

3. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which it is tobe performed.

TECHNICAL FIELD:

[0001] The present disclosure relates to a pharmaceutical composition. More specifically, the present disclosure relates to a purified extract of processed polyherbal composition comprising effective therapeutic amount of Andrographis paniculata in the range of 5% to 50%; Glycyrrhiza glabra in the range of 1% to 50%; Plumbago indica in the range of 3% to 50%; Terminalia arjuna in the range of 5% to 50%; Phyllanthus niruri in the range of 10% to 65%; and pharmaceutically acceptable excipients, useful in the prevention and treatment of non-alcoholic fatty liver disease (NAFLD). Further, the present disclosure provides a safe composition, excellent *in vitro* anti-oxidant activity and HepG2 inhibition.

BACKGROUND:

[0002] Background description includes information that may be useful in understanding the present invention. It is not an admission that any of the information provided herein is prior art or relevant to the presently claimed invention, or that any publication specifically or implicitly referenced is prior art.

[0003] In developed countries, NAFLD is currently the primary cause of chronic liver disease. There is now no licensed therapy available, and the prevalence is increasing in lockstep with worldwide increases in obesity and type 2 diabetes. The prevalence of NAFLD among general population in India ranges from 9-53%. For the foreseeable future, NAFLD will dominate the hepatology scene. The challenges that this disease has experienced to date, with an emphasis on finding gaps in its diagnosis and care, and recommends future strategies to solve these constraints. Despite the rising instances of NAFLD, there is little understanding and practice of its natural history, staging, diagnosis, and therapy. Because there are no effective treatments for NAFLD, symptom reduction is the only option left to the physicians. The necessity of the hour is to discover appropriate therapy using evidence-based medicine.

[0004] In particular, fatty deposits, tissue degeneration, inflammation, cell degeneration, fibrosis, cirrhosis, elevation of free fatty acids, and other such abnormalities are frequently observed in patients with various forms of NAFLD and have come to be associated with nonalcoholic steatohepatitis.

[0005] Obesity is the physiological condition that is most frequently present in NAFLD patients, accounting for at least 70% of those with the disease. The degree of obesity in NAFLD patients seems to be unrelated to non-insulin-dependent diabetic mellitus and generally connected with the degree of steatosis. Nevertheless, non-insulin-dependent diabetes mellitus raises the risk of steatohepatitis, particularly in people who need insulin. Weight loss in patients before death does not seem to ameliorate the steatosis until a significant portion of the extra body weight is gone; conversely, obese patients who reduced weight before death may have a higher prevalence of steatohepatitis.

[0006] There is a need to provide a safe pharmaceutical composition and potent activity against HepG2 and DPPH free radical assay for treating liver diseases. The present disclosure provides a synergistic polyherbal composition useful for treating nonalcoholic fatty liver disease (NAFLD) including fatty liver (steatosis), nonalcoholic steatohepatitis (NASH), and cirrhosis (advanced scarring of the liver).

[0007] The present disclosure comprises purified extracts of processed polyherbal, not direct extracts from the plants. Wherein the purified extract of processed polyherbal shows excellent in vitro anti-oxidant and HepG2 cell line inhibition compared with standard drugs at particular concentration ranges for each combination.

[0008] The present disclosure satisfies the existing needs, as well as others, and generally overcomes the deficiencies found in the prior art.

OBJECTIVES:

[0009] An object of the present disclosure is to provides a polyherbal composition for pharmaceutical applications.

[0010] An object of the present disclosure is to provides a synergistic polyherbal composition for pharmaceutical applications.

[0011] An object of the present disclosure is to provides, synergistic polyherbal composition comprising an effective amount of Andrographis paniculata in the range of 5% to 50%; Glycyrrhiza glabra in the range of 1% to 50%; Plumbago indica in the range of 3% to 50%; Terminalia arjuna in the range of 5% to 50%; Phyllanthus niruri in the range of 10% to 65%; and pharmaceutically acceptable excipients.

[0012] Another object of the present disclosure is to provides, the synergistic polyherbal composition useful for treating nonalcoholic fatty liver disease (NAFLD) including fatty liver (steatosis), nonalcoholic steatohepatitis (NASH), and cirrhosis (advanced scarring of the liver).

[0013] Further, object of the present disclosure is to provides, the polyherbal composition provides excellent HepG2 cell line and DPPH free radical scavenging activity.

SUMMARY:

[0014] This summary is provided to introduce a selection of concepts in a simplified form that is further described below in the detailed description section. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0015] An aspect of present disclosure provides a synergistic poly-herbal composition, the composition comprising processed extracts of (i) Andrographis paniculata in the range of 5% to 50%; (ii) Glycyrrhiza glabra in the range of 1% to 50%; (iii) Plumbago indica in the range of 3% to 50%; (iv) Terminalia arjuna in the range of 5% to 50%; (v) Phyllanthus niruri in the range of 10% to 65%; and (vi) Pharmaceutically acceptable excipients, wherein the polyherbal composition provides excellent HepG2 cell line inhibition and DPPH free radical scavenging activity.

[0016] Various features, aspects and advantages of the inventive subject matter will become more apparent from the following detailed description of preferred embodiments.

DETAILED DESCRIPTION OF DRAWINGS:

[0017] Figure 1 shows DPPH Radical Scavenging activity of Standard Ascorbic acid with IC_{50} 10.89 µg/ml and R^2= 0.8088, y=0.2062x + 47.753.

[0018] Figure 2 shows DPPH Radical Scavenging activity of Polyherbal Formulation (PHF500) tablet with Standard Ascorbic acid with IC_{50} 15.50 µg/ml and R^2= 0.8507, y=0.2412x+46.261 (Formulation A).

[0019] Figure 3 shows DPPH Radical Scavenging activity of Polyherbal Formulation (PHF500) tablet with Standard Ascorbic acid with IC_{50} 10.87 µg/ml and R^2= 0.8047, y=0.253x+ 47.249 (Formulation B).

[0020] Figure 4 shows DPPH Radical Scavenging activity of Polyherbal Formulation (PHF500) tablet with Standard Ascorbic acid with IC_{50} 8.91 µg/ml and R^2= 0.8329, y=0.2532x+ 47.852 (Formulation C).

[0021] Figure 5 shows DPPH Radical Scavenging activity of *Andrographis paniculata* HAE with Standard Ascorbic acid**.** IC_{50} 25.29 µg/ml and R^2= 0.79, y=0.1578x + 46.008.

[0022] Figure 6 shows DPPH Radical Scavenging activity of *Glycyrrhiza glabra* HAE with Standard Ascorbic acid**.** IC_{50} =26.95µg/ml and R^2= 0.8291, y=0.24x+ 43.531.

[0023] Figure 7 shows DPPH Radical Scavenging activity of *Phyllanthus niruri* HAE with Standard Ascorbic acid**.** IC_{50} =10.27 µg/ml and R^2= 0.8715, y=0.2305x +47.632.

[0024] Figure 8 shows DPPH Radical Scavenging activity of *Plumbago indica* HAE with Standard Ascorbic acid**.** IC_{50} =46.09 µg/ml and R^2= 0.85, y=0.1558x + 42.818.

[0025] Figure 9 shows DPPH Radical Scavenging activity of *Terminalia arjuna* HAE with Standard Ascorbic acid**.** IC_{50} =13.81 µg/ml and R^2= 0.9486, y=0.2253x+46.887.

[0026] **Figure 10** shows percentage cell viability of HepG2 cells treated by PHF500 tablet.

DETAILED DESCRIPTION:

[0027] It is to be understood that the present disclosure is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the drawings. The present disclosure is capable of other embodiments, of being practiced, or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

[0028] All technical and scientific words used herein, unless otherwise defined, have the same meaning as commonly known by one having ordinary ability in the relevant field. The words "a" and "an" designate one or more (i.e., at least one) of the article's grammatical objects. Unless otherwise stated, weight is used to determine all percentages and ratios. All percentages and ratios are calculated based on the total final composition unless otherwise indicated.

[0029] As used herein, whether in a transitional phase or the body of a claim, the terms “comprise(s)” and “comprising” are to be interpreted as having an open-ended meaning. That is, the terms are to be interpreted synonymously with the phrases “having at least” or “including at least”. When used in the context of a process, the term “comprising” means that the process includes at least the recited steps but may include additional steps. When used in the context of a composition, the term “comprising” means that the composition includes at least the recited features or components but may also include additional features or components.

[0030] As used herein, the term "composition" is intended to encompass a product comprising the specified ingredients in the specified amounts, as well as any product which results, directly or indirectly, from combination of the specified ingredients in the specified amounts.

[0031] All composition described herein can be performed in suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided with respect to certain embodiments herein is

intended merely to better illuminate the disclosure and does not pose a limitation on the scope of the invention otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the disclosure.

[0032] The numerical values given for various physical parameters, dimensions and quantities are only approximate values and it is envisaged that the values higher than the numerical value assigned to the physical parameters, dimensions and quantities fall within the scope of the disclosure unless there is a statement in the specification to the contrary.

[0033] The term “antioxidant” as used herein includes a substance that protects cells from the damage caused by free radicals (unstable molecules made by the process of oxidation during normal metabolism).

[0034] Reference throughout this specification to “an embodiment” or “in an embodiment” means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrases “yet another embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0035] In an embodiment, the term "lubricant" is intended to mean substances used in tablet formulations to reduce friction during tablet compression. Such compounds include, by way of example and without limitation, calcium stearate, magnesium stearate, talc, mineral oil, stearic acid, zinc stearate, suitable combinations thereof and other such materials known to those of ordinary skill in the art.

[0036] As used herein, the term "glidant" is intended to mean agents used in tablet and capsule formulations to improve flow-properties during tablet compression and to produce an anti-caking effect. Such compounds include, by way of example and without limitation, Colloidal silicon dioxide, Microcrystalline cellulose, colloidal silica, calcium silicate, magnesium silicate, silicon

hydrogel, corn starch, talc, combinations thereof and other such materials known to those of ordinary skill in the art.

[0037] As used herein, the term "binders" is intended to mean substances used to cause adhesion of powder particles in tablet granulations. Such compounds include, by way of example and without limitation, starch, acacia alginic acid, tragacanth, carboxymethylcellulose sodium, poly (vinylpyrrolidone), compressible sugar (e.g., NuTab), ethylcellulose, gelatin, liquid glucose, methyl cellulose, povidone and pregelatinized starch, combinations thereof and other similar material known to those of ordinary skill in the art.

[0038] In an embodiment, the term "disintegrant" is intended to mean a compound used in solid dosage forms to promote the disruption of the solid mass into smaller particles which are more readily dispersed or dissolved. Exemplary disintegrants include, by way of example and without limitation, Cros Cramellose Sodium (AC-DI-Sol) & Cross povidone XL 10, starches such as corn starch, potato starch, pre- gelatinized and modified starched thereof, sweeteners, clays, such as bentonite, microcrystalline cellulose, carsium, alginates, sodium starch glycolate, gums such as agar, guar, locust bean, karaya, pectin, tragacanth, combinations thereof and other such materials known to those of ordinary skill in the art.

[0039] In an embodiment, the term "wetting agent" is intended to mean a compound used to aid in attaining intimate contact between solid particles and liquids. Exemplary wetting agents include, by way of example and without limitation, poloxamers, gelatin, casein, Glycerol mono-oleate, lecithin (phosphatides), gum acacia, cholesterol, tragacanth, stearic acid, benzalkonium chloride, calcium stearate, glycerol monostearate, cetostearyl alcohol, sodium lauryl sulphate, sodium dodecyl sulphate, cetomacrogol emulsifying carboxy methyl cellulose calcium, carboxy methylcellulose sodium, methyl cellulose, hydroxy ethyl cellulose, hydroxyl propyl cellulose, hydroxy propyl methyl cellulose phthalate, non-crystalline cellulose, magnesium aluminium silicate, triethanolamine, polyvinyl alcohol, and poly vinyl pyrrolidone (PVP) and their suitable combinations and other such materials known to those of ordinary skill in the art. Tyloxapol (a nonionic liquid polymer of the alkyl aryl polyether alcohol type, also known as superinone or triton) is another useful wetting agent which may be used.

[0040] The pharmaceutical composition according to the present invention may be in the form of tablet or capsule or a powder or a suspension in a liquid formulation or solutions, preferably in the form of tablet or capsule.

[0041] The present disclosure overcomes the aforesaid drawbacks of the above, and other objects, features, and advantages of the present disclosure will now be described in greater detail. Also, the following description includes various specific details and, is to be regarded as merely exemplary. Accordingly, those of ordinary skill in the art will recognize that: without departing from the scope and spirit of the present disclosure and its various embodiments there may be any number of changes and modifications described herein.

[0042] Aspects of the present disclosure are further understood in light of the following examples, which should not be considered as limiting the scope of the present disclosure.

[0043] An aspect of the present disclosure provides a synergistic poly-herbal composition, the composition comprising processed extracts of (i) *Andrographis paniculata* in the range of 5% to 50%; (ii) Glycyrrhiza glabra in the range of 1% to 50%; (iii) Plumbago indica in the range of 3% to 50%; (iv) Terminalia arjuna in the range of 5% to 50%; (v) Phyllanthus niruri in the range of 10% to 65%; and (vi) pharmaceutically acceptable excipients, wherein the polyherbal composition provides excellent HepG2 cell line inhibition and DPPH free radical scavenging activity.

[0044] An embodiment of the present disclosure provides the Andrographis paniculata is selected from the range of 5% to 50%, preferably 7% to 47% and more preferably 10% to 45%.

[0045] In an embodiment of the present disclosure provides the Glycyrrhiza glabra is selected from the range of 1% to 50%, preferably 2% to 40% and more preferably 3% to 25%.

[0046] Another embodiment of the present disclosure provides the Plumbago indica is selected from the range of 3% to 50%; preferably 5% to 40% and more preferably 10% to 35%.

[0047] Yet another embodiment of the present disclosure provides the Terminalia arjuna is selected from the range of 5% to 50%, preferably 7% to 44% and more preferably 10% to 40%.

[0048] In yet another embodiment of the present disclosure provides the Phyllanthus niruri is selected from the range of 10% to 65%; preferably 12% to 60% and more preferably 15 to 55%.

[0049] Further embodiment of the present disclosure provides the pharmaceutically acceptable excipients are selected from additives, gums, sweeteners, coatings, binders, disintegrants, lubricants, disintegration agents, suspending agents, granulating agents, solvents, colorants, glidants, anti-adherents, anti-static agents, surfactants, plasticizers, emulsifying agents, flavoring agents, viscosity enhancers and antioxidants or combination thereof.

[0050] Furthermore, embodiment of the present disclosure provides the composition is in the form of tablet, capsule, syrup, decoction, tinctures and infusion.

[0051] The stable pharmaceutical composition may be made by direct compression, wet granulation or dry granulation methods by techniques known to persons skilled in the art. Thus, for example,

[0052] In wet granulation process, the drug is mixed with one or more pharmaceutical excipients and granulated with suitable binding solution as described earlier, to form wet granules, the wet granules are dried and optionally sieved. The dried granules are mixed with one or more suitable excipients from those described elsewhere and then compressed into tablets or filled into capsules.

[0053] In direct compression process, the drug is mixed with all the pharmaceutical excipients required and then is either compressed into tablets or filled in capsules.

[0054] In dry granulation process the drug is mixed with one or more pharmaceutical excipients and compressed into slugs and these slugs are passed through required sieve. The sieved granules are mixed with one or more suitable excipients from those described elsewhere and then compressed into tablets or filled into capsules.

[0055] Furthermore, embodiment of the present disclosure provides, the extract of processed polyherbal that is prepared as described. After removal of chlorophyll and essential oil, the cleaned crude of each extract, referred to as de-oiled spent material, is processed further by washing with water and water is decanted. Ethyl acetate is added to the residual solid and stirred under heat for 30 minutes. The solution is filtered, and the solution is transferred to the de-solventizer. Ethyl acetate is removed. Finally, the warm form of product is transferred to open top drums.

[0056] The headings and abstract of the disclosure provided herein are for convenience only and do not interpret the scope or meaning of the embodiments.

EXAMPLES:

[0057] The present disclosure is further explained in the form of the following examples. However, it is to be understood that the foregoing examples are merely illustrative and are not to be taken as limitations upon the scope of the invention. Various changes and modifications to the disclosed embodiments will be apparent to those skilled in the art. Such changes and modifications may be made without departing from the scope of the invention.

Experimental Example 1: Preparation of Tablet:

[0058] The PHF tablet was prepared by mixing of 5 selected processed medicinal plants extract such as *Andrographis paniculata* (10%), *Glycyrrhiza glabra* (10%), *Plumbago indica* (20%), *Terminalia arjuna* (20%), *Phyllanthus niruri* (40%). All the excipients and processed extracts were weighed accurately as per the formulations and passed through the vibrational shifter, the prepared binding solution starch was processed and mixed in the Rapid Granulation Mixture (RGM) slowly for 15 mins. Now sift the Microcrystalline, croscarmellose sodium (AC-DI-Sol), cross Povidone XL 10 and PHF extract through 40 mesh sifting and placed in octagonal blending for 30 mins for complete mixing. Later the processed mixture was allowed to dry on Fluidized bed dryer (FBD). The lumps were collected from the FBD and checked for the moisture content, once the moisture content is attained, it is transferred into multimill.

[0059] The granules were loaded again in FDB bowl and checked for inlet, product and outer temperature for drying process. After that again it is processed through vibrational shifter for

coarse powder. In the pre-lubrication processes, it is checked for dry granules and extra granules necessary for the compression. Unload the granules from the FBD and sift it through #20 mesh size. After that lubrication is processed by adding Magnesium stearate through #60 mesh and added to polybag octagonal blending for 3 mins. After the mixing the compression of tablet was done with punch size of 19.5 X 9.0 mm, having upper punch with a break line and lower punch with a plain surface with talc has a lubricant. The coating of tablet was carried out using Neocota machine following standard procedure.

Development of Polyherbal Formulation (PHF):

Table 1: Formulae for Tablet Preparation (Formulation A)

S.no	Name of the Ingredient	mg/Tablet
Dry Mixing Granulation		
1	*Andrographis paniculate*	30.0
2	*Glycyrrhiza glabra*	35.0
3	*Plumbago indica*	93.75
4	*Terminalia arjuna*	141.25
5	*Phyllanthus niruri*	200.0
6	Cros Cramellose Sodium (AC-DI-Sol)	41.0
7	Microcrystalline cellulose plain	180.0
8	Starch plain	50.0
9	Colloidal silicon dioxide	16.0
10	Cross povidone XL 10	10.0
11	Isopropyl alcohol	450.0
Lubrication		
12	Talc	3.2
13	Magnesium Stearate	3.2
14	Cross Cramellose Sodium (AC-DI-Sol)	25.0

Table 1A: Formulae for Tablet Preparation (Formulation B)

S.no	Name of the Ingredient	mg/Tablet
Dry Mixing Granulation		
1	*Andrographis paniculate*	35.0
2	*Glycyrrhiza glabra*	26.0
3	*Plumbago indica*	97.5
4	*Terminalia arjuna*	135.0
5	*Phyllanthus niruri*	206.5
6	Cros Cramellose Sodium (AC-DI-Sol)	41.0
7	Microcrystalline cellulose plain	180.0
8	Starch plain	50.0
9	Colloidal silicon dioxide	16.0
10	Cross povidone XL 10	10.0
11	Isopropyl alcohol	450.0
Lubrication		
12	Talc	3.2
13	Magnesium Stearate	3.2
14	Cross Cramellose Sodium (AC-DI-Sol)	25.0

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Table 1B: Formulae for Tablet Preparation (Formulation C)

S.no	Name of the Ingredient	mg/Tablet
Dry Mixing Granulation		
1	*Andrographis paniculate*	40.0
2	*Glycyrrhiza glabra*	38.75
3	*Plumbago indica*	101.25
4	*Terminalia arjuna*	110.0
5	*Phyllanthus niruri*	210.0
6	Cros Cramellose Sodium (AC-DI-Sol)	41.0
7	Microcrystalline cellulose plain	180.0
8	Starch plain	50.0
9	Colloidal silicon dioxide	16.0

10	Cross povidone XL 10	10.0
11	Isopropyl alcohol	450.0
Lubrication		
12	Talc	3.2
13	Magnesium Stearate	3.2
14	Cross Cramellose Sodium (AC-DI-Sol)	25.0

Various concentrations are tried, and the references given in Tables 1, 1A, and 1B show different concentrations of the tablet.

EXPERIMENTAL EXAMPLE 2: *IN VITRO* STUDY:

[0067] HepG2 ASSAY:

[0068] MTT assay is a colorimetric assay used for the determination of cell proliferation and cytotoxicity, based on reduction of the yellow-coloured water-soluble tetrazolium dye MTT to formazan crystals. Mitochondrial lactate dehydrogenase produced by live cells reduces MTT to insoluble formazan crystals, which upon dissolution into an appropriate solvent exhibits purple colour, the intensity of which is proportional to the number of viable cells and can be measured spectrophotometrically at 570nm. (Alley et al and Mosamann et al).

Materials:

[0069] Cell lines: HepG2 Human Hepatocellular adenocarcinoma cell lines (NCCS, Pune, India), Cell culture medium: DMEM- high Glucose - (#AL111, Himedia), Adjustable multichannel pipettes and a pipettor (Benchtop, USA), Fetal Bovine Serum (#RM10432, Himedia), MTT Reagent (5 mg/ml) (# 4060 Himedia), DMSO (#PHR1309, Sigma), D-PBS (#TL1006, Himedia), Doxorubicin (Cat No: D1515, Sigma), 96-well plate for culturing the cells (From Corning, USA), T25 flask (# 12556009, Biolite - Thermo), 50 ml centrifuge tubes (# 546043 TARSON), 1.5 ml centrifuge tubes (TARSON), 10 ml serological pipettes (TARSON),10 to 1000ul tips (TARSON).

Assay Controls:

(i) Medium control (medium without cells)

(ii) Negative control (medium with cells but without the experimental drug/compound)

(iii) Positive control (Medium with cells treated with Doxorubicin-1uM)

Percentage Cell viability is calculated using below formula:

Percentage cell viability = [Mean abs of treated cells/Mean abs of Untreated cells] x 100

The IC value was determined by using linear regression equation i.e. **Y=Mx+C.**

Here, Y = 50, M and C values were derived from the viability graph.

Test Concentrations:

[0070] In this study, given 1 test compound was evaluated to analyse the cytotoxicity effect on HepG2 cells.

Table 2. The concentrations of the test compound used to treat the cells are as follows:

S.No	Culture condition	Cell lines	Concentration treated to cells
1	Untreated	HEPG2	No Treatment
2	Blank	-	Only media without cells
3	STD (Dox-1μM)	HEPG2	1μM
4	PHF	HEPG2	1, 3, 10, 30, 100μg/ml

Table 3. MTT ASSAY for Formulation C

Culture condition	% cell viability
Untreated	100.00
Doxorubicin -1uM/ml	44.30
Tablet-1ug/ml	87.55
Tablet-3ug/ml	85.59
Tablet-10ug/ml	78.15
Tablet-30ug/ml	75.73
Tablet-100ug/ml	**51.32**

[0078] The MTT assay for formulation C results suggest that the given test compound, PHF Tablet has low cytotoxic in nature with IC_{50} value of 103.24 μg/ml on Human liver cancer cells and compound was showed toxicity on dose dependent manner. Doxorubicin with 1uM was used as a std control for the current study which showed the 44% cell viability after the treatment period of 24hours. In summary, given compound, PHF showed low toxic properties with decreased % cell viability values on concentration dependent manner and considered to be less cytotoxic in nature on Human liver cancer cells.

Determination of DPPH (1, 1-Diphenyl-2, Picryl-Hydrazyl) Radical Scavenging Activity:

[0079] Antioxidant activity for the PHF500 tablet and its composition such as ***Andrographis paniculata (Ap), Glycyrrhiza glabra (Gg), Phyllanthus niruri (Pn), Plumbago indica (Pi),*** **and** ***Terminalia arjuna (Ta)*** were estimated for their free radical scavenging activity by using DPPH (1, 1-Diphenyl-2, Picryl-Hydrazyl) free radicals. Samples solution at various concentrations (25, 50, 75, 100, 200µg/ml in methanol) was added to 1ml of DPPH solution (0.2mM in methanol) and allowed to stand for 30mins for complete reaction at room temperature. The samples were then observed for discoloration; from purple to yellow and pale pink were considered as strong and weak positive respectively, the absorbencies of the solutions were measured at 517 nm.

[0080] The IC_{50} value of the sample, which is the concentration of sample required to inhibit 50% of the DPPH free radical, was calculated using Log dose inhibition curve. Lower absorbance of the reaction mixture indicated higher free radical activity.

[0081] The IC_{50} value of the sample, which is the concentration of sample required to inhibit 50% of the DPPH free radical, was calculated using Log dose inhibition curve. Lower absorbance of the reaction mixture indicated higher free radical activity. The free radical scavenging activity of each sample was determined by comparing its absorbance with that of a blank solution (no sample). Standard ascorbic acid was used as reference. All the analysis was performed in triplicates and average values were taken (mean±SD).

Radical scavenging activity was calculated by the following equation:

$$Percentage\ DPPH\ inhibition = \frac{(Absorbance\ of control - Absorbance\ of sample)}{Absorbance\ of control} \times 100\%$$

Table 4: Standard-Ascorbic Acid (AA)

S.No	Conc. (µg/ml)	Control (Abs)	AA (Abs)	% Inhibition
1	25	0.38	0.19 ±0.01	48.42±0.31
2	50		0.17 ±0.02	53.68±0.31
3	75		0.13±0.02	66.31±0.21

4	100		0.08±0.02	78.94±0.32
5	200		0.06±0.01	84.21±0.48

Table 5: DPPH Antioxidant for PHF500 tablet [Formulation A]

S.no	Conc. (µg/ml)	Control (Abs)	PHF500 (Abs)	% Inhibition
1	25	0.38	0.21± 0.02	44.73±0.87
2	50		0.16±0.01	57.89± 0.45
3	75		0.12±0.02	67.78±0.21
4	100		0.07±0.02	79.97±0.34
5	200		0.04±0.01	89.47±0.31

Table 5A: DPPH Antioxidant for PHF500 tablet [Formulation B]

S.No	Conc. (µg/ml)	Control (Abs)	Abs	% Inhibition
1	25	0.38	0.21	44.73±0.41
2	50		0.166	56.89±0.45
3	75		0.100	74.72±38
4	100		0.069	81.93±0.67
5	200		0.031	91.84±0.47

Table 5B: DPPH Antioxidant for PHF500 tablet [Formulation C]

S. No	Conc. (µg/ml)	Control (Abs)	Abs	% Inhibition
1	25	0.38	0.21	44.73±0.54
2	50		0.15	59.89±0.32
3	75		0.11	71.72±0.67
4	100		0.08	78.93±0.78
5	200		0.04	89.84±0.43

Table 6: DPPH Antioxidant for *Andrographis paniculata (Ap)*

S.no	Conc. (µg/ml)	Control (Abs)	Ap (Abs)	% Inhibition
1	25	0.38	0.20± 0.02	45.26±0.21
2	50		0.18±0.01	50.52± 0.34
3	75		0.14±0.02	63.15±0.13

4	100		0.12±0.02	68.42±0.16
5	200		0.1±0.01	73.68±0.01

Table 7: DPPH Antioxidant for *Glycyrrhiza glabra (Gg)*

S.no	Conc. (µg/ml)	Control (Abs)	Gg (Abs)	% Inhibition
1	25	0.38	0.22± 0.01	42.1±0.35
2	50		0.18±0.02	52.6± 0.45
3	75		0.12±0.02	68.42±0.21
4	100		0.09±0.01	76.31±0.32
5	200		0.06±0.01	86.21±0.28

Table 8: DPPH Antioxidant for *Phyllanthus niruri (Pn)*

S.no	Conc. (µg/ml)	Control (Abs)	Pn (Abs)	% Inhibition
1	25	0.38	0.19± 0.01	48.89±0.24
2	50		0.16±0.01	55.15± 0.38
3	75		0.12±0.02	69.42±0.54
4	100		0.08±0.01	78.94±0.63
5	200		0.04±0.01	89.47±0.49

Table 9: DPPH Antioxidant for *Plumbago indica (Pi)*

S.no	Conc. (µg/ml)	Control (Abs)	Pi (Abs)	% Inhibition
1	25	0.38	0.21± 0.02	44.73±0.13
2	50		0.20±0.01	47.36± 0.45
3	75		0.17±0.02	55.26±0.21
4	100		0.13±0.02	65.78±0.41
5	200		0.11±0.01	71.05±0.38

Table 9: DPPH Antioxidant for *Terminalia arjuna (Ta)*

S.no	Conc. (µg/ml)	Control (Abs)	Ta (Abs)	% Inhibition
1	25		0.2± 0.02	47.26±0.03

2	50	0.38	0.15±0.01	60.52± 0.23
3	75		0.12±0.02	66.42±0.42
4	100		0.10±0.02	71.76±0.84
5	200		0.03±0.01	89.84±0.42

[0084] The absorbance at 517 nm by UV visible spectrophotometer was found to be as **0.06** and **0.04** for standard ascorbic acid and for PHF tablet respectively. The IC_{50} value obtained were as **10.89 µg/ml** and **15.50 µg/ml** for ascorbic acid and PHF tablet respectively. Additionally, individual plants at higher concentration captured more free radicals formed by DPPH resulting into decrease in absorbance and increase in % Inhibition.

[0085] The Label Claim of PHF tablet is 500mg, which is currently under pre-clinical trial. It is prepared by mixing appropriate dry processed extract of the herbal plants with appropriate excipients and made as dry mixing of granulation and then punched with tablet punching machine at size of 19.5 X 9.0 mm, having upper punch with a break line and lower punch with a plain surface. The Average weight of the tablet is 828.00mg.

[0086] The herbal plants (processed) Andrographis paniculata, Glycyrrhiza glabra, Terminalia arjuna, Plumbago indica, and Phyllanthus niruri which the antioxidation activity was tested for the prepared PHF as well as individual plant extracts. The selected combination showed excellent DPPH free radical scavenging activity. The processed herbal plant *Phyllanthus niruri* (IC_{50}-10.27 µg/ml) showed the best promising anti-oxidant activity when compared with the standard Ascorbic acid (IC50-10.89µg/ml), following which processed *Terminalia arjuna* (IC_{50} value of 13.81 µg/ml) and selected ratios having polyherbal composition shows excellent synergistic activity against fatty liver disease.

ADVANTAGES:

[0087] 1. Safe composition.

[0088] 2. The present disclosure provides excellent anti-oxidant and active against HepG2 cell line.

[0089] 3. The present disclosure provides the polyherbal tablet formulation is prepared for the treatment and management of Non-Alcoholic Fatty Liver Disorder.

We Claim:

1. A synergistic poly-herbal composition, the composition comprising processed extracts of:

(i) *Andrographis paniculata* in the range of 5% to 50%;

(ii) *Glycyrrhiza glabra* in the range of 1% to 50%;

(iii) *Plumbago indica* in the range of 3% to 50%;

(iv) *Terminalia arjuna* in the range of 5% to 50%;

(v) *Phyllanthus niruri* in the range of 10% to 65%; and

(vi) Pharmaceutically acceptable excipients;

wherein the polyherbal composition provides an excellent HepG2 cell line inhibition and DPPH free radical scavenging activity.

2. The composition as claimed in claim 1, wherein the *Andrographis paniculata* is selected from the range of 5% to 50%, preferably 7% to 47% and more preferably 10% to 45%.

3. The composition as claimed in claim 1, wherein the *Glycyrrhiza glabra* is selected from the range of 1% to 50%, preferably 2% to 40% and more preferably 3% to 25%.

4. The composition as claimed in claim 1, wherein the *Plumbago indica* is selected from the range of 3% to 50%; preferably 5% to 40% and more preferably 10% to 35%.

5. The composition as claimed in claim 1, wherein the *Terminalia arjuna* is selected from the range of 5% to 50%, preferably 7% to 44% and more preferably 10% to 40%.

6. The composition as claimed in claim 1, wherein the *Phyllanthus niruri* is selected from the range of 10% to 65%; preferably 12% to 60% and more preferably 15 to 55%.

7. The composition as claimed in claim 1, wherein the pharmaceutically acceptable excipients are selected from additives, gums, sweeteners, coatings, binders, disintegrants, lubricants, disintegration agents, suspending agents, granulating agents, solvents, colorants, glidants, anti-

adherents, anti-static agents, surfactants, plasticizers, emulsifying agents, flavoring agents, viscosity enhancers and antioxidants or combination thereof.

8. The composition as claimed in claim 1, wherein the composition is in the form of tablet, capsule, syrup, decoction, tinctures and infusion.

For Dr. Kaliappan Ilango

Anand D

Anand Durai

Regd. Patent Agent [IN/PA-4447]

Dated: 29th April, 2023

ABSTRACT

A SYNERGISTIC POLY-HERBAL COMPOSITION FOR FATTY LIVER DISEASE

The present disclosure relates to a pharmaceutical composition. More specifically, the present disclosure relates to a purified extract of processed polyherbal composition comprising effective therapeutic amount of Andrographis paniculata in the range of 5% to 50%, Glycyrrhiza glabra in the range of 1% to 50%, Plumbago indica in the range of 3% to 50%, Terminalia arjuna in the range of 5% to 50%, Phyllanthus niruri in the range of 10% to 65%, and pharmaceutically acceptable excipients useful in the prevention and treatment of non-alcoholic fatty liver disease (NAFLD). Further, the present disclosure provides safe and effective composition and excellent in vitro anti-oxidant activity and HepG2 cell line inhibition.

For Dr. Kaliappan Ilango

Anand D

Anand Durai

Regd. Patent Agent [IN/PA-4447]

Dated: 29th April, 2023

FORM 2

THE PATENTS ACT 1970

39 OF 1970

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THE PATENT RULES 2003

COMPLETE SPECIFICATION

(SEE SECTIONS 10 & RULE 13)

1. TITLE OF THE INVENTION

"METHOD OF DESIGNING A 2x2 MIMO ANTENNA"

2. APPLICANT(S)

NAME	NATIONALITY	ADDRESS
RAJALAKSHMI ENGINEERING COLLEGE	Indian	Rajalakshmi Nagar Thandalam, Chennai, Tamil Nadu, 602105, India

3. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which it is to be performed

METHOD OF DESIGNING A 2x2 MIMO ANTENNA

FIELD OF THE INVENTION

[0001]The present disclosure relates generally to communication field, and more particularly, to a design of 2X2 Multiple Input Multiple Output (MIMO) antenna for ISM, WIFI, WIMAX AND WLAN applications.

BACKGROUND OF THE INVENTION

[0002]Antenna is a device used for radiating or receiving radio waves. In other words, the antenna is the transitional structure between free space and a guiding device (used to transport electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver). In addition to receiving or transmitting energy, an antenna in an advanced wireless system usually required to optimize or attenuate the radiation energy in some directions and suppress it in others. Thus, it serves as a directional device in addition to a probing device. It takes various forms to meet the particular need at hand, and it may be a piece of conducting wire, an aperture, a patch, an assembly of elements(array), a reflector, a lens, and so forth. For wireless communication systems, the antenna is one of the most critical components. A good design of the antenna can relax system requirements and improve overall system performance.

[0003]Although the concept of a micro strip antenna dates back to 1953 and was granted a patent in 1955, it wasn't until the 1970s that the technology began to garner significant interest. The micro strip patch is made to have a maximum pattern that is consistent with the patch (broadside radiator). By carefully selecting the mode (field configuration) of stimulation beneath the patch, this is achieved. Prudent mode selection can potentially result in end-fire radiation. The length L of

the element for a rectangular patch is typically 0/3 < L < 0/2. A dielectric sheet separates the strip from the ground plane.

[0004]Micro strip patch antennas are compatible with MMIC designs, low profile, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, and very versatile in terms of resonant frequency, polarisation, pattern, and impedance when the specific patch shape and mode are selected. Furthermore, adaptive elements with changeable resonant frequency, impedance, polarisation, and pattern can be created by introducing loads such as pin and varactor diodes between the patch and the ground plane.

[0005]The word "MIMO" denotes the use of multiple antennas at the transmitter and receiver in wireless technology. Modern usage of the term "MIMO" refers particularly to a realistic method that makes use of multipath propagation to send and receive multiple data signals concurrently over a single radio channel. MIMO is fundamentally distinct from smart antenna technologies like beam forming and diversity that were created to improve the performance of a single data transmission. Including IEEE 802.11n (Wi-Fi), IEEE 802.11ac (Wi-Fi), HSPA+ (3G), WiMAX, and Long-Term Evolution, MIMO has become a crucial component of wireless communication protocols (LTE). The new MIMO wireless technology is being used by Wi-Fi, Long Term Evolution (LTE), and many other radio, wireless, and RF technologies to deliver enhanced link capacity and spectral efficiency along with better link stability employing what were previously considered as interference channels.

OBJECT OF THE INVENTION

[0006]The object of the present invention is to provide a Flame Retardant 4 (FR4) material with an excellent mechanical strength and high insulating qualities at low cost.

[0007]Another object of the present invention is to provide a Parasitic Strip element which reduces the mutual coupling between MIMO antenna elements.

[0008]Yet another object of the present disclosure is to provide a Parasitic Strip element which enhances correlation coefficient, radiation efficiency and isolation between ports.

[0009]These and another objects and advantages will become more apparent when reference is made to the following description and accompanying drawings.

SUMMARY OF THE INVENTION

[0010]A solution to one or more drawbacks of the existing technology and additional advantages are provided through the present disclosure. Additional features and advantages are realized through the technicalities of the present disclosure. Other aspects of the disclosure are described in detail herein and are considered to be a part of the claimed disclosure.

[0011]The main aspect of the present invention is a 2x2 Multiple Input Multiple Output (MIMO) Antenna with a parasitic element for isolation enhancement to find application in Wi-Fi, Wi-Max, and 5G. The present invention has 2 antenna configurations to implement MIMO technology, which enhance the data rate, transfer rate of the information signal. The antennas are positioned orthogonally and isolated with a patch called the parasitic element which enhances the isolation property of the antenna. The parasitic element consists of custom designed patch structure which improves the working principle of the element. The base and the patch are designed by Copper metal, and the Ground is made up of FR-4 Substrate with an Epsilon value of 4.4 that is ideal for commercial antenna usage. The Isolation Enhancement indicating parameter S12 has a value of -30dB which supports novelty for the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]Figure 1a illustrates the rectangular shaped single patch antenna as provided in the present invention;

[0013]Figure 1b illustrates the parasitic strip element as provided in the present invention;

[0014]Figure 2 illustrates the MIMO arrangement with parasitic strip element as provided in the present invention;

[0015]Figure 3a and 3b illustrates the graphical representation of the return loss for simulated model and fabricated model respectively as provided in the present invention;

[0016]Figure 4a and **4b** illustrates the graphical representation of the antenna isolation for simulated model and fabricated model respectively as provided in the present invention;

[0017]Figure 5 and **6** illustrates the graphical representation of the Envelope Correlation Coefficient (ECC) and diversity gain obtained from the proposed antenna design respectively as provided in the present invention;

[0018]Figure 7a and **7b** illustrates the graphical representation of Voltage Standing Wave Ratio (VSWR) for simulated model and fabricated model respectively as provided in the present invention;

[0019]Figure 8 illustrates the radiation pattern of the proposed antenna design as provided in the present invention;

[0020]Figure 9a and **9b** illustrates the top view and bottom view of the fabricated patch antenna with parasitic strip respectively as provided in the present invention;

[0021]Figure 10 illustrates the pictorial representation of testing of a fabricated antenna using Vector Network Analyzer (VNA) as provided in the present invention;

[0022]The figures of the present subject matter depict for illustration only. A person skilled in the art will easily recognize from the following description that

the illustration herein may be employed without departing from the principles of the disclosure described herein.

DETAILED DESCRIPTION OF THE INVENTION

[0023]The present invention will now be described hereinafter with reference to the accompanying drawings in which a preferred embodiment of the invention is shown. This invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiment set forth herein. Rather, the embodiment is provided so that this disclosure will be thorough, and will fully convey the scope of the invention to those skilled in the art.

[0024]Many aspects of the invention can be better understood with references made to the drawings below. The components in the drawings are not necessarily drawn to scale. Instead, emphasis is placed upon clearly illustrating the components of the present invention. Moreover, like reference numerals designate corresponding parts through the several views in the drawings. Before explaining at least one embodiment of the invention, it is to be understood that the embodiments of the invention are not limited in their application to the details of construction and to the arrangement of the components set forth in the following description or illustrated in the drawings. The embodiments of the invention are capable of being practiced and carried out in various ways. In addition, the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

[0025]Referring to **Figure 1a**, a rectangular shaped patch (100a) with the dimensions of 12 x 15 x 0.035 mm^3 was designed as depicted. The proposed antenna is constructed with patch of thickness 0.035 mm and the ground of thickness 0.035 mm wherein the patch is made of the material copper, and the

ground is made of the material copper. The substrate (102) is made of FR-4 material which possesses a dielectric constant of 4.4. The microstrip line feeding technique is used to feed the monopole antenna. Another antenna (100b) with the same parameters is designed and placed orthogonal to the each other.

[0026]Referring to **Figure 1b** and **Figure 2**, the parasitic strip element (101) is placed between two orthogonally placed Antenna patch elements (100a & 100b) which increases the Isolation Capability of the antennas. The type of isolation enhancement technique used in the disclosure is the parasitic element method. Use of parasitic elements between the MIMO antennas (100a & 100b) is another method of reducing mutual coupling. It also enhances correlation coefficient, radiation efficiency and isolation between ports (104a & 104b). The parasitic structures are not directly connected to the proposing antennas. An opposite coupling field is created in the parasitic elements (101) wherein some coupled field current between the antennas (100a & 100b) are terminated. This in turn reduces the mutual coupling among MIMO antenna (100a & 100b) elements. Reduction in the mutual coupling indicates enhancement in the isolation parameter of the proposed MIMO design.

[0027] Figure 2 consist of antennas (100a & 100b) placed at orthogonal position with respect to each other. A parasitic strip (101) placed in between the two antennas (100a & 100b). The disclosed structure can shield the antennas resulting in reduced interference levels. A pin shaped patch is designed and transformed vertically to form the rectangular parasitic strip like (101) structure as shown in Figure 2. The usage of parasitic strip is to reduce the mutual coupling present between the antennas (100a & 100b). The strip (101) is not directly connected to the radiating antennas. The creation of an opposite coupling field in the parasitic component (101), some coupled field current between the antennas (100a & 100b) is terminated. As a result, the mutual coupling between MIMO antenna elements is reduced and the isolation property is enhanced.

Table: 1 Optimized geometrical specification of single patch micro strip antenna

Parameters	Dimensions(mm)
Substrate width	5
Substrate length	30
Substrate thickness	1.6
Feed length	18
Feed width	3
Patch length	12
Patch width	15
Parasitic element length	3.5
Parasitic element width	23

[0028]To characterize a MIMO antenna system, several important parameters need to be evaluated along with basic single antenna parameters namely return loss, isolation, Envelope Correlation Coefficient (ECC), diversity gain, Voltage Standing Wave Ratio (VSWR) and radiation pattern.

[0029]Referring to **Figure 3a and 3b**, a graphical representation of the return loss for simulated model and fabricated model for the present invention is depicted. The ratio of the antenna's input power to the power reflected back from the source defines return loss. It is measured in decibels (dB). It is used to represent the S11 parameter. If s11=0, then no power is radiated. It shows the impedances of the patch elements are matched. The return loss of the invention is -53dB at 5.8 GHz frequency.

[0030] Referring to **Figure 4a and 4b**, a graphical representation of the antenna isolation for simulated model and fabricated model for the present invention is depicted. Antenna isolation is a measure of how one antenna picks up radiation from another. It is measured in decibels. Use of parasitic strip (101) is the

isolation enhancement technique adapted and is found to be around -31dB at 5.8 GHz frequency. S12 is used to refer isolation.

[0031]Referring to **Figure 5**, a graphical representation of the Envelope Correlation Coefficient (ECC) for the present disclosure is depicted. ECC determines the correlation among the radiators and diversity performance of MIMO antenna system. ECC can be obtained from the S-parameters using the formula,

$$\rho_e = \frac{|S_{11}^{\star} S_{12} + S_{21}^{\star} S_{22}|^2}{(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2)}$$

The ECC value is below 0.0001 at 5.8 GHz frequency.

[0032]Referring to **Figure 6**, a graphical representation of the diversity gain for the present disclosure is depicted. Diversity gain measures how much a diversity scheme improves the signal-to-interference ratio. It is measured in decibels. From Figure 6, it is observed that the diversity gain of the antenna is above 9.998 approximately.

[0033]Referring to **Figure 7a** and **7b**, a graphical representation of Voltage Standing Wave Ratio (VSWR) for simulated model and fabricated model for the present disclosure is depicted. It defines how good the micro-strip patch antenna and feed line are matched to their impedances. The VSWR is calculated by,

$$\text{VSWR} = (1+\rho) / (1-\rho)$$

The value of VSWR for the proposed invention is below 1.1 for both the antennas.

[0034]Referring to **Figure 8**, a radiation pattern for the present disclosure is depicted. The disclosed antenna design reveals the process of energy radiates and/or receives into space.

Table: 2 Result Analysis

ANALYZED PARAMETER	OBTAINED RESULT
Frequency	5.8 GHz
Isolation	-44.36 dB
Return loss	-26.02 dB
ECC	0.0001
Diversity Gain	>9.99
VSWR	<1.1

[0035]Referring to **Figure 9a** and **9b** illustrates the top view and bottom view (13 & 14) of the fabricated patch antenna with parasitic strip for the present disclosure is depicted. Mask for the fabrication of patch antenna was designed using AutoCAD. To transfer the mask image on electro plated copper PCB board photolithography technique was used. The cut size pieces of PCB sheets were cleaned to remove the surface impurities using organic solvents and then dried with hot air gun before coating the positive photo resist (PPR) on it. The PPR coated substrate was pre-baked in an oven at 900C to remove the solvent and stuffing the film. The baked substrate was exposed on indigenously developed mask aligner with inbuilt exposure system and mask as prepared earlier. The exposed substrate was developed in 20% KOH solution. After transferring the mask images on substrate, it was placed in oven at temperature 1300C for 30 min for hard baking. The exposed unwanted features were etched out in solution of FeCl3. The etched Cu pattern was rinsed in DI water and air-dried. The fabricated micro strip antenna (100a & 100b) was mounted on properly designed and prefabricated copper sheet. This copper sheet acts as ground plate. BNC connector is soldered at the feed point on the fabricated antenna. **Figure 10** is the pictorial

representation of testing of a fabricated antenna using Vector Network Analyzer (VNA).

DESIGN GEOMETRICS:

The Microstrip Patch Antenna Calculation Process is as follows,

Step 1: Calculation of the Width (W),

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Step 2: Calculation of the Effective Dielectric Constant. This is based on the height, dielectric constant of the dielectric and the calculated width of the patch antenna,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Step 3: Calculation of the Effective length:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$$

Step 4: Calculation of the length extension ΔL:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Step 5: Calculation of actual length of the patch:

$$L = L_{eff} - 2\Delta L$$

where,

f_0 is the Resonance Frequency

W is the Width of the Patch

L is the Length of the Patch

h is the thickness

ε_r is the relative Permittivity of the dielectric substrate

c is the Speed of light: 3×10^8

[0036]The foregoing description of embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention. The embodiments were chosen and described in order to explain the principals of the invention and its practical application to enable one skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

We claim:

1. A method of designing a 2x2 MIMO antenna (13 & 14) comprising:
   two radiating patches (100a & 100b) orthogonal to each other;
   a parasitic strip element (101) in between the two radiating patches;
   a dielectric substrate (102) and a ground plane (103);

   said radiating patches (100a & 100b) made of metallic sheets of thickness 0.035mm implemented on the said dielectric substrate (102);

   said ground plane (103) made of metallic sheets of thickness 0.035mm implemented on the said dielectric substrate (102); and

   said dielectric substrate (102) is made of Flame Retardant 4 (FR4) material having dielectric constant of 4.4, relative permittivity of 4.3, permeability of 1 and loss tangent of 0.025.

2. The method of designing a 2x2 MIMO antenna (13 & 14) claimed in claim 1, wherein the said parasitic strip element (101) reduces mutual coupling between the antennas (100a & 100b) and enhances correlation coefficient, radiation efficiency and isolation between ports (104a & 104b).

3. The method of designing a 2x2 MIMO antenna (13 & 14) claimed in claim 1, wherein the said antenna is having substrate width of 5mm, substrate length of 30mm, substrate thickness of 1.6mm, feed length of 18mm, feed width of 3mm, patch length of 12mm, patch width of 15mm, parasitic element length of 3.5mm and parasitic element width of 23mm.

4. The method of designing a 2x2 MIMO antenna (13 & 14) claimed in claim 1, wherein the said antenna is having frequency of 5.8 GHz, isolation of -44.36 dB, return loss of -26.02 dB, Envelope Correlation Coefficient

(ECC) of 0.0001, diversity gain above 9.998 and Voltage Standing Wave Ratio (VSWR) below 1.1.

Dated this 29th day of April, 2023

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APPLICANT'S AGENT

FORM 2

THE PATENTS ACT 1970

39 OF 1970

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THE PATENT RULES 2003

COMPLETE SPECIFICATION

(SEE SECTIONS 10 & RULE 13)

1. TITLE OF THE INVENTION

"METHOD OF DESIGNING A 2x2 MIMO ANTENNA"

2. APPLICANT(S)

NAME	NATIONALITY	ADDRESS
RAJALAKSHMI ENGINEERING COLLEGE	Indian	Rajalakshmi Nagar Thandalam, Chennai, Tamil Nadu, 602105, India

3. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which it is to be performed

METHOD OF DESIGNING A 2x2 MIMO ANTENNA

FIELD OF THE INVENTION

[0001]The present disclosure relates generally to communication field, and more particularly, to a design of 2X2 Multiple Input Multiple Output (MIMO) antenna for ISM, WIFI, WIMAX AND WLAN applications.

BACKGROUND OF THE INVENTION

[0002]Antenna is a device used for radiating or receiving radio waves. In other words, the antenna is the transitional structure between free space and a guiding device (used to transport electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver). In addition to receiving or transmitting energy, an antenna in an advanced wireless system usually required to optimize or attenuate the radiation energy in some directions and suppress it in others. Thus, it serves as a directional device in addition to a probing device. It takes various forms to meet the particular need at hand, and it may be a piece of conducting wire, an aperture, a patch, an assembly of elements(array), a reflector, a lens, and so forth. For wireless communication systems, the antenna is one of the most critical components. A good design of the antenna can relax system requirements and improve overall system performance.

[0003]Although the concept of a micro strip antenna dates back to 1953 and was granted a patent in 1955, it wasn't until the 1970s that the technology began to garner significant interest. The micro strip patch is made to have a maximum pattern that is consistent with the patch (broadside radiator). By carefully selecting the mode (field configuration) of stimulation beneath the patch, this is achieved. Prudent mode selection can potentially result in end-fire radiation. The length L of

the element for a rectangular patch is typically 0/3 < L < 0/2. A dielectric sheet separates the strip from the ground plane.

[0004]Micro strip patch antennas are compatible with MMIC designs, low profile, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, and very versatile in terms of resonant frequency, polarisation, pattern, and impedance when the specific patch shape and mode are selected. Furthermore, adaptive elements with changeable resonant frequency, impedance, polarisation, and pattern can be created by introducing loads such as pin and varactor diodes between the patch and the ground plane.

[0005]The word "MIMO" denotes the use of multiple antennas at the transmitter and receiver in wireless technology. Modern usage of the term "MIMO" refers particularly to a realistic method that makes use of multipath propagation to send and receive multiple data signals concurrently over a single radio channel. MIMO is fundamentally distinct from smart antenna technologies like beam forming and diversity that were created to improve the performance of a single data transmission. Including IEEE 802.11n (Wi-Fi), IEEE 802.11ac (Wi-Fi), HSPA+ (3G), WiMAX, and Long-Term Evolution, MIMO has become a crucial component of wireless communication protocols (LTE). The new MIMO wireless technology is being used by Wi-Fi, Long Term Evolution (LTE), and many other radio, wireless, and RF technologies to deliver enhanced link capacity and spectral efficiency along with better link stability employing what were previously considered as interference channels.

OBJECT OF THE INVENTION

[0006]The object of the present invention is to provide a Flame Retardant 4 (FR4) material with an excellent mechanical strength and high insulating qualities at low cost.

[0007]Another object of the present invention is to provide a Parasitic Strip element which reduces the mutual coupling between MIMO antenna elements.

[0008]Yet another object of the present disclosure is to provide a Parasitic Strip element which enhances correlation coefficient, radiation efficiency and isolation between ports.

[0009]These and another objects and advantages will become more apparent when reference is made to the following description and accompanying drawings.

SUMMARY OF THE INVENTION

[0010]A solution to one or more drawbacks of the existing technology and additional advantages are provided through the present disclosure. Additional features and advantages are realized through the technicalities of the present disclosure. Other aspects of the disclosure are described in detail herein and are considered to be a part of the claimed disclosure.

[0011]The main aspect of the present invention is a 2x2 Multiple Input Multiple Output (MIMO) Antenna with a parasitic element for isolation enhancement to find application in Wi-Fi, Wi-Max, and 5G. The present invention has 2 antenna configurations to implement MIMO technology, which enhance the data rate, transfer rate of the information signal. The antennas are positioned orthogonally and isolated with a patch called the parasitic element which enhances the isolation property of the antenna. The parasitic element consists of custom designed patch structure which improves the working principle of the element. The base and the patch are designed by Copper metal, and the Ground is made up of FR-4 Substrate with an Epsilon value of 4.4 that is ideal for commercial antenna usage. The Isolation Enhancement indicating parameter S12 has a value of -30dB which supports novelty for the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]Figure 1a illustrates the rectangular shaped single patch antenna as provided in the present invention;

[0013]Figure 1b illustrates the parasitic strip element as provided in the present invention;

[0014]Figure 2 illustrates the MIMO arrangement with parasitic strip element as provided in the present invention;

[0015]Figure 3a and 3b illustrates the graphical representation of the return loss for simulated model and fabricated model respectively as provided in the present invention;

[0016]Figure 4a and **4b** illustrates the graphical representation of the antenna isolation for simulated model and fabricated model respectively as provided in the present invention;

[0017]Figure 5 and **6** illustrates the graphical representation of the Envelope Correlation Coefficient (ECC) and diversity gain obtained from the proposed antenna design respectively as provided in the present invention;

[0018]Figure 7a and **7b** illustrates the graphical representation of Voltage Standing Wave Ratio (VSWR) for simulated model and fabricated model respectively as provided in the present invention;

[0019]Figure 8 illustrates the radiation pattern of the proposed antenna design as provided in the present invention;

[0020]Figure 9a and **9b** illustrates the top view and bottom view of the fabricated patch antenna with parasitic strip respectively as provided in the present invention;

[0021]Figure 10 illustrates the pictorial representation of testing of a fabricated antenna using Vector Network Analyzer (VNA) as provided in the present invention;

[0022]The figures of the present subject matter depict for illustration only. A person skilled in the art will easily recognize from the following description that

the illustration herein may be employed without departing from the principles of the disclosure described herein.

DETAILED DESCRIPTION OF THE INVENTION

[0023]The present invention will now be described hereinafter with reference to the accompanying drawings in which a preferred embodiment of the invention is shown. This invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiment set forth herein. Rather, the embodiment is provided so that this disclosure will be thorough, and will fully convey the scope of the invention to those skilled in the art.

[0024]Many aspects of the invention can be better understood with references made to the drawings below. The components in the drawings are not necessarily drawn to scale. Instead, emphasis is placed upon clearly illustrating the components of the present invention. Moreover, like reference numerals designate corresponding parts through the several views in the drawings. Before explaining at least one embodiment of the invention, it is to be understood that the embodiments of the invention are not limited in their application to the details of construction and to the arrangement of the components set forth in the following description or illustrated in the drawings. The embodiments of the invention are capable of being practiced and carried out in various ways. In addition, the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

[0025]Referring to **Figure 1a**, a rectangular shaped patch (100a) with the dimensions of 12 x 15 x 0.035 mm^3 was designed as depicted. The proposed antenna is constructed with patch of thickness 0.035 mm and the ground of thickness 0.035 mm wherein the patch is made of the material copper, and the

ground is made of the material copper. The substrate (102) is made of FR-4 material which possesses a dielectric constant of 4.4. The microstrip line feeding technique is used to feed the monopole antenna. Another antenna (100b) with the same parameters is designed and placed orthogonal to the each other.

[0026]Referring to **Figure 1b** and **Figure 2**, the parasitic strip element (101) is placed between two orthogonally placed Antenna patch elements (100a & 100b) which increases the Isolation Capability of the antennas. The type of isolation enhancement technique used in the disclosure is the parasitic element method. Use of parasitic elements between the MIMO antennas (100a & 100b) is another method of reducing mutual coupling. It also enhances correlation coefficient, radiation efficiency and isolation between ports (104a & 104b). The parasitic structures are not directly connected to the proposing antennas. An opposite coupling field is created in the parasitic elements (101) wherein some coupled field current between the antennas (100a & 100b) are terminated. This in turn reduces the mutual coupling among MIMO antenna (100a & 100b) elements. Reduction in the mutual coupling indicates enhancement in the isolation parameter of the proposed MIMO design.

[0027] Figure 2 consist of antennas (100a & 100b) placed at orthogonal position with respect to each other. A parasitic strip (101) placed in between the two antennas (100a & 100b). The disclosed structure can shield the antennas resulting in reduced interference levels. A pin shaped patch is designed and transformed vertically to form the rectangular parasitic strip like (101) structure as shown in Figure 2. The usage of parasitic strip is to reduce the mutual coupling present between the antennas (100a & 100b). The strip (101) is not directly connected to the radiating antennas. The creation of an opposite coupling field in the parasitic component (101), some coupled field current between the antennas (100a & 100b) is terminated. As a result, the mutual coupling between MIMO antenna elements is reduced and the isolation property is enhanced.

Table: 1 Optimized geometrical specification of single patch micro strip antenna

Parameters	Dimensions(mm)
Substrate width	5
Substrate length	30
Substrate thickness	1.6
Feed length	18
Feed width	3
Patch length	12
Patch width	15
Parasitic element length	3.5
Parasitic element width	23

[0028]To characterize a MIMO antenna system, several important parameters need to be evaluated along with basic single antenna parameters namely return loss, isolation, Envelope Correlation Coefficient (ECC), diversity gain, Voltage Standing Wave Ratio (VSWR) and radiation pattern.

[0029]Referring to **Figure 3a and 3b**, a graphical representation of the return loss for simulated model and fabricated model for the present invention is depicted. The ratio of the antenna's input power to the power reflected back from the source defines return loss. It is measured in decibels (dB). It is used to represent the S11 parameter. If s11=0, then no power is radiated. It shows the impedances of the patch elements are matched. The return loss of the invention is -53dB at 5.8 GHz frequency.

[0030] Referring to **Figure 4a and 4b**, a graphical representation of the antenna isolation for simulated model and fabricated model for the present invention is depicted. Antenna isolation is a measure of how one antenna picks up radiation from another. It is measured in decibels. Use of parasitic strip (101) is the

isolation enhancement technique adapted and is found to be around -31dB at 5.8 GHz frequency. S12 is used to refer isolation.

[0031]Referring to **Figure 5**, a graphical representation of the Envelope Correlation Coefficient (ECC) for the present disclosure is depicted. ECC determines the correlation among the radiators and diversity performance of MIMO antenna system. ECC can be obtained from the S-parameters using the formula,

$$\rho_e = \frac{|S_{11}^{\star} S_{12} + S_{21}^{\star} S_{22}|^2}{(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2)}$$

The ECC value is below 0.0001 at 5.8 GHz frequency.

[0032]Referring to **Figure 6**, a graphical representation of the diversity gain for the present disclosure is depicted. Diversity gain measures how much a diversity scheme improves the signal-to-interference ratio. It is measured in decibels. From Figure 6, it is observed that the diversity gain of the antenna is above 9.998 approximately.

[0033]Referring to **Figure 7a** and **7b**, a graphical representation of Voltage Standing Wave Ratio (VSWR) for simulated model and fabricated model for the present disclosure is depicted. It defines how good the micro-strip patch antenna and feed line are matched to their impedances. The VSWR is calculated by,

$$\text{VSWR} = (1+\rho) / (1-\rho)$$

The value of VSWR for the proposed invention is below 1.1 for both the antennas.

[0034]Referring to **Figure 8**, a radiation pattern for the present disclosure is depicted. The disclosed antenna design reveals the process of energy radiates and/or receives into space.

Table: 2 Result Analysis

ANALYZED PARAMETER	OBTAINED RESULT
Frequency	5.8 GHz
Isolation	-44.36 dB
Return loss	-26.02 dB
ECC	0.0001
Diversity Gain	>9.99
VSWR	<1.1

[0035]Referring to **Figure 9a** and **9b** illustrates the top view and bottom view (13 & 14) of the fabricated patch antenna with parasitic strip for the present disclosure is depicted. Mask for the fabrication of patch antenna was designed using AutoCAD. To transfer the mask image on electro plated copper PCB board photolithography technique was used. The cut size pieces of PCB sheets were cleaned to remove the surface impurities using organic solvents and then dried with hot air gun before coating the positive photo resist (PPR) on it. The PPR coated substrate was pre-baked in an oven at 900C to remove the solvent and stuffing the film. The baked substrate was exposed on indigenously developed mask aligner with inbuilt exposure system and mask as prepared earlier. The exposed substrate was developed in 20% KOH solution. After transferring the mask images on substrate, it was placed in oven at temperature 1300C for 30 min for hard baking. The exposed unwanted features were etched out in solution of FeCl3. The etched Cu pattern was rinsed in DI water and air-dried. The fabricated micro strip antenna (100a & 100b) was mounted on properly designed and prefabricated copper sheet. This copper sheet acts as ground plate. BNC connector is soldered at the feed point on the fabricated antenna. **Figure 10** is the pictorial

representation of testing of a fabricated antenna using Vector Network Analyzer (VNA).

DESIGN GEOMETRICS:

The Microstrip Patch Antenna Calculation Process is as follows,

Step 1: Calculation of the Width (W),

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Step 2: Calculation of the Effective Dielectric Constant. This is based on the height, dielectric constant of the dielectric and the calculated width of the patch antenna,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Step 3: Calculation of the Effective length:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$$

Step 4: Calculation of the length extension ΔL:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Step 5: Calculation of actual length of the patch:

$$L = L_{eff} - 2\Delta L$$

where,

f_0 is the Resonance Frequency

W is the Width of the Patch

L is the Length of the Patch

h is the thickness

ε_r is the relative Permittivity of the dielectric substrate

c is the Speed of light: 3×10^8

[0036]The foregoing description of embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention. The embodiments were chosen and described in order to explain the principals of the invention and its practical application to enable one skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

We claim:

1. A method of designing a 2x2 MIMO antenna (13 & 14) comprising:
   two radiating patches (100a & 100b) orthogonal to each other;
   a parasitic strip element (101) in between the two radiating patches;
   a dielectric substrate (102) and a ground plane (103);

   said radiating patches (100a & 100b) made of metallic sheets of thickness 0.035mm implemented on the said dielectric substrate (102);

   said ground plane (103) made of metallic sheets of thickness 0.035mm implemented on the said dielectric substrate (102); and

   said dielectric substrate (102) is made of Flame Retardant 4 (FR4) material having dielectric constant of 4.4, relative permittivity of 4.3, permeability of 1 and loss tangent of 0.025.

2. The method of designing a 2x2 MIMO antenna (13 & 14) claimed in claim 1, wherein the said parasitic strip element (101) reduces mutual coupling between the antennas (100a & 100b) and enhances correlation coefficient, radiation efficiency and isolation between ports (104a & 104b).

3. The method of designing a 2x2 MIMO antenna (13 & 14) claimed in claim 1, wherein the said antenna is having substrate width of 5mm, substrate length of 30mm, substrate thickness of 1.6mm, feed length of 18mm, feed width of 3mm, patch length of 12mm, patch width of 15mm, parasitic element length of 3.5mm and parasitic element width of 23mm.

4. The method of designing a 2x2 MIMO antenna (13 & 14) claimed in claim 1, wherein the said antenna is having frequency of 5.8 GHz, isolation of -44.36 dB, return loss of -26.02 dB, Envelope Correlation Coefficient

(ECC) of 0.0001, diversity gain above 9.998 and Voltage Standing Wave Ratio (VSWR) below 1.1.

Dated this 29th day of April, 2023

5

FETSI V

10 **IN/PA-4512**

APPLICANT'S AGENT

Title of the Invention: MANUFACTURING OF STAINLESS STEEL 316 GRADE MILLING INSERT THROUGH MACHINING PROCESS.

APPLICANT NAME: A.PHANINDRA

NATIONALITY: INDIA

ADDRESS: 7-33, SIDDHARTHA NAGAR, DAMMAIGUDA VIA NAGARAM, ECIL POST, HYDERABAD, TELENGANA – 500 083

FIELD OF INVENTION: MECHANICAL AND MANUFACTURING ENGINEERING.

INVENTORS:

1. **Name**: A.PHANINDRA
   Organisation: DEPARTMENT OF MECHANICAL ENGINEERING, KASETSART UNIVERSITY, BANGKOK, THAILAND. Mail: addepalli.phanindhra@gmail.com

2. **Name**: DR. WORAPONG SAWANGSRI
   Organisation: DEPARTMENT OF MECHANICAL ENGINEERING, KASETSART UNIVERSITY, BANGKOK, THAILAND. Mail: fengwps@ku.ac.th

3. **Name**: DR. SAIFUL ANWAR CHE GHANI.
   Organisation: FACULTY OF MECHANICAL AND AUTOMOTIVE ENGINEERING, UNIVERSITI MALAYSIA PAHANG, PAHANG, MALAYSIA. Mail: anwarcg@ump.edu.my

Abstract

Invention comprise of manufacturing process of the milling cutting insert from stainless steel 316 grade material. Milling cutting insert is changeable cutting insert used in peripheral, spinning milling cutter with atleast one cutting edge located between rake surface and relief flank surfaces.

Invention background:

- ✓ The end mill cutting insert is used in milling cutter tool holder consists of metal body having planar base which extends upper surface-the rake surface- which are intersected by side surface-relief flank. The end mill cutting insert has one or multiple edges which are created at intersection between the relief flank and the rake surface.
- ✓ The insert is fixed in the cutter body(Tool holder) so that the cutting edge is situated on the outer part, which helps in circular cutting pathway of the tool holder and it is positioned with reference to rotational axis by a certain angle with reference to axial rake angle.
- ✓ The significance of axial rake angle has direct effect on stability of cutter tool while conducting cutting operation and also the endurance of the cutting edge. With tool holders having changeable insert, provides for large axial rake angles creates structural declination of the cutter tool. Resulting in construction of milling cutter tools with low axial rake angles.
- ✓ Various types of materials are used for tool cutting insert manufacturing such as carbide, titanium, titanium alloy and metal coated inserts.
- ✓ Stainless steel grade 316 is combination of carbon(0.08%), Manganese (2%), Phosphorous (0.045%), Sulfur (0.030%), Silicon(1.00 %), Chromium(16-18 %), Nickle (10-14 %) & Molybdenum (2-3 %).
- ✓ Stainless steel 316 grade is mostly used as medical grade stainless steel. The another popular grade of stainless stell is 304 grade. Difference between both grades 304 & 316 is addition of molybdenum (2-3%) in grade 316.
- ✓ Molybdenum makes stainless steel grade 316 resistant to corrosion. The strength and toughness of molybdenum increases the heat and wear resistance of the stainless steel 316 grade.

Summary of invention:

- Object of the present invention is manufacturing of stainless steel grade 316 end mill insert for milling cutter tool. As per present invention, insert is used in peripheral rotary milling cutter tool which is cylindrical in shape and provide with one or multiple insert slots. Cutting insert consists of cutting edges situated between cutting rake surface and relief flank surface of the insert.
- The cutting insert according to the inventions are manufactured by sintering process, machining process or by grinding process.
- Objective of the present inventions is Manufacturing of stainless steel 316 grade milling insert through cutting and machining process.
- Stainless steel grade 316 milling insert has been through four different steps during manufacturing process to obtain to obtain final size and shape like insert.

- First step of methodology is Electrical discharge machining(EDM), Wire cut from stainless steel 316 grade raw material to required shape and size.
- Second step of the methodology is block up machining of the stainless steel 316 grade on the vertical milling machine.
- Third step of the methodology is Surface grinding of the stainless steel 316 grade machined piece.
- Fourth step of the methodology is creating the hole slot at the centre of the machined stainless steel 316 grade piece.
- Nose or cutting point of the insert is said to be an intersectional meeting point where cutting edge, relief surface and rake surface. Cutting point can be observed on the outer part of the insert when it is fixed on cutter tool.
- The cutting insert is of parallelipipedal in shape, which comprise of two pair cutting edges. First relief flank surface and cutting rake surface define first pair of opposite cutting edges. Simultaneously second relief flank surface and cutting rake surface define second pair of opposite cutting edges. Both cutting edges are on the diagonally opposite side of the insert.
- The cutting insert according to invention is of parallelipipedal shape. Both cutting edges are spaced from their concerned rake surface by land surfaces. In accordance of the invention, same insert can be used alternatively with appropriate cutter tool holder, on performing face milling operations. For this purpose, two pairs of relief flank surfaces are present with common insert corner.

Brief Description of Insert drawings:

Fig 1. Step by step method for SS316 milling insert manufacturing

Fig 2.1. Perspective view of stainless steel 316 grade insert according to invention.

Fig 2.2 Perspective view of machined stainless steel 316 grade insert according to invention.

Fig 3.1. Top view of the stainless steel 316 grade insert of Fig 2.1.

Fig 3.2. Top view of the machined stainless steel 316 grade insert of Fig 2.1.

Fig 4.1. Side view of the stainless steel 316 grade insert of Fig 2.1

Fig 4.2. Side view of the machined stainless 316 grade insert of Fig 2.1

Fig 5.1 Front view of the stainless steel 316 grade insert of Fig 2.1.

Fig 5.2 Front view of the machined stainless-steel grade 316 insert of Fig 2.1

Fig 6. Schematic side elevation of milling cutter with fixed cutting insert as per the invention.

DESCRIPTION OF THE INVENTION

- Figure 1 explains the methodology of manufacturing of stainless steel grade 316 milling insert.
- 20mm in width, 4mm thick and 200mm in length stainless steel grade 316 plate was used as raw material for machining.

- As observed in figures 2.1 through 5.2 of the drawings, and machined stainless steel grade 316 insert. A stainless steel 316 grade milling cutting insert fig 2.1 is parallelepipedal in shape and established with primary pair of opposing cutting edges 2 and 3 appropriately defined in between rake surface 4 and 5, primary relief flank surface 6 as shown are machined through wire cutting process in electrical discharge machine.
- The stainless steel 316 grade milling cutter insert is moreover provided with secondary pair of opposing cutting edges 7 and 8 in fig 2.1 appropriately defined in between rake surfaces 9 and 10, secondary relief flank surface 11 as shown are machined through wire cutting process in electrical discharge machine.
- The dimensions of the stainless steel 316 milling cutting insert as shown in figure 4.1. The length of the cutting insert is 10.84mm through 7 and 9, similarly the length on opposite side of the insert is same as 10.84mm through 8 and 10 are machine through wire cutting process in electrical discharge machine.
- The dimensions of the stainless steel 316 grade milling cutting insert shown in figure 5.1. The width of the cutting insert is 6mm through 2 and 4, similarly the length on side of the insert is same as 6 mm through 3 and 5 are machined through wire cut process in electrical discharge machine.
- The dimensions of the cutting insert shown in figure 5.1. The thickness of the cutting insert is 3mm which includes all sections of insert are machined through wire cut process in electrical discharge machine. In the figure 5.1 it can be observed from relief flank surface 6 point of view.
- The curved intersection point 13 between the cutting edges 2 and 7 through relief flank surfaces 6 and 11 is at angle 85°. Similar curved intersect point is available at diagonally opposite location between cutting edges 3 and 8 and through relief flank surfaces 5 and 10.
- The Present inventions has been categorically stated with referring to inserts having flank relief angle at 11°.
- Surface grinding is performed on the surface of the stainless steel 316 grade piece after wire cut process on the piece.
- Two circular slots holes are created at the centre of the cutting insert as shown in figure 2.1 and 3.1. The diameter of the slot holes ⌀ = 2.80 mm. Machined from drilling with copper electrodes in Electrical discharge nachine
- Through the slots with the help of screws insert can be mounted on tool holder 12 as shown in figure 6.

- The cutting inserts are being made with pairing of adjacent cutting edges 2,7 and 8,3. Where as at least one cutting edge from each pairs are made with high relief flank angle, are specifically useful during milling operations.

- In this action the milling cutter rotates around its longitudinal axis with respect to work piece. The milling effect can be observed by longitudinal directional operation by edges of the inserts. Thereby ensuring simultaneous milling by the transversely directed cutting edges of the inserts.

Claims

1. For the use of milling operation, rotatory milling cutter consists of cylindrical holder (12), one or multiple replaceable cutting inserts(1). Cutting inserts are formed with minimum of one cutting edges (2,3) determined between rake surfaces(4,5) and relief flank surfaces (6)of the insert (1).
2. A stainless steel 316 grade milling cutting insert (1) the said relief angle is substantially equal to 11° is machined through wire cutting method.
3. A stainless steel 316 grade milling cutter insert (1), the length of the insert (1) is 10.84mm, width of the insert(1) is 6.00 mm and thickness of the insert (1) is 3.00mm machined through wire cutting method.
4. A Stainless steel 316 grade milling cutting insert(1) is parallelepipedal in shape which comprises of primary pair of opposing cutting edges(2,3) determined between primary pair of cutting rake surface (4,5) and relief flank surface (6). A secondary pair of opposing cutting edges (7,8) are determined by cutting rake surfaces (9,10) and with relief flank surface (11) is machine through wire cutting method .
5. A stainless stell 316 grade milling cutting insert (1) according to claim 2 and 3 is manufactured through machining on electrical discharge machine .
6. A stainless steel 316 grade milling cutting insert (1), relief flank surfaces (6,11) establish pairs of consecutive relief flank surfaces.
7. The diameter of the screw slot at the centre of the stainless steel 316 grade milling cutter insert (1) is ⌀ = 2.80 mm.
8. A stainless steel grade 316 milling cutter insert(1), the relief flank surface (11) extended in length compared to (6).
9. A stainless steel grade 316 milling cutter insert (1), secondary cutting edges (6,7) are finally in parallel to base edges.

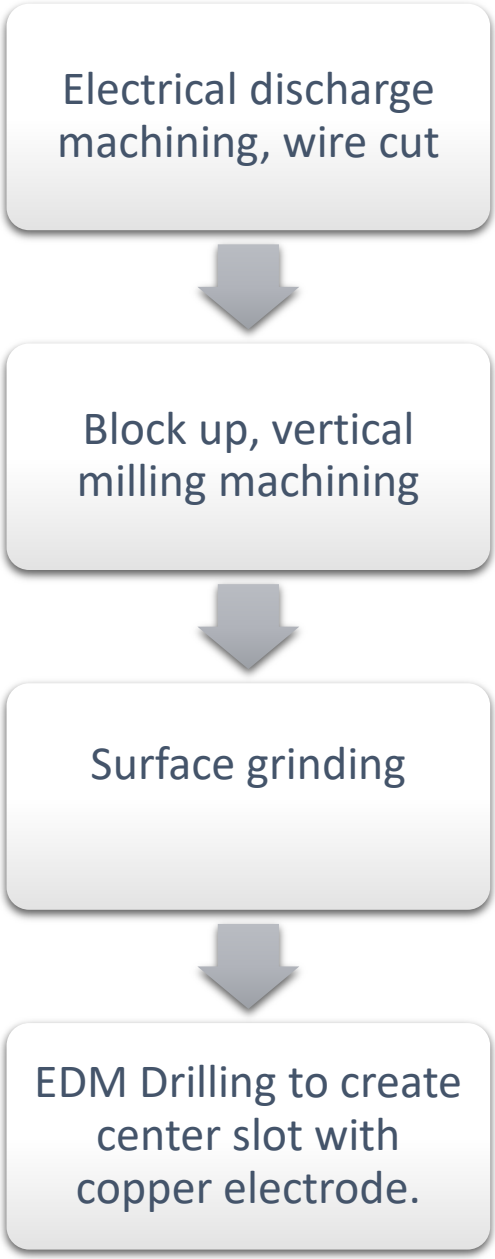

Figure 1 Step by step method for SS316 milling insert manufacturing

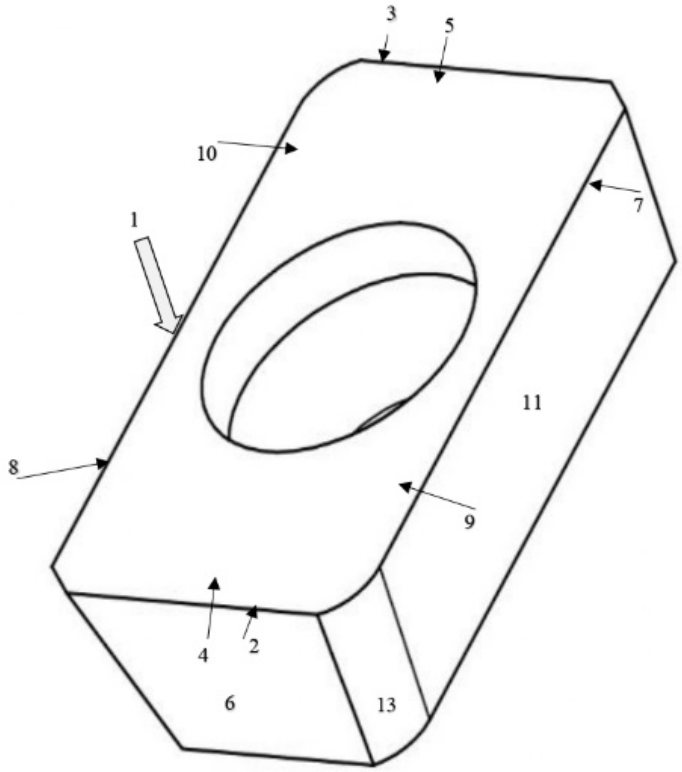

Figure 2.1 Perspective view of stainless steel 316 grade insert according to invention.

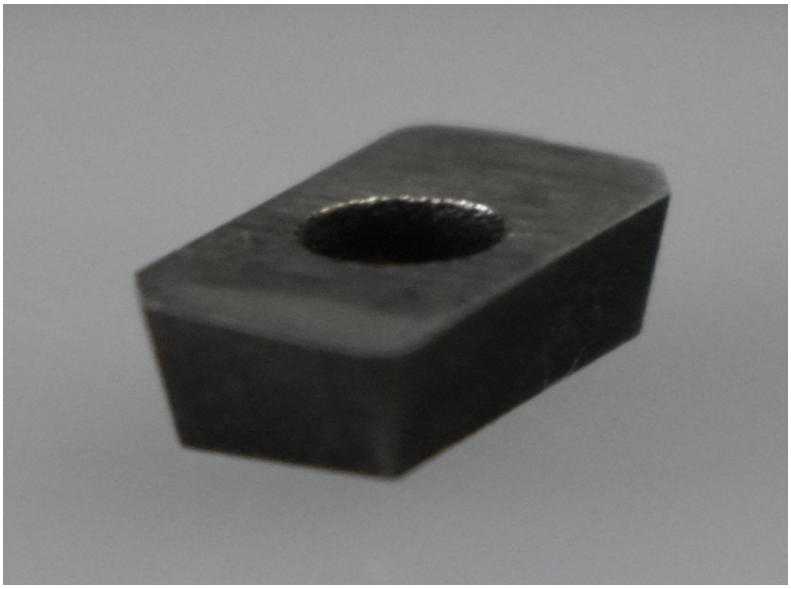

Figure 2.2 Perspective view of machined stainless steel 316 grade insert according to invention

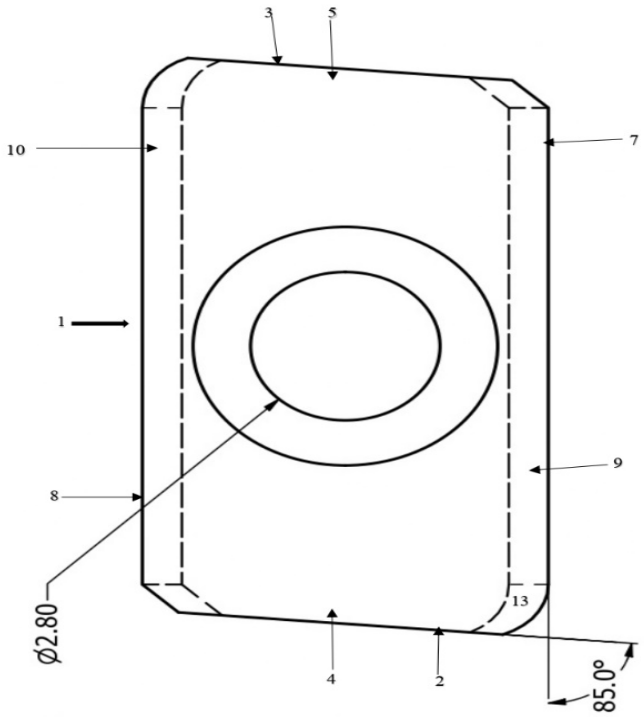

Figure 3.1 Top view of the stainless steel 316 grade insert

Figure 3.2

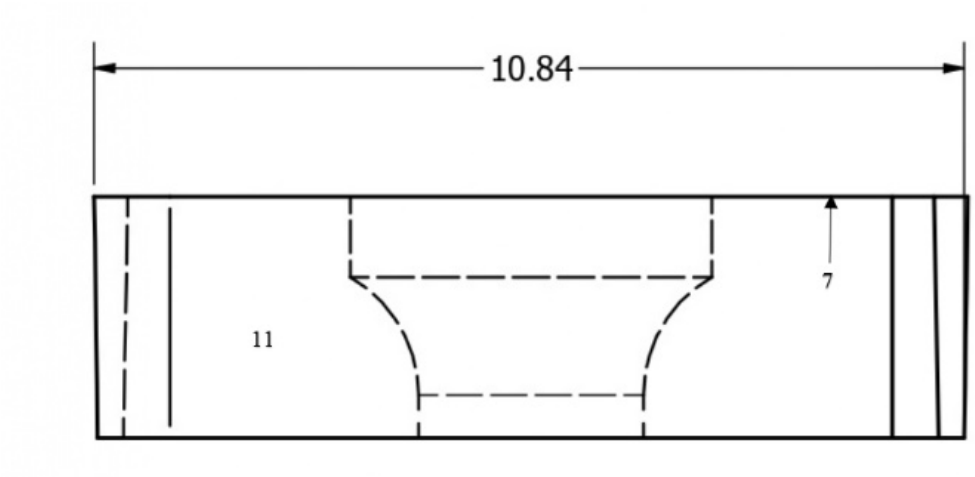

Figure 4.1 Top view of the machined stainless steel 316 grade insert

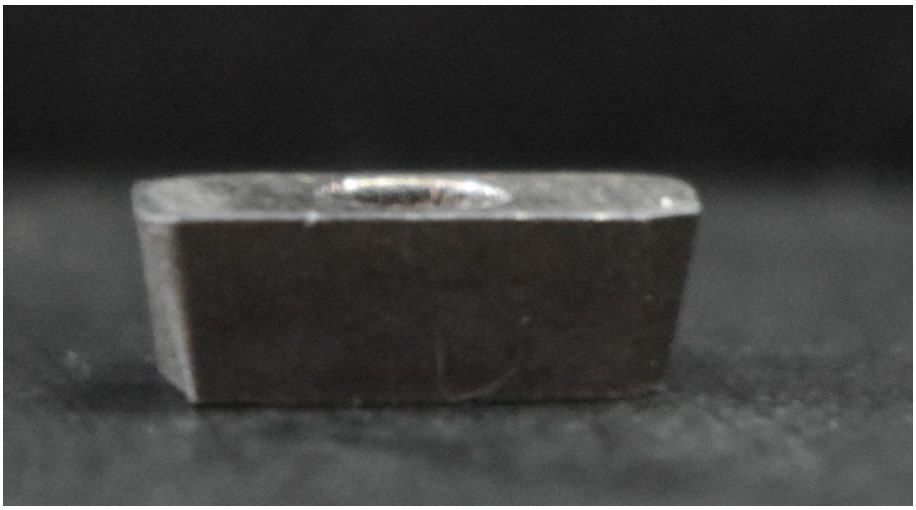

Figure 4.2 Side view of the machined stainless 316 grade insert

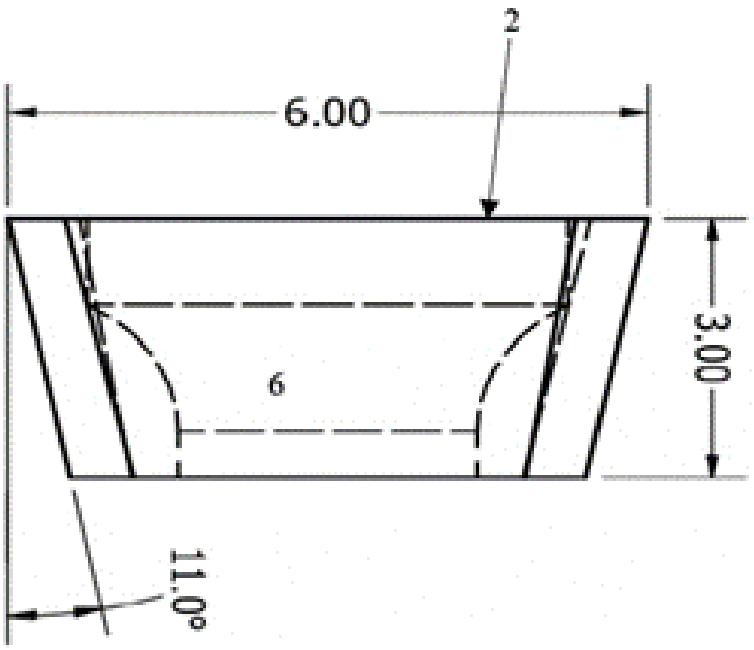

Figure5.1 Front view of the stainless steel 316 grade insert

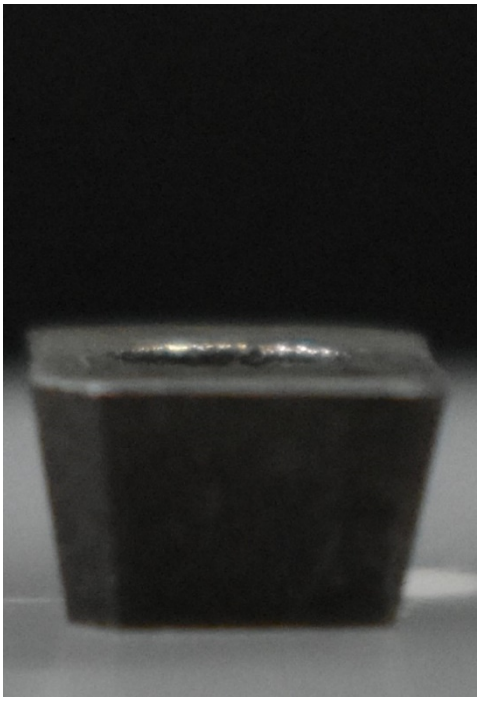

Figure 5.2 Front view of the machined stainless-steel grade 316 insert

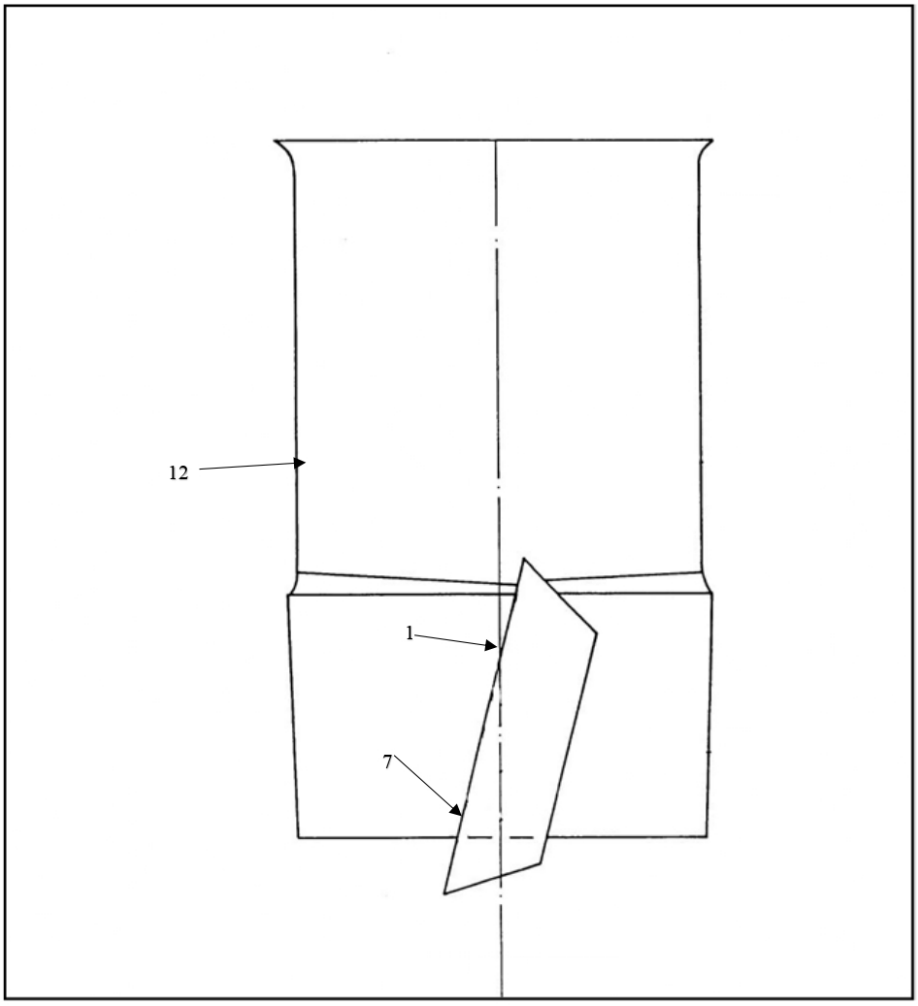

Figure 6 Schematic side elevation of milling cutter with fixed cutting insert as per the invention

FORM 2

THE PATENT ACT 1970
(39 of 1970)
&
The Patents Rules, 2003
PROVISIONAL/COMPLETE SPECIFICATION
(See section 10 and rule 13)

1.TITLE OF THE INVENTION: Speed reduction and accident prevention system for EV motor drives

2. APPLICANT(S)

(a)NAME: Mr. Rishikesh Tike
NATIONALITY: INDIAN
ADDRESS: D. Y. Patil College of Engineering, Akurdi
Assistant Professor Mechanical Engineering Department
611, Mangalmurti Banglow, Lane No. 5 Sahyadri Nagar Wai,
Satara, Maharashtra 412803

(b)NAME: Mr. Roshan Wani
NATIONALITY: INDIAN
ADDRESS: D. Y. Patil College of Engineering, Akurdi
Mechanical Engineering Department Final Year student
37, Yashwant Nagar near Ramanand Nagar Bus Stop,
Jalgaon, Maharashtra 425001

(c)NAME: Mr. Saurav Khandave
NATIONALITY: INDIAN
ADDRESS: D. Y. Patil College of Engineering, Akurdi
Mechanical Engineering Department Final Year student
Near Vitthal Mandir, At Sangavi Maval, Post Talegaon,
Pune, Maharashtra 412106

(d)NAME: Mr. Suraj Yadav
NATIONALITY: INDIAN
ADDRESS: D. Y. Patil College of Engineering, Akurdi
Mechanical Engineering Department Final Year student
Karanjkhop, Taluka- Koregaon,
Satara Maharashtra 415525

(e)NAME: Mr. Swarup Nanche
NATIONALITY: INDIAN
ADDRESS: D. Y. Patil College of Engineering, Akurdi
Mechanical Engineering Department Final Year student
378, Pandur Mayekarwadi Kudal,
Sindhudurg Maharashtra 416812

(f)NAME: Mr. Komal Sawant
NATIONALITY: INDIAN
ADDRESS: 15, Ambegaon Pathar,Building no. B6
Pune Maharashtra 411046

3. PREAMBLE TO THE DESCRIPTION	
PROVISIONAL	COMPLETE (✓)

4. DESCRIPTION:

An emitter and a receiver make up the system. When we set the radio emitter at a location with a high risk of accident, the signal is then picked up by the receiver. The wave transmits a signal to the Arduino Uno, which activates a buzzer or an LED light depending on the object's distance. The SOS system is then put into place in the final step, and if we notice a car is out of control, it is controlled by automatic action and other automobiles are alerted. To ensure people's safety, the speed restriction is implemented in stages, each with a distinct percentage reduction.

Microcontrollers, transceivers, motors, and small car assemblies are used in the system. Project Car provides insight into the future of automotive safety. The project system can prevent many accidents and save lives.

The system is useful for hill climbing where possibility of accidents is high and there are many sharp turns and blind turns. The system will automatically detect the accident-causing turns and warn the driver. Also if there is possibility of accident due to driver, the system will warn other vehicles around it and will reduce the damage due to accidents. The system is very user friendly. This system will increase the economy of a vehicle. After the detection of blind turns or sharp turns, it will reduce the speed. The vehicle will also avoid accident by alerting other vehicles around the accident causing vehicle.

The system consists of:

- Radio frequency emitter
- Radio frequency receiver
- Arduino Uno board
- Buzzer
- LED light
- Motor

5. CLAIMS

"I/WE claim

1. Reduced the accident on the road near hotspot region.
2. Designed and developed accident prevention system.
3. Achieved the safety of people and reduced accidents damage.
4. Automated the driving process.

6. DATE AND SIGNATURE

Dated this 29/04/2023

Signature: -

Name of the signatory: - Mr. Rishikesh H. Tike
Name of the signatory: - Mr. Roshan Wani
Name of the signatory: - Mr. Saurav Khandave
Name of the signatory: - Mr. Suraj Yadav
Name of the signatory: - Mr. Swarup Nanche
Name of the signatory: - Mrs. Komal Sawant

7. ABSTRACT OF THE INVENTION

To reduce accidents in areas with a high accident rate, safety is paramount in the automotive industry. Minimizing the loss of life and property is the goal. According to field surveys, accidents occur when people are in a rush to reach their destination near sharp turns, slippery roads, direction changes, school zones, and hospital zones. Therefore, the automatic speed control for vehicles in this area. The goal is to create and build a vehicle control system that reduces speed gradually while automatically reducing it in hotspot regions. The Communication with the system with the help of the transmitter and receiver in their zone and the signal is passed then motor is speed reduced systematic manner and finally stopping of the car according to conditions. System work to achieve the safety of vehicle. Once the technique is implemented the accidents will be reduced.

Note:

***Repeat boxes in case of more than one entry.**
***To be signed by the applicant(s) or by authorized registered patent agent.**
***Name of the applicant should be given in full, family name in beginning.**
***Complete address of the applicant should be given stating the postal index no./code, and country.@†@**
***Strike out the column which is/are not applicable.**

FORM 2

THE PATENTS ACT,1970

(39 OF1970)

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The Patents Rules, 2003

COMPLETE SPECIFICATION

(Seesection10; rule 13)

1. Title of the Invention– "A SYSTEM OF AUTOMATIC MULTISTAGE DEEP DRAWING PROCESS FOR SHEET METAL COMPONENT BY USING AI TECHNIQUE"

2. Applicant(s)

a) **NAME:** PARUL UNIVERSITY (Faculty of Parul Institute of Engineering and Technology)
b) **NATIONALITY**: An Indian Education Institute
c) **ADDRESS:** Parul Institute of Engineering and Technology, Parul University, P.O. Limda Tal. Waghodia, Dist. Vadodara, Gujarat - 391760, INDIA

a) **NAME:** BHATT, DR. MALLIKA RAVI
b) **NATIONALITY**: An Indian
c) **ADDRESS:** Assistant Professor, BCA Dept., S. S. Agrawal College, Navsari, Affiliated to Veer Narmad South Gujarat University, Surat, Gujarat, 396446, INDIA

a) **NAME:** BHATT, DR. RAVI
b) **NATIONALITY**: An Indian
c) **ADDRESS:** Assistant Professor, Mechanical Engineering Department, C. G. Patel Institute of Technology, Uka Tarsadia University, Maliba Campus, Gopal Vidyanagar, Bardoli-Mahuva Road, Tal. Mahuva, Surat, Gujarat, 394350, INDIA

a) **NAME:** VEKARIYA , DR. VIPUL
b) **NATIONALITY**: An Indian
c) **ADDRESS:** Dean & Principal, FET, Parul University, P.O. Limda, Tal-Waghodia, Dist.-Vadodara, Gujarat, 391760, INDIA

a)	**NAME:**	JOSHI , DR. SNEHAL K
b)	**NATIONALITY**:	An Indian Education Institute
c)	**ADDRESS:**	Faculty Dean of Computer Science and Information Technology Faculty, Veer Narmad South Gujarat University, Surat, Gujarat, INDIA
a)	**NAME:**	TADHANI , JAYDEEP R.
b)	**NATIONALITY**:	An Indian
c)	**ADDRESS:**	Research Scholar Gujarat Technological University, Lecturer, Information Technology, Government Polytechnic, Rajkot, Gujarat, INDIA

3. PREAMBLE TO THE DESCRIPTION

The following specification describes the invention.

FIELD OF INVENTION:

The present invention relates Application of AI in the Working Model for Sheet Metal Component (SMC) Die for Multistage Deep Drawing Process.

BACKGROUND OF INVENTION:

The increasing demand for advanced techniques in Artificial Intelligence (AI) has made them more affordable and reliable in solving challenges in science, engineering, and technology. In the last two decades, AI techniques such as Fuzzy logic, Artificial Neural Networks, Expert Systems, and Genetic Algorithms have been developed and applied in various fields, including science, computing, agriculture, medicine, engineering, and industries. The current work focuses on using a knowledge-based expert system, which is a combination of rules, knowledge, and image processing, to develop an automated design for die and punch tools used in sheet metal forming operations, as well as to analyze fatigue. Among different manufacturing techniques, forming techniques have the highest share in global manufacturing industries due to their versatile applications in the automobile, aerospace, and household equipment industries. Sheet metal forming is a subprocess of forming, which involves deforming a thin sheet of metal using a punch-die set.

Expert systems are a type of artificial intelligence that is designed to mimic the decision-making abilities of a human expert in a specific domain. In the field of manufacturing, expert systems can be used to help with a variety of tasks, such as design, production planning, and control. These systems can help small manufacturing companies by providing expert-level knowledge and decision-making capabilities without the need to hire a highly qualified human expert. Additionally, expert systems can be used to automate certain tasks, such as the control of production processes, which can increase efficiency and reduce the need for human operators. Overall, expert systems have a wide range of applications in the manufacturing industry and can provide many benefits to businesses.

In connection to this, a literature survey is divided into subsections.
namely,

- Research Survey on the use of expert systems in different fields

- Research Survey on the use of expert systems in the manufacturing industry
- Research Survey on the use of expert systems in metal forming processes.
- Research Survey on the use of image processing in expert systems
- Research Survey on the use of expert systems for fatigue analysis.

Sabzi et al. conducted a study using an expert system in the agricultural field for the identification of potato crops. The study employed a meta-heuristic algorithm for the identification of weeds in potato crops, with a focus on precision in spraying. The algorithm was based on minimizing color and texture properties and utilized a neural network classifier and its parameters for search purposes. The system achieved high precision, with an accuracy level of over 98%, and completed the task in less than 0.8 seconds.

In the work reported by Nascimento et al., an expert system development was used to direct and suggest the most effective and appropriate pests for teak plantation in forestry. The system, called ENOTECA, aims to reduce loss of plantation due to harmful insects, with a specific focus on large scale teak plantation in Brazil. The system utilizes a mobile device as the user interface and can identify 23 types of insects, providing real-time suggestions for appropriate remedies for a given teak tree or for an entire area.

Expert architecture is an artificial intelligence technique used to solve problems by transforming human knowledge and expertise into computer programs using various software tools. Xie et al. developed a knowledge-based computer-aided process planning (CAPP) system using a CAD environment and a global and concurrent data integration platform. The real-time knowledge-based system integrates manufacturing and design. It was concluded that the integrated and concurrent CAD/CAPP/CAM system improves manufacturing efficiency, product quality and reduces costs.

Rama Rao et al. have studied the use of electrochemical machining (ECM) for material removal and surface roughness. They used a genetic algorithm in their research. Pratihar have studied the use of Electro discharge machining (EDM) for the same purpose and used an adaptive network-based fuzzy system to address the problem. Dubey and Yadava have studied the use of LBM machining process for surface roughness and dross inclusion and used a fuzzy model in their research.

Prasad and Somasundaram developed a computer-aided die design system (CADDS). The system was able to automatically generate strip-layout, perform design checks for various die components, and generate assembly views and a bill of materials for a blanking die. The system was developed by interfacing AutoCAD with AutoLISP.

Ramana and Rao presented a system for automated manufacturability evaluation. The system included design evaluation, process planning, data and knowledge modeling for shearing and bending operations.

Ghatrehnaby and Arezoo developed an algorithm for an automated nesting and piloting system for progressive dies. Their work focused on geometrical optimization of nesting and piloting in a CAD system. Kim and Park presented an expert system for automating the process design of axisymmetric hot steel forging operation. It was a rule-based system written in Fortran and AutoLISP, and operated in the AutoCAD environment.

SUMMARY OF PRESENT INVENTION

The main aspect of the present invention comprising uses rules and knowledge in a systematic manner to design dies. Architecture includes three steps: input, process, and output. Input parameters such as thickness, diameter, material type, and stress values are used to create scenarios. The model is regulated by certain governing regulations during the process. The information of die design experts is used to convert the input into two cases. The architecture design is executed with the help of the user, user interface, and interface engine.

DETAILED DESCRIPTION OF THE INVENTION

The background, summary and the above description includes information that may be useful in understanding the present disclosure. It is not an admission that any of the information

provided herein is prior art or relevant to the presently claimed inventive subject matter, or that any publication specifically or implicitly referenced is prior art.

In some embodiments, the numbers expressing dimensions, quantities, quantiles of ingredients, properties of materials, and so forth, used to describe and claim certain embodiments of the disclosure are to be understood as being modified in some instances by the term "about." Accordingly, in some embodiments, the numerical parameters set forth in the written description and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by a particular embodiment. In some embodiments, the numerical parameters should be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of some embodiments of the disclosure are approximations, the numerical values set forth in the specific examples are reported as precisely as practicable. The numerical values presented in some embodiments of the disclose may contain certain errors necessarily resulting from the standard deviation found in their respective testing measurements.

As used in the description herein and throughout the claims that follow, the meaning of "a," "an," and "the" includes plural reference unless the context clearly dictates otherwise. Also, as used in the description herein, the meaning of "in" includes "in" and "on" unless the context clearly dictates otherwise.

As used herein, and unless the context dictates otherwise, the term "coupled to" is intended to include both direct coupling (in which two elements that are coupled to each other contact each other) and indirect coupling (in which at least one additional element is located between the two elements). Therefore, the terms "coupled to" and "coupled with" are used synonymously.

Unless the context dictates the contrary, all ranges set forth herein should be interpreted as being inclusive of their endpoints, and open-ended ranges should be interpreted to include commercially practical values. Similarly, all lists of values should be considered as inclusive of intermediate values unless the context indicates the contrary.

The recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless otherwise indicated

herein, each individual value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g. "such as") provided with respect to certain embodiments herein is intended merely to better illuminate the disclosure and does not pose a limitation on the scope of the claimed inventive subject matter. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the inventive subject matter.

Groupings of alternative elements or embodiments of the inventive subject matter disclosed herein are not to be construed as limitations. Each group member can be referred to and claimed individually or in any combination with other members of the group or other elements found herein. One or more members of a group can be included in, or deleted from, a group for reasons of convenience and/or patentability. When any such inclusion or deletion occurs, the specification is herein deemed to contain the group as modified thus fulfilling the written description of all Markush groups used in the appended claims.

The following discussion provides many example embodiments of the inventive subject matter. Although each embodiment represents a single combination of inventive elements, the inventive subject matter is considered to include all possible combinations of the disclosed elements. Thus if one embodiment comprises elements A, B, and C, and a second embodiment comprises elements B and D, then the inventive subject matter is also considered to include other remaining combinations of A, B, C, or D, even if not explicitly disclosed. Various objects, features, aspects and advantages of the inventive subject matter will become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawing figures in which like numerals represent like components.

It should be apparent to those skilled in the art that many more modifications besides those already described are possible without departing from the inventive concepts herein. The inventive subject matter, therefore, is not to be restricted except in the scope of the appended claims. Moreover, in interpreting both the specification and the claims, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or

steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced. Where the specification claims refers to at least one of something selected from the group consisting of A, B, C and N, the text should be interpreted as requiring only one element from the group, not A plus N, or B plus N, etc.

Aspects of the machine and techniques are described beneath with reference to illustrative embodiments. The references to illustrative embodiments underneath are not made to restriction the scope of the claimed subject matter. Instead, illustrative embodiments are used to useful resource inside the description of numerous aspects of the device. The description, made by means of way of example and reference to illustrative reference is not meant to be limiting as regards any component of the claimed problem remember.

One of the embodiments of the present invention comprising, rules and knowledge have been employed in a systematic manner. The architecture of the execution flow is given. The information of die design experts (industry, academia and professions) are converted into two cases i.e. scenario 1 and scenario 2. It can be seen from Fig that architecture design comprises of three steps viz. Input, process and output. These are executed with the help of the user, user interface and interface engine The input module requires the input parameters which includes the thickness of the blank/workpiece, blank diameter, cup diameter, material type, yield stress (YS) of the material and ultimate tensile stress (UTS) of the material. Among them, thickness, blank and cup diameter relates the physical configuration of the raw material and finished product. The material type, yield stress and ultimate tensile stress are the material specific aspects. During the process, the model is regulated by certain governing regulations. The main regulations are fetched from industry experts.

The threshold conditions for scenario 1 and scenario 2 are presented in Table.

Rules Regulations	**Scenario 1 (condition)**	**Scenario 2 (action)**
Regulation 1	current shape is a cup of 1, 2 or 3 elements (Height, width and	the previous shape is a circular blank

	diameter)	
Regulation 2	The cup is axisymmetric	blank (raw material) dimensions are circular plate
Regulation 3	The work material starts. sliding with the punch head in the die bottom	stretching of the material initiates
Regulation 4	draw completed but unwanted geometrical shape predicted	predicted a defect
Regulation 5	punch cannot travel more than punch size	deformation cannot be completed
Regulation 6	multi-stage deep drawing is introduced	LDR must look after for intermediated pass except for the last pass
Regulation 7	bucking and/or wrinkling exhibits	reduce compressive stresses
Regulation 8	thickness ratio (TR) for wrinkling phenomenon	
	Very thin	TR<0.005
	Thin	0.005 < TR < 0.015
	Moderate	0.015 < TR < 0.025
	Thick	TR > 0.025
Regulation 9	Die radius	
	Steel	4 to 6 time thicker than material
	Stainless Steel or Aluminium	5 to 10 time thicker than material
Regulation 10	Punch Radius	
	Steel	4 to 8 time thicker
	Stainless Steel or Aluminium	8 to 10 time thicker

The calculation parts of the physical attributes are defined by the height and width of the desired product. Therefore, this task is segmented in two parts (a) Height determination of target object from the image (using image processing concept) (b) Blank diameter, clearance (gap), punch and die profile, no of a draw, punch diameter, Die diameter and load calculation. (Using rules and knowledge-based concept)

(a) Height determination of target object from the image (using image processing concept)

Based on the concept addressed in Fig. 2, it is required to provide final product dimensions (height and width) to arrive at the design of die for that product. Manual input of these data may encounter a human error and therefore semi-skilled user/operator is required. To overcome this limitation, the image recognition concept is introduced wherein the dimensions are calculated from the image itself.

Figure 3 represents the sample image of which the height is required to be calculated. In this case, the known property is width. It is due to the reason that present research is based on the deep drawing operation wherein the diameter (width) of the product is lesser than the height. The Canny edge detection method is employed during the edge detection. It is performed using Python and OpenCV libraries. These data are synchronized with the GUI (graphic user interface) of the developed expert architecture.

(b) Blank diameter, clearance (gap), punch and die profile, no of the draw, punch diameter, Die diameter and load calculation. (Using rules and knowledge-based concept)

The input variables are calculated using the standard equations Ghosh and Malik, Hosford and Caddell and ASM handbook. Also, the inputs gathered from the industries are incorporated with the empirical equations. These inputs are utilized with regulations using VB.NET and AUTOCAD to derive the outputs. The methodology of the determination of the output variable is presented below.

- Blank diameter
- Clearance

- Punch and die profile.
- No. of a draw
- Punch and Die diameter.
- Forces

This framework is limited to three different types of material i.e. mild steel, stainless steel and aluminum because these are the major material types used in domestic household appliances. The materials properties are required to fill are yield stress and ultimate stress. Corresponding other material properties (i.e. density, poisons ratio, elastic limit etc.) are already used during the programming. Hence, very few data are required for initiation.

In summary, the proposed model is a viable solution for determining tooling configuration using image processing and backward chaining. The model has been tested in an industrial setting and has been found to be accurate and precise. Additionally, the model can generate manufacturing drawings for different numbers of draws, and can also predict the die life and fatigue life of the die through finite element analysis and expert system modules. Overall, the research suggests that this model can be an effective tool for tooling configuration in manufacturing.

A prototype of an intelligent model has been developed in the current research for the Sheet Metal Cutting (SMC) die process. The model generates tooling and analyzes it using inputs such as product geometry and material properties (yield stress and ultimate stress). The height of the product is determined using image processing techniques. The prototype is able to predict the necessary blank diameter, clearance, punch-die profile, number of draws, and forces required for punch and blank holder. Additionally, it generates manufacturing drawings of all necessary tooling for the process.

The manufacturing drawing can include the design specifications for the estimated tooling configuration, which can be provided directly to the tool manufacturer for fabrication. This enables clear communication of the desired tool design and can help ensure that the final product meets the necessary requirements for the manufacturing process.

The manufacturing drawing can also be used to perform analysis directly using ABAQUS scripting. Additionally, the fatigue life of the die can be calculated automatically, which helps to determine the expected lifespan of the tool and identify any potential issues before it is used in the manufacturing process.

While the disclosed embodiments show the device with four wheel assemblies, with adjustments to the elements and components the device , it is contemplated that the device may be embodied with three wheels or three wheel assemblies, by using a single front wheel assembly, or with five or more wheels, by adding a central front wheel as-assembly, for example, without affecting the other advantages and features described herein.

The above description is given by way of example, and not limitation. Given the above disclosure, one skilled in the art could devise variations that are within the scope and spirit of the disclosure herein. Further, the various features of the embodiments disclosed herein can be used alone, or in varying combinations with each other and are not intended to be limited to the specific combination described herein. Thus, the scope of the claims is not to be limited by the illustrated embodiments.

Applicants' Name: - PARUL UNIVERSITY (Faculty of Parul Institute of Engineering and Technology); BHATT, DR. RAVI; VEKARIYA, DR. VIPUL; TADHANI, JAYDEEP R.

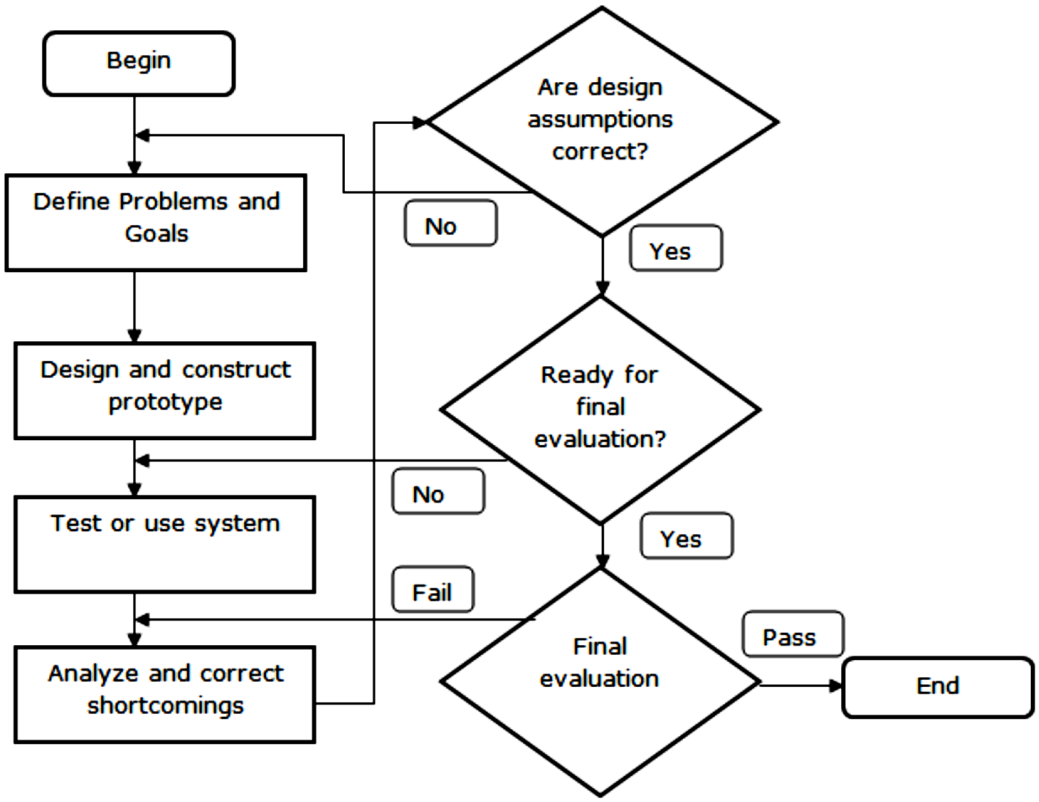

Figure 1

Dated this 08th April 2023.

Name and Sign of the Applicant's

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
Joshi , Dr. Snehal K	Tadhani , Jaydeep R.		

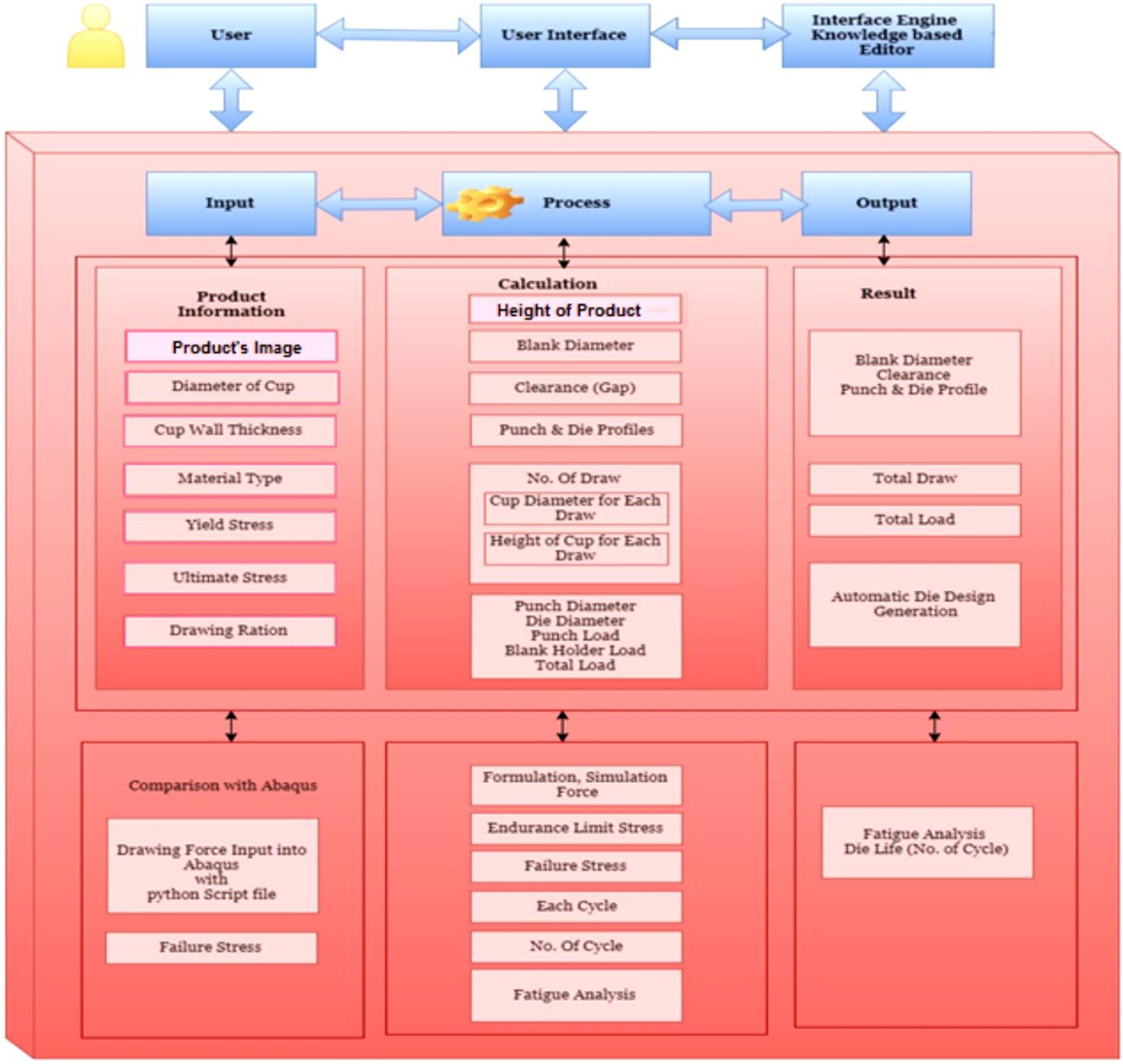

Figure 2

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Name and Sign of the Applicant's

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
Joshi , Dr. Snehal K	Tadhani , Jaydeep R.		

Figure 3

Dated this 08th April 2023.

Name and Sign of the Applicant's

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
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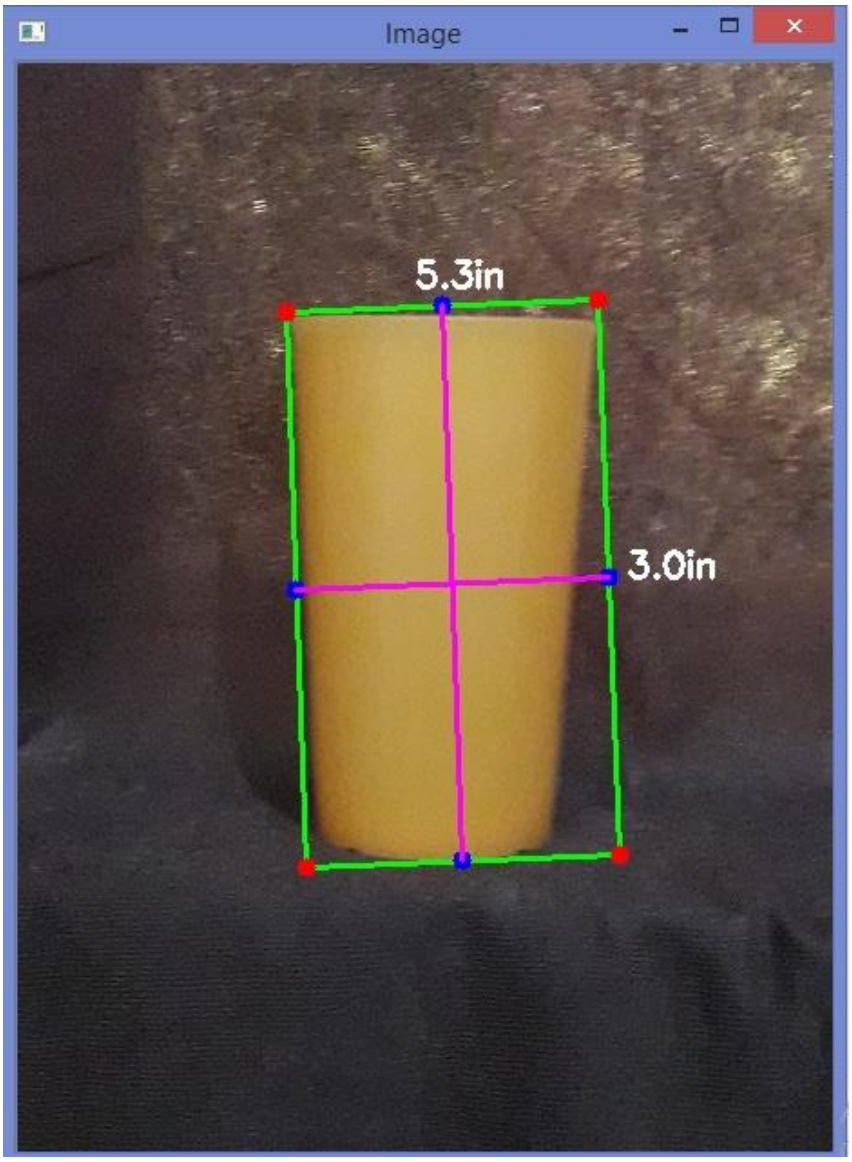

Figure 4

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Name and Sign of the Applicant's

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
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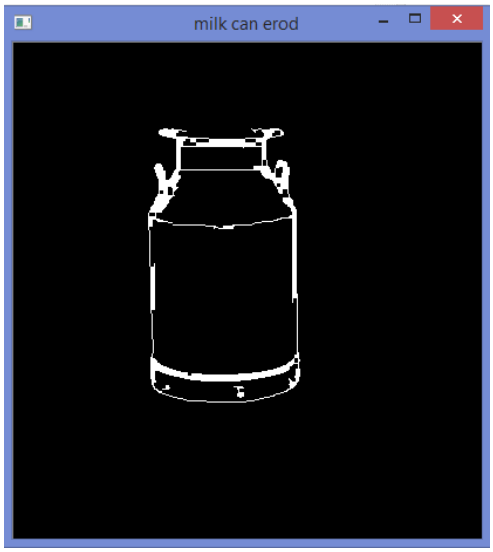

Figure 5: Erosion of Milk Cane

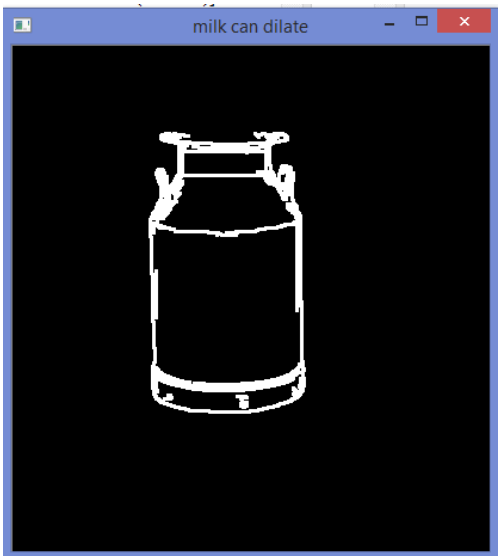

Figure 6: Dilation of Milk Cane

Figure 7: Original Image

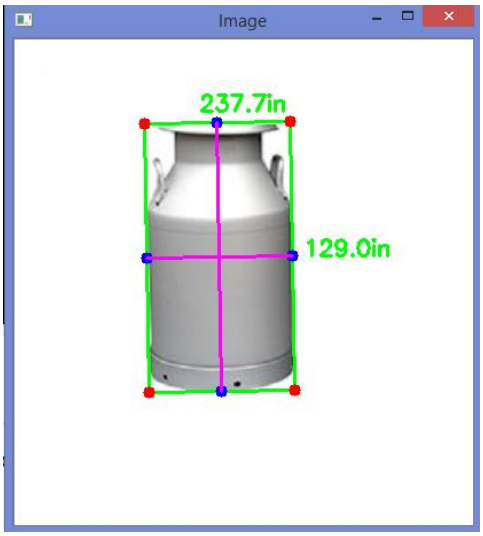

Figure 8: Final Image

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5 **Name and Sign of the Applicant's**

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
Joshi , Dr. Snehal K	Tadhani , Jaydeep R.		

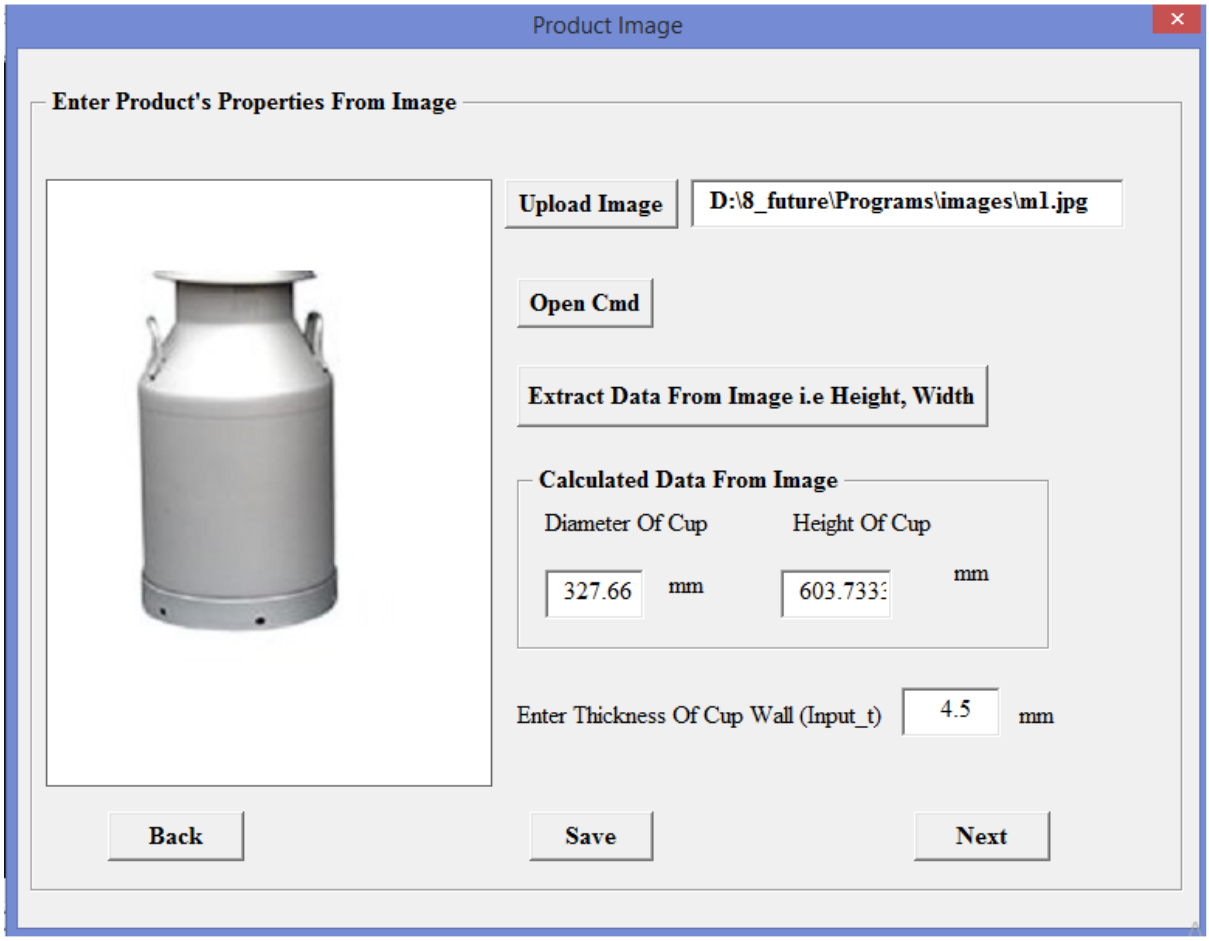

Figure 9

Dated this 08th April 2023.

Name and Sign of the Applicant's

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
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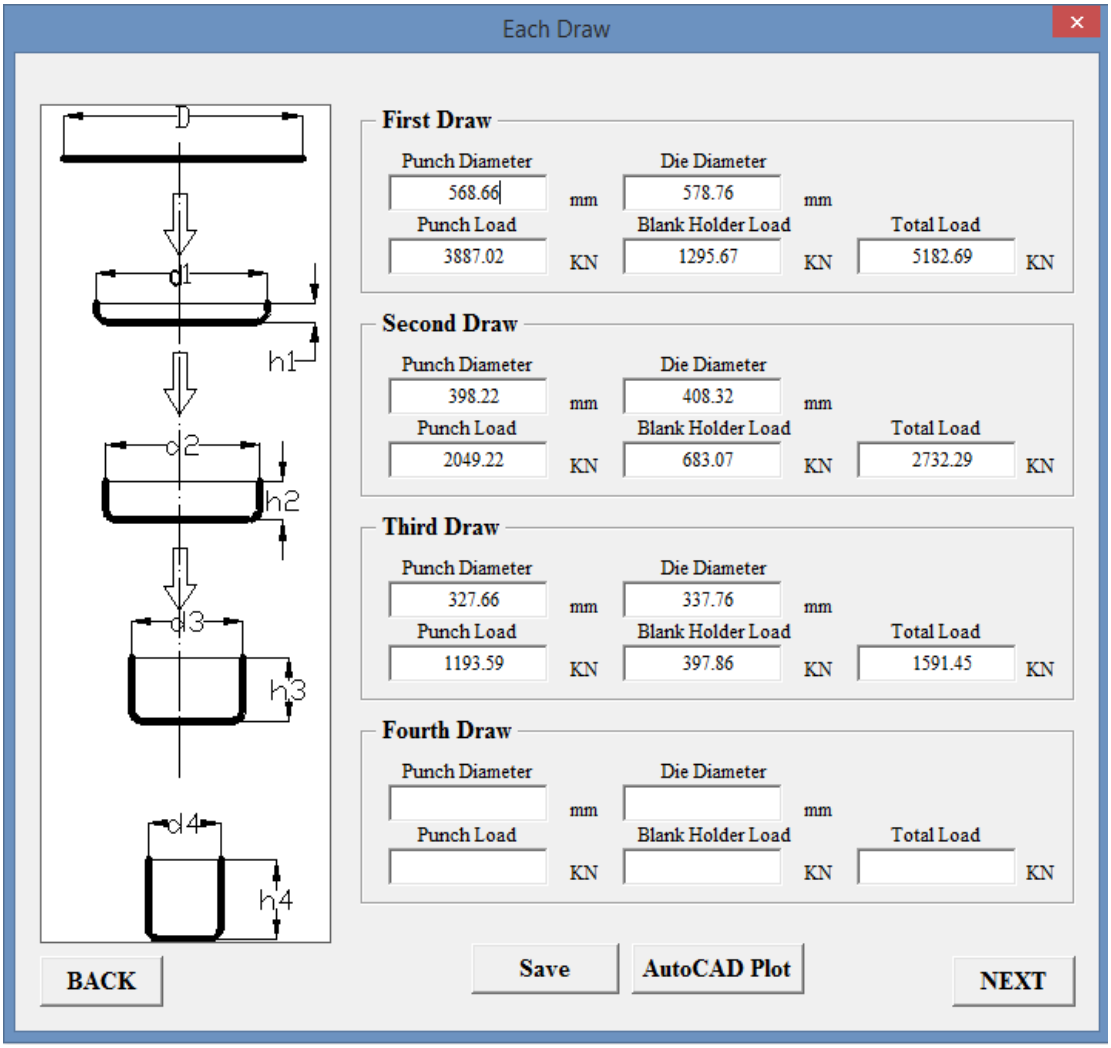

Figure 10

Dated this 08th April 2023.

Name and Sign of the Applicant's

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
Joshi , Dr. Snehal K	Tadhani , Jaydeep R.		

Applicants' Name: - PARUL UNIVERSITY (Faculty of Parul Institute of Engineering and Technology); BHATT, DR. RAVI; VEKARIYA, DR. VIPUL; TADHANI, JAYDEEP R.

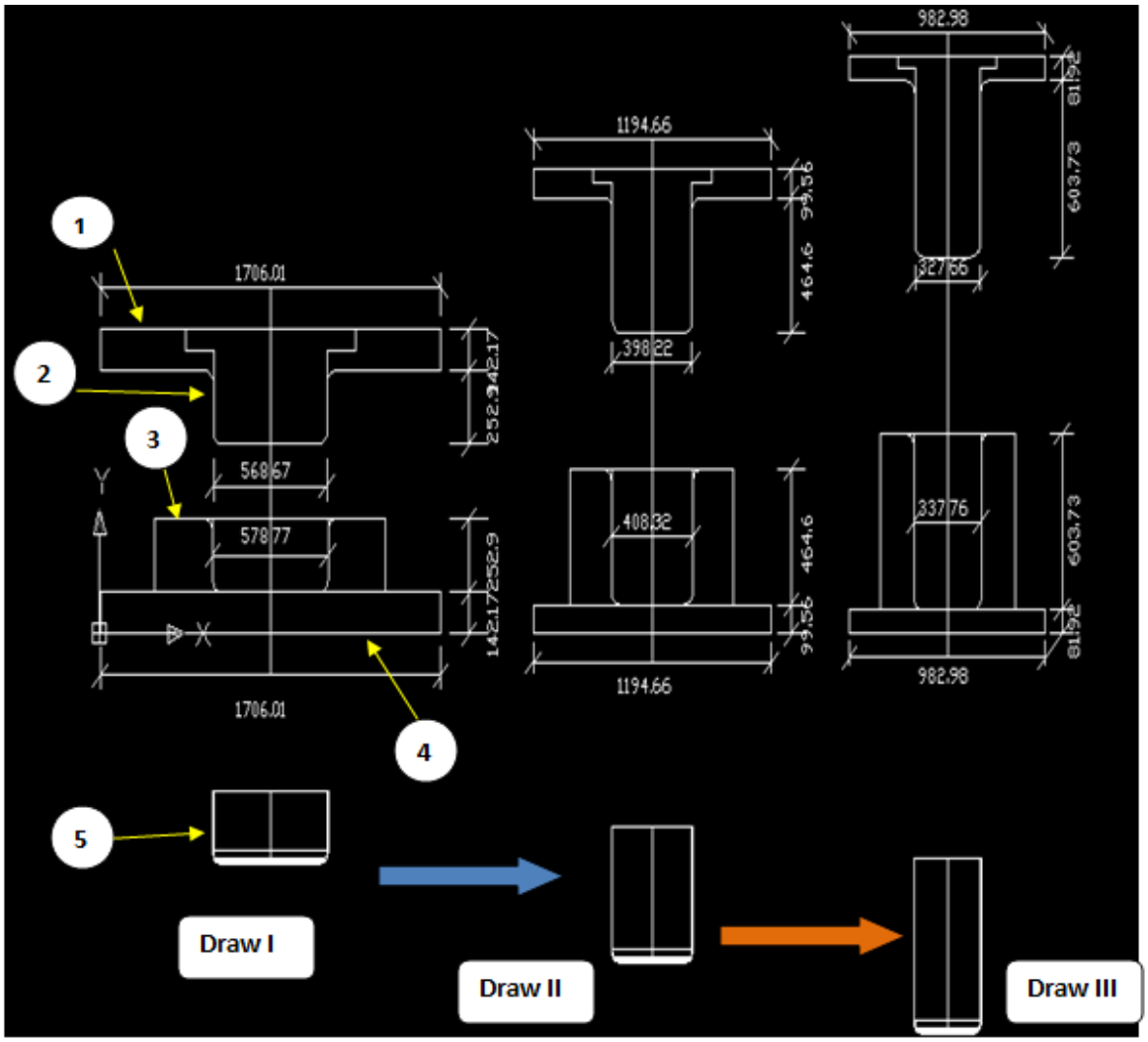

Figure 11

Dated this 08th April 2023.

Name and Sign of the Applicant's

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
Joshi , Dr. Snehal K	Tadhani , Jaydeep R.		

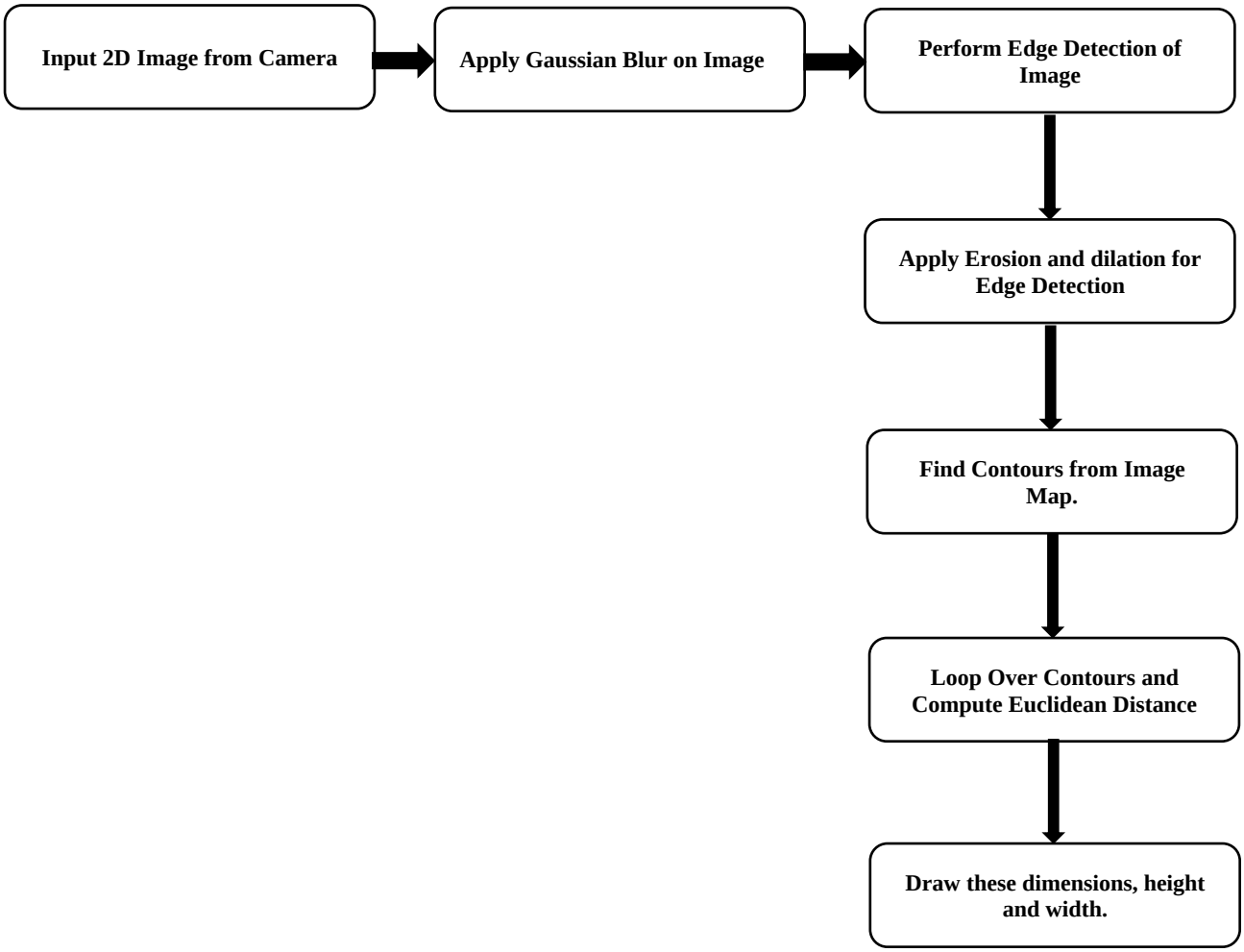

Figure 12

Dated this 08th April 2023.

Name and Sign of the Applicant's

Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
Joshi , Dr. Snehal K	Tadhani , Jaydeep R.		

Claims,

We Claim,

[CLAIM 1] A system of automatic multistage deep drawing process for sheet metal component by using AI technique characterized by:

I. a method for designing a die for a multi-stage deep drawing process comprising
   a) receiving input data from final product shape and material properties; in which an expert system to analyze the input data and determine optimal die geometry and process parameters,
   b) and displaying the determined optimal die geometry and process parameters.

II. a system for designing a die for a sheet metal component using artificial intelligence, apparatus comprising:
   a) an input device for receiving input data related to a desired final product shape and material properties, in which a processor configured to use an expert system to analyze the input data and determine optimal die geometry and process parameters,
   b) and display device configured to display the determined optimal die geometry and process parameters.

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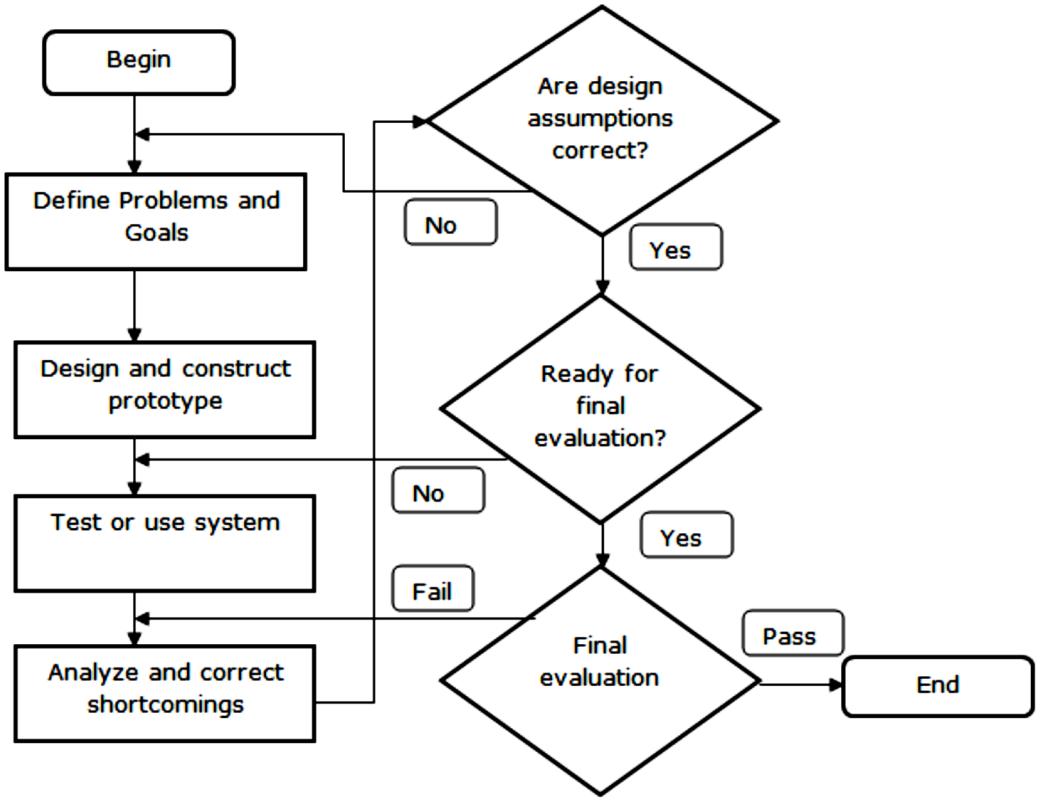
Dr. Geetika Patel, Trustee & Medical Director (On Behalf of Parul University)	Bhatt, Dr. Mallika Ravi	Bhatt, Dr. Ravi	Vekariya , Dr. Vipul
Joshi , Dr. Snehal K	Tadhani , Jaydeep R.		

ABSTRACT

The system of automatic multistage deep drawing process for sheet metal component by using AI technique comprising AI in the Working Model for Sheet Metal Component (SMC) Die for Multistage Deep Drawing Process. In which method for designing a die for a multi-stage deep drawing process having receiving input data from final product shape and material properties; in which an expert system to analyze the input data and determine optimal die geometry and process parameters, and also displaying the determined optimal die geometry and process parameters. Other ways system for designing a die for a sheet metal component using artificial intelligence input device for receiving input data related to desired final product shape and material properties, in which processor configured to use an expert system to analyze the input data and determine optimal die geometry and process parameters, display device configured to display the determined optimal die geometry and process parameters. [Figure 1]



Form 2

THE PATENT ACT 1970

(39 Of 1970)

&

The Patent Rules,2003

COMPLETE SPECIFICATION

DESIGN OF AUTONOMOUS SENTRY ROBOT FOR SURVEILLANCE AND SECURITY

Name of the Applicants: Thottempudi Pardhu & BVRIT HYDERABAD College of Engineering for Women

Nationality: Indian

Address : Department of ECE,BVRIT HYDERABAD College of Engineering for Women, Bachupally, Hyderabad-500090, Telangana

The following Specification particularly describes the invention and the manner in which it is performed.

Field of the Invention:

The current invention relates to sentry robots, more specifically, to sentry robots that can perform wide and narrow monitoring at close and far distances while automatically alerting the command control room.

Description of the Related Art:

In the 21st century, intelligent robotics is one of the most promising new technologies that will influence the fields of industry and defense. The development of AI has allowed for this to happen. Specifically, a monitoring and sentinel system is a complex setup that employs numerous technologies, including ultra-low brightness cameras, image recognition, image processing and storage, voice recognition, servo technology, image tracking, and system control.

Strategic national infrastructure like airports, harbors, and nuclear power plants have seen a rise in the requirement for intelligent monitoring and sentry robot systems in tandem with the expansion of the security business. In particular, the military wants a system like this to improve sentry efficiency during peacetime. A variety of unmanned equipment that can take over soldiers' 3D (dangerous, dirty, and boring) tasks has been developed and put to use to increase their safety and effectiveness during times of war. Artificial intelligence (AI)-based unmanned robots can effectively replace human labor and make a significant improvement to military competitiveness.

Specifically, monitoring and sentry robots can play a significant role in the creation of a military strategy. Robots are also immune to fatigue and reduced focus brought on by soldiers performing repetitive tasks while on sentry duty, which is important for monitoring and sentry. Additionally, when given access to weapons, the system is capable of precise tracking, quick responses, and high-speed, accurate shooting—abilities that are particularly useful in times of conflict.

A camera's field of view is limited, which is a problem for the shooting control system. Also, the traditional sentry and monitoring system, which is based on a single video camera or a common monitoring camera, is a simple form of automation that can't intelligently find and follow a target.

Summary Of the Invention:

The current invention offers a monitoring and Sentry robot to address the aforementioned issues as well as any additional ones that may arise. This robot can perform both broad and targeted surveillance over both short and long distances, and to immediately notify the command center of any anomalies it detects.

According to one embodiment of the invention, a sentry robot has a base, a main body positioned on a pivot, the master camera that can rotate along with the main body, and an active camera that can rotate about the main body in the horizontal and vertical planes.

Two cameras make up the master camera, each of which is attached to the side of the main body. The main body has a frame that projects forward and can rotate left and right alongside it, and the frame has a master camera that can also rotate up and down and left and

right. The sentry robot might also be armed with a rifle that can track a target while the active camera is in motion. A gun installed on the main body would fire in the same direction as the live feed from the camera.

Additionally, the sentry robot has a driving section that controls the primary camera, secondary camera, and active camera. Images are analyzed, targets are recognized and tracked with the help of this driving section.

A networked base is also included with the sentry robot. The main body is attached to and supported by the base, the main body connection portion is rotatable concerning the base connection portion, the base connection portion houses the pivot ring gear, the main body connection portion contains the pivot drive gear, the pivot drive motor rotates the pivot drive gear, and the master camera rotation shaft is housed in the main body connection portion.

The security-based door-accessing mechanism provided by our invention also uses three different combinations of sensing inputs, including face recognition for person detection and authentication, authorized fingerprint authentication information, and keypad password access. The robot section sends a signal for Zigbee network-enabled door access when any one of the three features is used.

Brief Description of The Drawings:

This section will brief the embodiments used in our invention The sentry robot.

Fig.1 Indicates the Block Diagram of our innovation at the joystick Section

Fig 2. Indicates the Block Diagram of our innovation at the Robot Section-1

Fig 3. Indicates the Block Diagram of our innovation at the Robot Section-2

Fig4. Indicates the Block Diagram of our innovation at the Door Section

Fig.5. Indicates the Circuit Diagram of the Interfacing of various components with the Microcontroller at the joy stick section.

Fig.6. Indicates the Circuit Diagram of the Interfacing of various components with the Microcontroller at Robot section-1.

Fig.7. Indicates the Circuit Diagram of the Interfacing of various components with the Microcontroller at Robot section-2.

Fig.8. Indicates the Circuit Diagram of the Interfacing of various components with the Microcontroller at the Door Section.

Fig.9. Indicates the Front panel View of our innovation

Fig.10.Indicates the Bottom panel View of our innovation

Fig.11.Indicates the Side panel View of our innovation

Detailed Description and Future Scope of Our Invention:

Our invention "**Sentry Robot**" is mainly intended to design a Robot, which is a sentry robot and door accessing which is capable of operating for three modes of security using a wireless Zigbee communication network. The invention aims to design a sentry robot wirelessly controlled through a joystick and using Zigbee wireless technology. The system also facilitates for security-based door-accessing mechanism using three combinations of sensing inputs that can achieve the following innovative features.

1. Face recognition-based person detection and authentication
2. Finger print based authorized authentication details
3. Keypad based password accessing

When the three features get accessed then the robot section sends the signal for door accessing using the zigbee network.

The entire system consists of three sections: Transmitter section used modules in the innovation are: Zigbee modules for establishing wireless communication, joystick for controlling robot directions, LCD for displaying status messages using zigbee. The receiver section or robot section consists of Robot interfaced with DC motors, finger print for authentication, Face recognition accessing from MATLAB PC, Keypad for entering password, IR sensor for obstacle detection, LCD for display, Buzzer for alerting when Entered password is incorrect, Voice module for alerting messages announcements from APR33A3 when human presence detects in front of robot using IR sensor. The other receiver section consists of Relay for magnetic door lock for locking and unlocking mechanism which activates based on signal received.

We use wireless zigbee to send the signals from joystick section to robot and from robot to door accessing point. Relay drivers connect to the robot's microcontroller, which is responsible for regulating the robot's movements, and the robot's DC motors.

This innovation can be extended using multiple ultrasonic sensors and a PIR sensor, this robot becomes capable of detecting human beings in the apartments. Adding more parts to this innovation will allow us to use it in a wide variety of contexts in the future.

When a wireless camera is attached to a robot, we can monitor its surroundings from an indoor location using only GPRS and GPS and a personal computer. This robot has a wide range of applications and can be used in a variety of situations.

Robots equipped with bomb detectors can be remotely controlled from a computer and dispatched to dangerous environments like battlefields, forests, and coal mines. Once there, the robots' sensors will pick up on any explosives in the area and relay that information to the robot's microcontroller, which will then relay it to the transceiver and, finally, the computer. Rather than risking human life by sending people into potentially hazardous areas, we can instead send a robot equipped with a temperature sensor to collect that data and relay it to the microcontroller, which in turn relays it to the transceiver, from which the data can be retrieved on the computer. Coal mines, potentially hazardous areas, and other places can all benefit from having robots equipped with smoke sensors so workers can learn more about the conditions there. A sensor collects data, which is then passed on to a microcontroller, which in turn sends the data on to a transceiver, and finally to a personal computer.

We can use the robot to farm by attaching the appropriate tools to it. To help with farming tasks that are best handled away from the office, this robot can be programmed to move in any of four directions: forward, backward, left, or right.

We can use the computer to FIRE the robot at a target by connecting a firing instrument and a wireless camera. Here, cameras allow us to see the enemy and FIRE at them from the comfort of a computer, saving lives and reducing the workload for our soldiers in dangerous situations like the one that unfolded in Mumbai.

Drawings:

Figure.1

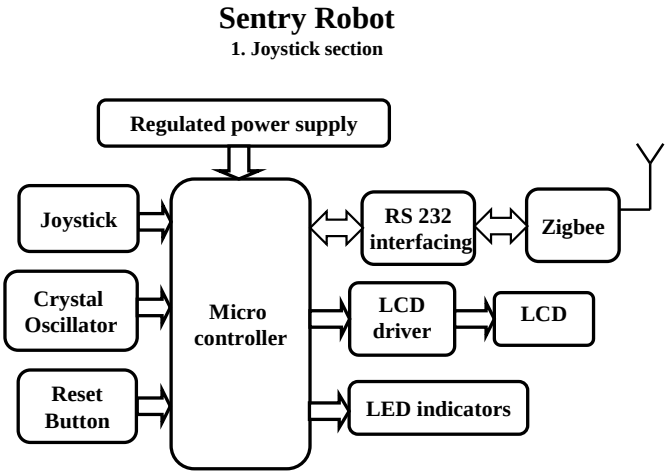


Figure.2

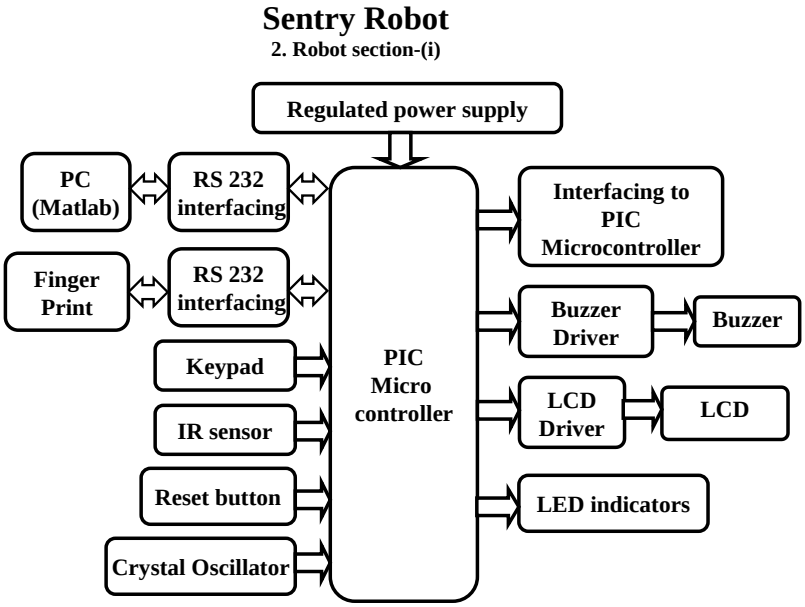


Figure.3

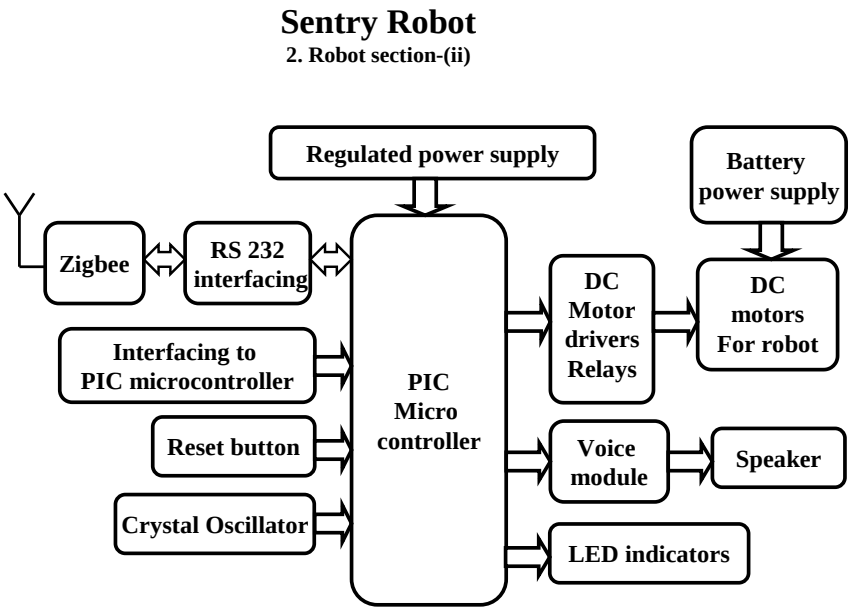


Figure.4

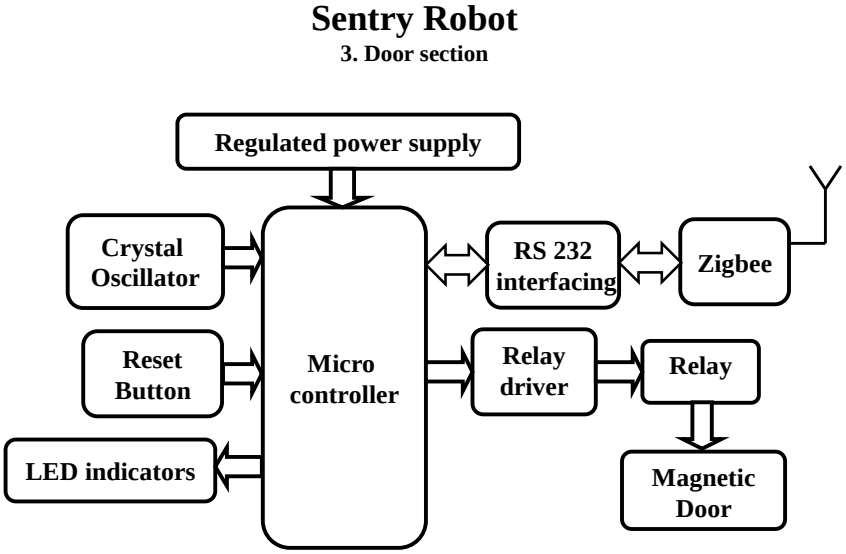


Figure.5

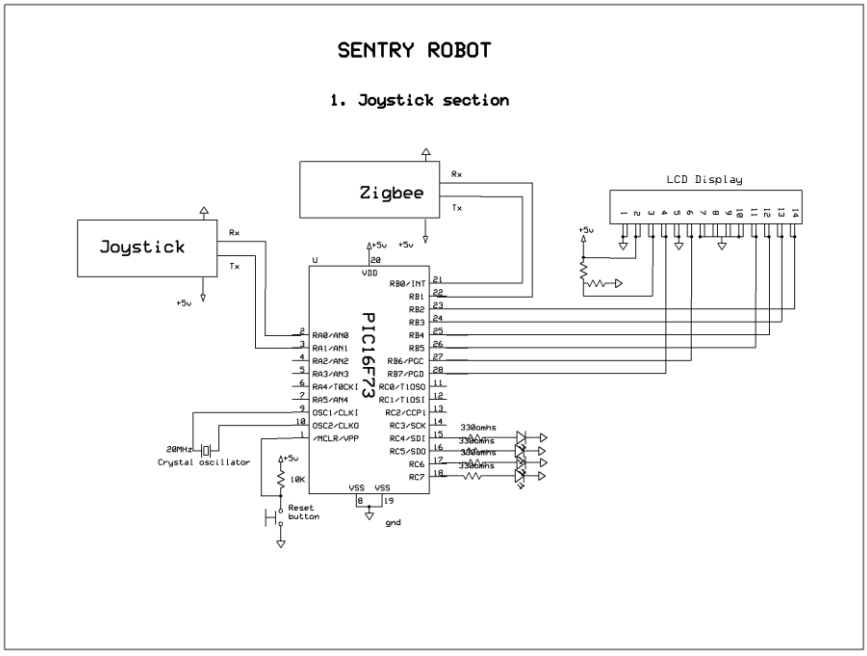


Figure.6

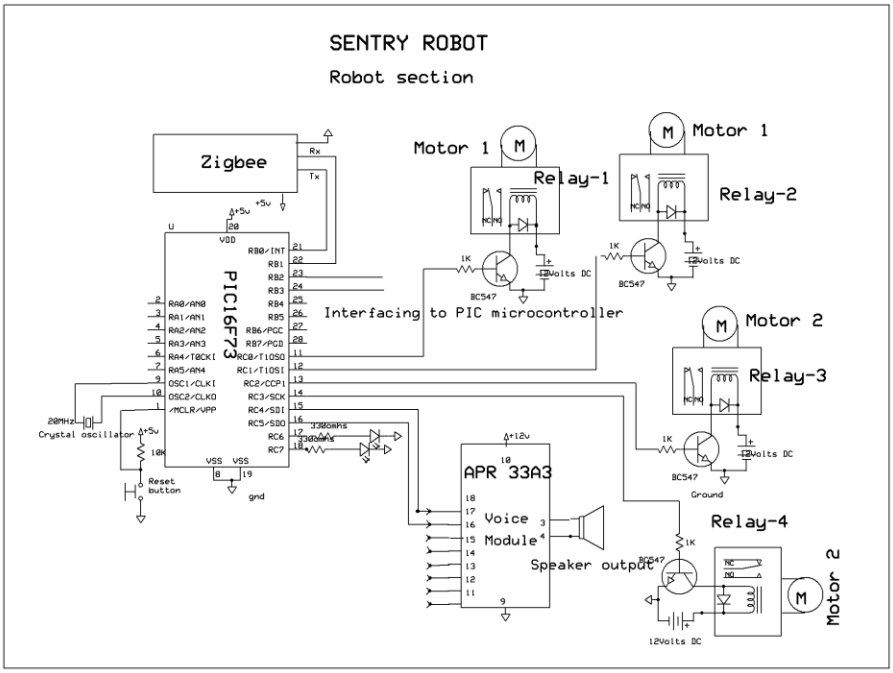


Figure.7

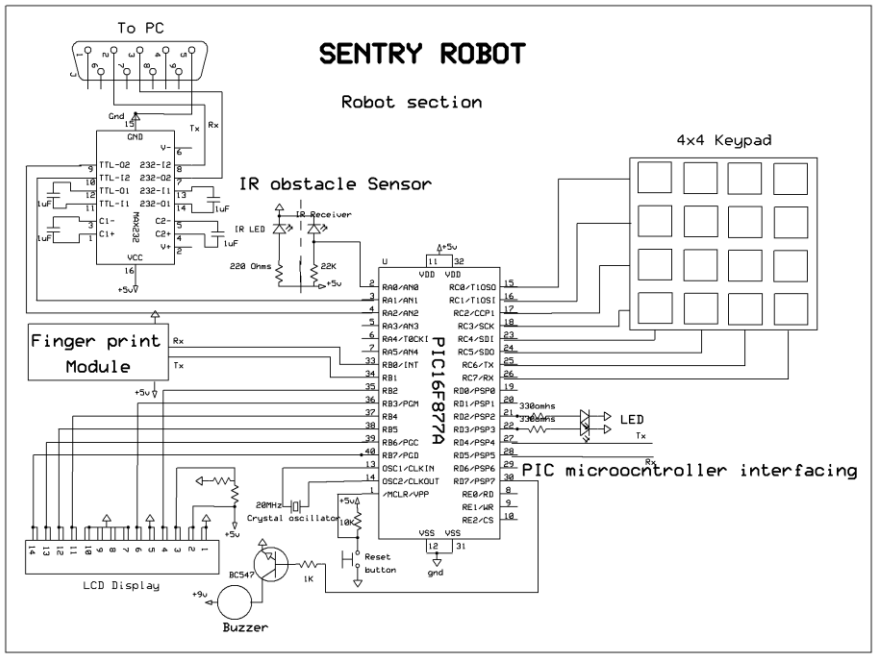


Figure.8

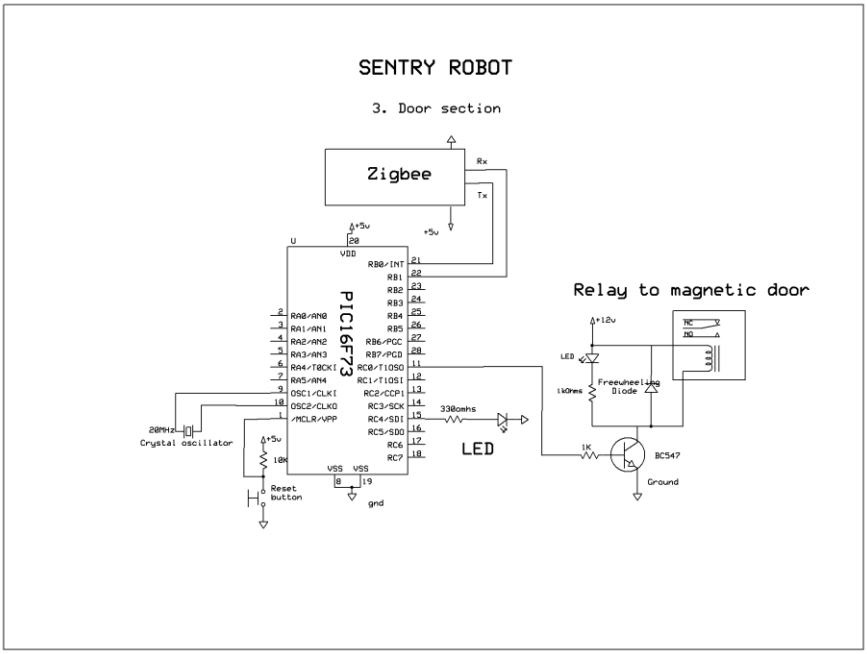


Figure.9

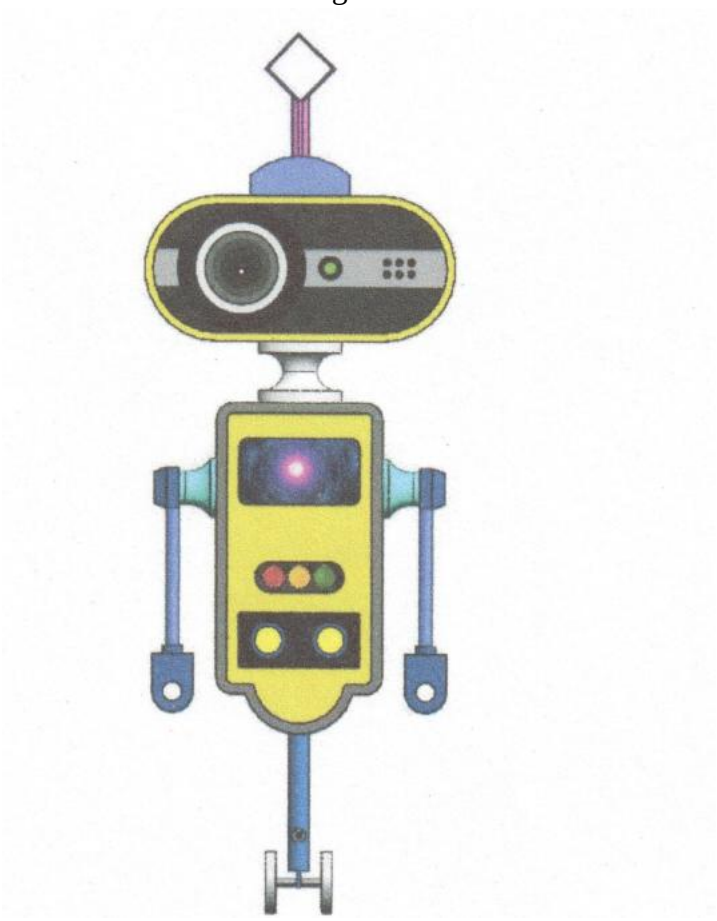


Figure.10

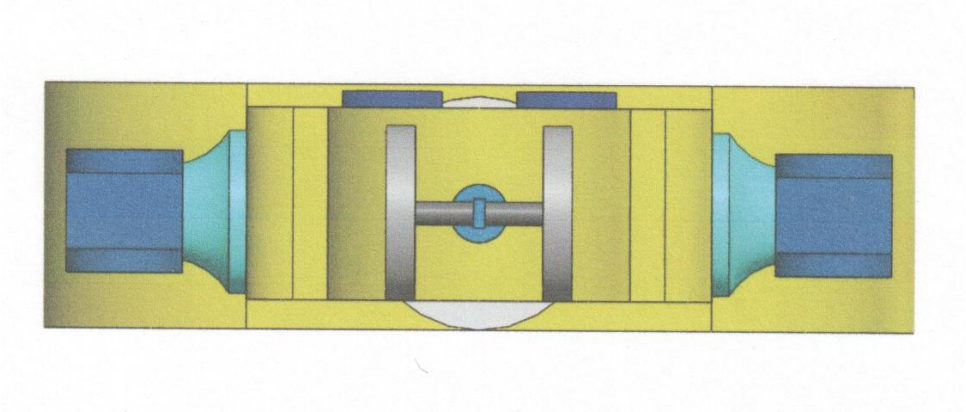
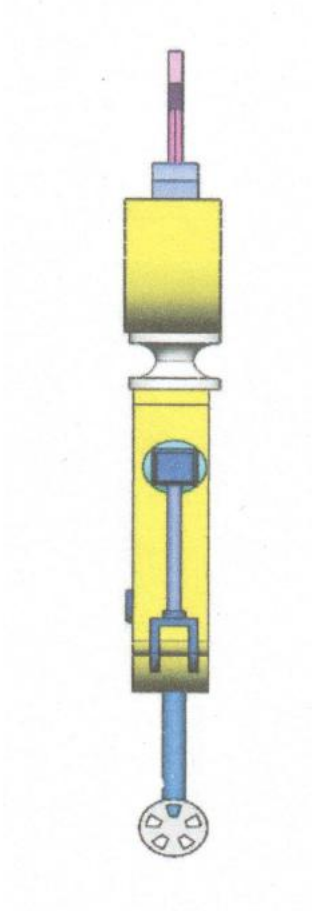


Figure.11



What is claimed is:

1. The description of a sentry robot includes a master camera that can rotate alongside the main body and an active camera positioned on the main body that can rotate up and down and left and right in relation to the main body.
   A Finger Print Sensor, Keypad, Voice Module, Zigbee and other peripherals are interfaced in Robot Section and DC motors are interfaced at door section

2. The sentry robot described in claim 1 can also have two cameras, one installed on each side of the main body, serving as the master camera.

3. The sentry robot described in claim 1 further features a frame that extends forward from the main body and onto which the master camera is mounted, allowing for horizontal and vertical rotation.

4. The sentry robot of claim 1 has a base connection component. supporting the bulk and connecting it to the bottom; pivoting in both the horizontal and vertical axes with respect to the base connection portion, a pivot ring gear mounted on the base connection portion, a pivot drive gear mounted on the main body connection portion and engaged with the pivot ring gear, a pivot drive motor powered by the pivot drive gear, a motor turning the master camera rotation shaft, and a master camera connection portion installed on the base connection portion.

5.The Sentry Robot Claim 1 further comprises Fingerprint Module for Capturing the fingerprints of the persons entering the premises. if and only if the fingerprints are matched the person is allowed through door section otherwise command control will be alerted through buzzer and voice module claimed in claim 1.

6. The Sentry Robot Claim 1 further comprises a Keypad Module for Capturing the Secret pin of the persons entering the premises. if and only if the pin is matched the person is allowed through door section otherwise command control will be alerted through buzzer and voice module claimed in claim 1.

7. The Sentry Robot Claim 1 further comprises a camera Module for Capturing the image of the persons entering the premises. if and only if the image is matched the person is allowed through door section otherwise command control will be alerted through buzzer and voice module claimed in claim 1.

8.The sentry Robot Claim 1 Further comprises Zigbee modules. If a person passes all the checks claimed in claim 5,6,7 then only zigbee module communicates with the zigbee at door section as claimed in claim 1 and person is allowed.

9. All the Coding used to program the microcontroller to perform all the tasks claimed from claims 1 to 8.

Abstract:

This Invention aims in designing a sentry robot and door access which is capable of operating for three modes of security using a wireless Zigbee communication network. The project aims in designing a sentry robot that is wirelessly controlled through a joystick and using Zigbee wireless technology. The system also facilitates for security-based door-accessing mechanism using three combinations of sensing inputs that can achieve the following innovative features.

1. Face recognition-based person detection and authentication

2. Finger print based authorized authentication details

3. Keypad based password accessing

When the three features get accessed then the robot section sends the signal for door access using the ZigBee network.

FORM 2

THE PATENTS ACT 1970

39 OF 1970

&

THE PATENT RULES 2003

COMPLETE SPECIFICATION

(SEE SECTIONS 10 & RULE 13)

1. TITLE OF THE INVENTION

A Machine learning based framework for observation of covid patient using Block Chain

2. APPLICANTS (S)

NAME	NATIONALITY	ADDRESS
Er. Sandeep Gupta	Indian	DIRECTOR Techieshubhdeep IT solutions pvt Ltd Gwalior, Madhya Pradesh
Priyanka Gupta	Indian	Director Techieshubhdeep IT solutions Pvt Ltd Gwalior, Madhya Pradesh

2. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which it is to be performed

A Machine learning based framework for observation of covid patient using Block Chain

FIELD OF INVENTION

[0001] The present invention relates to the technical field of observation the post covid patient. The field of the invention is to determine the health-related issuedpost covid recovery using machine learning and block chain technique.

[0002] More particularly, this present invention relates to the field of remotely observation the patients recovered from covid-19 disease for any health-related issues using machine learning and block chain technique.

BACKGROUND & PRIOR ART

[0003] The subject matter discussed in the background section should not be assumed to be prior art merely as a result of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in-and-of-themselves may also be inventions.

[0004] In this global pandemic situation due to covid-19 disease where most of the population of the world is affected by this disease. Patients are getting recovered from the covid disease and returning to their home post successful recovery from the disease. But, after recovering from the disease, many of the recovered patients are having different kinds of health-related issues and doctors

are also suggesting to periodically monitor the health of the said patients. It is not feasible at all the times to periodically monitor the health as sometimes the patient is not able to identify the health issues and health deteriorates gradually and affect the patient at random. There are various kind of health issues that patients are observing post covid recovery like cardiac arrest, lungs problem etc.

[0005] The symptoms of these diseases arose gradually after covid recovery. The identification/detection of these symptoms is not an easy task for an ordinary person. Further, the inference of these system is also very complex task. In our homes and day to day life, it is not possible also to timely monitor and consult to the doctors every day. Hence, there is a need of the system that can automatically monitor and identify the symptoms arise post covid recovery and timely provide suitable direction/alarm to the patients for a health and peaceful life.

[0006] The proposed system here is based on machine learning and block chain technology. Machine learning and block-chain technology are the latest technology that automates the human life and able to take decision intelligently Machine learning is an intelligence demonstrated by machines, unlike the natural intelligence displayed by humans and animals. As the use of machine learning based models are increasing in every field for improving the effectiveness and correctness of the work to be done. The machine learning models are based on various models that makes the said system more competent and capable in the said field. Machines can work and act like a human if they have enough information. So, in machine learning, knowledge engineering plays a vital role. The relation between objects and properties are established to implement knowledge engineering.

[0007] Further, block chain technology is very useful in storing and securing knowledge and information on the internet. The block chain technology helps to

make sensitive healthcare transactions immutable leading to data integrity and non-repudiation. Hence, there is a need of a system and method based on machine learning models and block-chain technology to monitor the post covid health issues in patients and avoid mishappening with a person and family. There are various prior art that aim to resolve the said issue which are discussed below:

[0008] US8663106 B2 – A observation system comprises a module having at least one sensor and preferably skin and ambient temperature sensors within a housing. The device may be durable or disposable. The housing may be provided with certain surface features and shapes to facilitate mounting on and interface with the skin of the wearer for more accurate temperature measurement. A receiver may be provided to obtain and display data from the module. The module may also display the output data. The output data comprises both detected and derived data relating to physiological and contextual parameters of the wearer and may be transmitted directly to a local recipient or remotely over a communications network. The system is capable of deriving and predicting the occurrence of a number of physiological and conditional states and events and reporting the same as output data.

[0009] US10362940 B2 – A system includes one or more sensors mounted on a mobile patient; a wireless transceiver to communicate with a remote station; and a processor coupled to the sensor and the wireless transceiver to request assistance if the processor detects a fall by the mobile patient. Further, a method to provide personal emergency response for a patient includes wearing a mobile device with a help button and at least one or more accelerometers on the patient to detect patient motion; determining a fall based on detected motions including one or more changes in height or one or more accelerations associated with movements by the patient; waiting for a predetermined period to detect if the

patient can recover from the fall and automatically requesting assistance if the patient is unable to recover from the fall; and requesting assistance if the patient pushes the help button.

[0010] US20210113105 A1 – A method and system for calculating, estimating, or observation the physiological parameters of a subject. At least one processor, when executing instructions, may perform one or more of the following operations. A first signal representing a pulse wave relating to heart activity of a subject may be received. A plurality of second signals representing time-varying information on the pulse wave may be received. A blood oxygen level of the subject based on the plurality of second signals may be determined. A first feature in the first signal may be identified. A second feature in one of the pluralities of second signals may be identified. A pulse transit time based on a difference between the first feature and the second feature may be computed. A blood pressure of the subject may be calculated based on the pulse transit time.

[0011] US20170079582 A1 – A method of determining a value of a physiological parameter for a subject at a selected state includes obtaining, via a device located a distance from the subject, a value of the physiological parameter of the subject at a particular time-of-day, and applying a time-dependent relationship function to the obtained physiological parameter value via a processor to determine a value of the physiological parameter at the selected state.

[0012] US20180228435 A1 – A wearable device for detecting and/or measuring physiological information from a subject includes a housing, at least one optical emitter supported by the housing, at least one optical detector supported by the housing, a first light guide supported by the housing, a second light guide supported by the housing, a motion sensor supported by the housing, and a

processor supported by the housing. The processor is configured to calculate footsteps, distinguish footsteps from heart beats, and to remove footstep motion artifacts from signals produced by the at least one optical detector. Also, the processor is configured to process signals produced by the at least one optical detector to determine subject heart rate and to produce integrity data about the subject heart rate. The process is further configured to generate a multiplexed output serial data string comprising the subject heart rate and the integrity data.

[0013] US10834483 B2 – A biometric observation device configured to be worn by a subject includes a physiological sensor configured to detect and/or measurephysiological information from the subject, and a processor configured to analyze signals from the physiological sensor to detect a signature unique to the subject wearing the biometric observation device, and determine if the detected signature is a first signature associated with the biometric observation device being worn or a second signature associated with the biometric observation device not being worn. The first and second signatures are generated by the processor prompting the subject to indicate at prior times when the biometric observation device is being worn and is not being worn.

[0014] US20190099130 A1 - An ear-worn device includes a speaker, an optical emitter, an optical detector, a processor, and a housing configured to be positioned within an ear of a subject, wherein the housing encloses the speaker, optical emitter, optical detector, and processor. The housing includes at least one window that exposes the optical emitter and optical detector to the ear of the subject, and the housing includes at least one aperture through which sound from the speaker can pass. Light transmissive material is located between theoptical emitter and the at least one window and is configured to deliver light emitted from the optical emitter to an ear region of the subject at one or more predetermined locations. Light transmissive material is positioned between the

optical detector and the at least one window and is configured to collect light external to the housing and deliver the collected light to the optical detector.

[0015] US8764651 B2 – A heart observation system for a user includes a body wearable appliance placed on or near the user skin and having one or more sensors to capture fitness data and a wireless transceiver to communicate fitness data; and a processor coupled to the wireless transceiver to receive fitness data.

[0016] US20170347894 A1 – A system and method for continuous observation of central (aortic) and peripheral Blood Pressure. The system includes a fully mobile, non-invasive, continuous blood pressure observation system that includes one or more Biostrip devices affixed on a user, coupled with an application running on a computing device, which is further connected to a web server in the cloud. The system performs various computations on the Biostrip device, or on the gateway device (Smartphone or Smartwatch), or on the Cloud, and provides the user and authorized third parties with various insights about the blood pressure levels of the user. Further, the system enables the user to receive biofeedback training for controlling hypertension, and schedule online appointments, pay online for such appointments, share data the data securely to obtain insights.

[0017] CN105832317 A – A system for measuring Stroke Volume (SV), Cardiac Output (CO) and heart force (CP) of a patient, the system having: 1) an impedance sensor connected to at least two electrodes having an impedance circuit that processes analog signals from the electrodes to measure an impedance signal (TBEV waveform); 2) an ECG sensor connected to at least two electrodes and comprising an ECG circuit that processes analog signals from the electrodes to measure an ECG signal; 3) an optical sensor connected to an optical probe and comprising an optical circuit that processes signals from

the probe to measure at least one optical signal of the patient; 4) a processing system that analyzes the ECG, TBEV and optical signals in order to determine SV, the processing system typically being worn on the wrist of the patient and connected to the optical sensors by a wired interface, and to the TBEV and ECG sensors by a wired or wireless interface.

[0018] Besides this, there are various prior arts in the state of the art that claims to resolve the problem of observation the health-related issues periodically and automatically but the approach adopted for solving the same need to be further refined. Hence, there is a need to provide a method and system for observation post covid patient using machine learning models and block chain technology. The aim of the present invention is to resolve the above mentioned issued using machine learning models and block chain technology to automatically and timely monitor post covid patient about anomaly in health and provide timely consultation to the patient to avoid any kind of mishappening.

[0019] Groupings of alternative elements or embodiments of the invention disclosed herein are not to be construed as limitations. Each group member can be referred to and claimed individually or in any combination with other members of the group or other elements found herein. One or more members of a group can be included in, or deleted from, a group for reasons of convenience and/or patentability. When any such inclusion or deletion occurs, the specification is herein deemed to contain the group as modified thus fulfilling the written description of all Markus groups used in the appended claims.

[0020] As used in the description herein and throughout the claims that follow, the meaning of “a,” “an,” and “the” includes plural reference unless the context clearly dictate otherwise. Also, as used in the description herein, the meaning of “in” includes “in” and “on” unless the context clearly dictates otherwise.

[0021] The recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless otherwise indicated herein, each individual value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

[0022] The use of any and all examples, or exemplary language (e.g. “such as”) provided with respect to certain embodiments herein is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the invention.

[0023] The above information disclosed in this Background section is only for enhancement of understanding of the background of the invention and therefore it may contain information that does not form the prior art that is already known in this country to a person of ordinary skill in the art.

SUMMARY OF THE INVENTION

[0024] Before the present invention, are described, it is to be understood that this application is not limited to the particular systems, and methodologies described, as there can be multiple possible embodiments which are not

expressly illustrated in the present disclosure. It is also to be understood that the terminology used in the description is for the purpose of describing the particular versions or embodiments only and is not intended to limit the scope of the present application. This summary is provided to introduce concepts related to systems and methods for Sybil detection in web data and the concepts are further described below in the detailed description. This summary is not intended to identify essential features of the claimed subject matter nor is it intended for use in determining or limiting the scope of the claimed subject matter.

[0025] The present invention mainly solves the technical problems existing in the prior art. In response to these problems, the present invention discloses a method and system for automatically and timely monitor the post covid patient about any health-related issues and create a medical history/data of the patient using block chain technology to provide timely consultation to the patient. The given solution is based on the machine learning models which are competent enough to train themselves through the past scans/data and database provided to the said model on the server. The proposed invention comprises of central server which comprises of the initial database which is used to train the machine learning based model to automatically identity the any health-related anomalies based on the data available related to the patient. The said system is trained enough using the test cases and databases that can identify the any kind of health-related issues and infer the data available about the patient and detect timely any health abnormality and takes doctors consultation with respect to said data and alarm/notify the patient timely about any mishappening or unwellness. The said model is backed with the database of patients monitored data. Such data transaction and storage are executed using block chain technology. Block chain technology helps in maintain data integrity and

security. Block chain technology effectively performs to make sensitive healthcare transactions immutable leading to data integrity and non-repudiation.

[0026] The proposed invention comprises smart wearable devices which may be in the form smart watch, electronic tag, chest strap or any kind of smart wearable devices which are registered with the patients need to be monitored. These smart wearable devices gather the data/information continuously. The said data is locally stored within the small memory provided within the smart wearable device. These smart wearable devices comprise various biomedical sensors which automatically measures and records a plurality of physiological data from sensors in contact with the patient's body. The smart wearable device collects various kind of physiological and other parameters including but not limited to body temperature, heart rate variability, motion, sleep, stress, fitness level, recovery level, effect of a workout routine on health, caloric expenditure etc. Further, these smart wearable devices periodically upload the collected data to a database using block chain technology in which it is stored along with similar health histories for other patients. The said smart wearable devices communicates to the communication network through Bluetooth standard protocol. The information collected through the smart wearable devices along with the metadata is transferred and stored using a public or private distributed cryptographic hash ledger method to create a stable, tamperproof index that permits auditing and tracing information transit over an or several electronic networks. The said information is compressed and encrypted using secure encryption methods such as quantum-safe / quantum- secure / quantum-resilient methods that secures the key and the payload independently, and then storing the information on the server.

[0027] The present invention discloses a computer implemented method for observation post covid patient for health-related anomaly, wherein the

computer implemented method is performed by a computing unit, wherein the computing unit comprises a processor and memory, communication unit. The said system also comprises a central server which is equipped with the machine learning based model to automatically infer the data gathered related to a patient about any health abnormality. The computing unit is in communication with the central server via any communication means. The said computing device provide user interface to interact with the system and helps in registering the post covid recovered patients to be monitored. The said user interface may be in the form of mobile application also. Further, unique wearable devices are registered with the patients. The computer implemented method comprising steps of: obtaining various health parameters continuously using smart wearable devices and stored locally, sending and storing the collected data to the central server periodically through communication network using block chain technology. The collected data is automatically and periodically inferred using machine learning model related to patient about any health-related abnormality. If any abnormality is detected by the said machine learning model is detected by the system, then a notification is sent to the doctor along with the details of the patient. The doctor can provide recommendation to the patient accordingly. The doctor can also periodically fetch data related to a patient using mobile application or user interface and provide near real-time observation and treatment to save lives of post covid patient besides their valuable time and effort. The patient can also access the said system using mobile application or user interface.

[0028] An aspect of the present disclosure relates to a computer implemented method for observation post covid recovered patient, wherein the computing unit/mobile terminal comprises a processor and memory, communication unit and a user interface or mobile application to access the system, the method comprises: registering the patient, associating smart wearable devices with the

patient, automatically obtaining various physiological and health parameters continuously in the local memory using biomedical sensors in smart wearable devices, periodically transmitting the gathered data to the central server and storing said data on central database using block chain technology, identifying health abnormality using collected data and machine learning model; sending alert/notification to the doctor in case of abnormality, doctors access the data related to patient using user interface or mobile application and advices to the patient time to time. Thus, doctor can view post covid patient health details and support near real-time observation and treatment to save lives of post covid patient besides their valuable time and effort. The user or post covid patient can also access the said system using user interface or mobile application.

[0029] Another aspect of the present disclosure relates to a system for observation post covid recovered patient, wherein the computing unit/mobile terminal comprises a processor and memory, communication unit and a user interface or mobile application to access the system, the method comprises: registering the patient, associating smart wearable devices with the patient, automatically obtaining various physiological and health parameters continuously in the local memory using biomedical sensors in smart wearable devices, periodically transmitting the gathered data to the central server and storing said data on central database using block chain technology, identifying health abnormality using collected data and machine learning model; sending alert/notification to the doctor in case of abnormality, doctors access the data related to patient using user interface or mobile application and advices to the patient time to time.

[0030] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the

claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

OBJECTIVE OF THE INVENTION

[0031] A primary object of the present invention is to provide a method for observation post covid recovered patient using machine learning models and block chain technology and data collected related to patient using smart wearable devices equipped with various biomedical sensors.

[0032] Yet another object of the present invention is to provide a system for observation post covid recovered patient using machine learning models and block chain technology and data collected related to patient using smart wearable devices equipped with various biomedical sensors. The said system provides real-time observation and treatment to save lives of post covid patient besides their valuable time and effort

BRIEF DESCRIPTION OF DRAWINGS

[0033] To clarify various aspects of some example embodiments of the present invention, a more particular description of the invention will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. It is appreciated that these drawings depict only illustrated embodiments of the invention and are therefore not to be considered limiting of its scope. The invention will be described and explained with additional specificity and detail through the use of the accompanying drawings.

[0034] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the embodiments belong. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing, suitable methods and materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

[0035] In order that the advantages of the present invention will be easily understood, a detail description of the invention is discussed below in conjunction with the appended drawings, which, however, should not be considered to limit the scope of the invention to the accompanying drawings, in which:

[0036] Figure 1 shows block-diagram of the embodiments of the present invention.

[0037] Figure 2 shows a flow-diagram of computer implemented method for observation post covid patient in accordance with the present invention.

DETAIL DESCRIPTION

[0038] The present invention relates to a computer implemented framework for observation post covid patient using machine learning model and block chain technique.

[0039] Although the present disclosure has been described with the purpose of observation post covid patient using machine learning model and block chain technique, it should be appreciated that the same has been done merely to illustrate the invention in an exemplary manner and to highlight any other purpose or function for which explained structures or configurations could be used and is covered within the scope of the present disclosure.

[0040] Some embodiments of this disclosure, illustrating all its features, will now be discussed in detail. The words and other forms thereof are intended to be open ended in that an item or items following any one of these words is not meant to be an exhaustive listing of such item or items, or meant to be limited to only the listed item or items. It must also be noted that as used herein and in the appended claims, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Although any systems and methods similar or equivalent to those described herein can be used in the practice or testing of embodiments of the present disclosure, the exemplary systems and methods are now described. The disclosed embodiments are merely exemplary of the disclosure, which may be embodied in various forms.

[0041] Various modifications to the embodiment will be readily apparent to those skilled in the art and the generic principles herein may be applied to other embodiments. However, one of ordinary skill in the art will readily recognize that the present disclosure is not intended to be limited to the embodiments

illustrated, but is to be accorded the widest scope consistent with the principles and features described herein.

[0042] Figure 1 show a block-diagram of the system for observation post covid recovered patient as per the embodiments of the present invention. According to the present invention, the said system comprises smart wearable devices (103) for collecting timely and automatically physiological and other health related parameters using biomedical sensors. Patient or user can also input the data by accessing the said system using mobile application or user interface if any. The data collected by the smart wearable devices is continuously captured and stored in local memory of the smart wearable devices. The collected data is periodically transmitted to the central server via the network means. The said network means may be WiFi/Bluetooth/LAN/WAN or any other technology used for transmitting the data from one location to the another. The smart wearable devices may be smart watches, electronic tag, chest strip or any kind of smart wearable device. The communication network (101) helps in transmitting and receiving data to and from the other embodiments of the system. The said communication network may be WiFi/Bluetooth/LAN/WAN. The databases (102) reside at the central server which is used to train the central server according to the adopted machine learning model and helps the central server in analyzing and identifying/inferring the received data. The central server (104) uses machine learning model and process the data according to the present invention. The said central server is trained using the past data provided in the database and test cases. The computing unit (105) helps as a user interface to the user and displaying the outputted results on the display of the computing unit. Further, the expert/doctor and user/patient can access the said system using mobile application also.

[0043] Figure 2 shows the flow-diagram of computer implemented method for observation the post covid recovered patient regarding health anomaly in

accordance with the present invention. The computer implemented method first Train central server using database/test cases according to machine learning model at step 201. The smart wearable devices collect data continuously related to physiological and other health related parameters using various kinds of biomedical sensors and said data is stored in the local memory of smart wearable devices at step 202. The captured or collected data related to patient may be but not limited to body temperature, heart rate variability, motion, sleep, stress, fitness level, recovery level, effect of a workout routine on health, caloric expenditure or any kind of health-related parameter. The computer implemented method further comprising the steps of: periodically sending the collected data to the central server at step 203. The collected data related to a patient is transmitted and stored at the central server using block chain technique. The collected data along with metadata is transmitted using cryptographic hash ledger method to create a stable, tamperproof index that permits auditing and tracing information transit over an or several electronic networks / transmission methods. The said data is encrypted using secure encryption methods such as quantum-safe / quantum- secure / quantum-resilient methods that secures the data and metadata independently The stored data related to patient is periodically inferred by the machine learning model using central server for detection of any abnormal pattern at step 204; The provided machine learning model is competent enough to infer or analyse the collected data and finding abnormal pattern. The detection of any abnormal pattern is sent to the expert doctor immediately along with the notification to the doctor. The doctor can access the said system and data using user interface on any computing device or through mobile application. The expert/doctor then analyser or assess the data and advice the patient at step 205. The said system then notifies the patient about advice of doctor immediately as prescribed at step 206. The user or patient can access the said system using mobile application or user interface and act as prescribed. In this way, the said system is competent enough to

automatically and sufficiently monitor the post covid recovered patient and provide real-time observation to save lives.

[0044] The figures and the foregoing description give examples of embodiments. Those skilled in the art will appreciate that one or more of the described elements may well be combined into a single functional element. Alternatively, certain elements may be split into multiple functional elements. Elements from one embodiment may be added to another embodiment. For example, order of processes described herein may be changed and are not limited to the manner described herein. Moreover, the actions of any flow diagram need not be implemented in the order shown; nor do all of the acts need to be necessarily performed. Also, those acts that are not dependent on other acts may be performed in parallel with the other acts. The scope of embodiments is by no means limited by these specific examples.

[0045] Although implementations for invention have been described in a language specific to structural features and/or methods, it is to be understood that the appended claims are not necessarily limited to the specific features or methods described. Rather, the specific features and methods are disclosed as examples of implementations for the invention.

CLAIMS

We claim:

1. A computer implemented framework for observation post covid recovered patient using machine learning model and block-chain technology, where in the computer implemented method is performed by a computing unit proving user interface or mobile application for accessing system, wherein the computing unit comprises a processor, a memory communication unit, wherein the computer implemented method comprising steps of:

   train the central server using databases and test cases (201);

   gather continuously physiological and health related parameter through smart wearable devices having biomedical sensors (202);

   transmitting collected data periodically using block-chain technique to central server (203);

   detecting abnormal pattern in collected data related to patient using machine learning model (204);

   accessing through user interface or mobile application the collected data by expert doctor based on notification received by system or periodically (205);

   analysing the accessed data and advice the patient accordingly;

   notifying the patient about doctor prescription (206);

   accessing the prescription through user interface or mobile application and act as prescribed (207).

2. The computer implemented method as claimed in claim 1, wherein physiological or health related parameters are but not limited to body temperature, heart rate variability, motion, sleep, stress, fitness level, recovery level, effect of a workout routine on health, caloric expenditure.

3. The computer implemented method as claimed in claim 1, wherein the communication network may be based on the WiFi, Bluetooth, Local Area Network, Wide Area Network or the combination thereof and smart wearable devices may be but not limited to smart watch, electronic tag, chest strip.

4. The computer implemented method as claimed in claim 1, wherein the central server works on machine learning models and information is transmitted and stored using block chain technique.

5. A framework for observation post covid recovered patient using machine learning model and block-chain technology, wherein the computer implemented method is performed by a computing unit proving user interface or mobile application for accessing system, wherein the computing unit comprises a processor, a memory communication unit, the system comprising:
   a communication network (101) to transmit/receive data from other embodiments of the system;
   database (102) to train the central server according to the machine learning model;
   smart wearable devices having various biomedical sensor (103) to continuously collect physiological or health parameters;
   a central server (104) to analyze and process received data and analyze the abnormal pattern;
   a computing unit (105) providing user interface or mobile application for accessing the system.

A Machine learning based framework for observation of covid patient using Block Chain

ABSTRACT

The present invention relates to a method for observation post covid recovered patient using machine learning model and block chain technique. The objective of present invention is to solve the anomalies presented in the prior art techniques and technologies related to healthcare monitor of patient who has recovered for the covid-19 disease. The disclosure presents a block chain integrated remote post covid patient observation which is machine learning and Biomedical sensor based smart wearable devices for collecting various physiological and health related parameters of the patient. Its aim is to help remotely living post covid patient to gain access to healthcare units seamlessly and avail services without time and geographical restrictions. The invention is integrated with block chain technology in order to make sensitive healthcare transactions immutable leading to data integrity and non-repudiation. Further, the system is equipped enough with machine learning models to infer the data available and detect any abnormal pattern related to health issues. It has provision to capture post covid patient vital signs and send to doctors. The mobile application or user interface pulls data from the machine learning model based central server and showed to doctor from time to time. Thus, doctor can view post covid patient health details and support near real-time observation and treatment to save lives of post covid patient besides their valuable time and effort. In this way, the observation of post covid recovered patient becomes easy patient and family can be avoided from harm of lives.

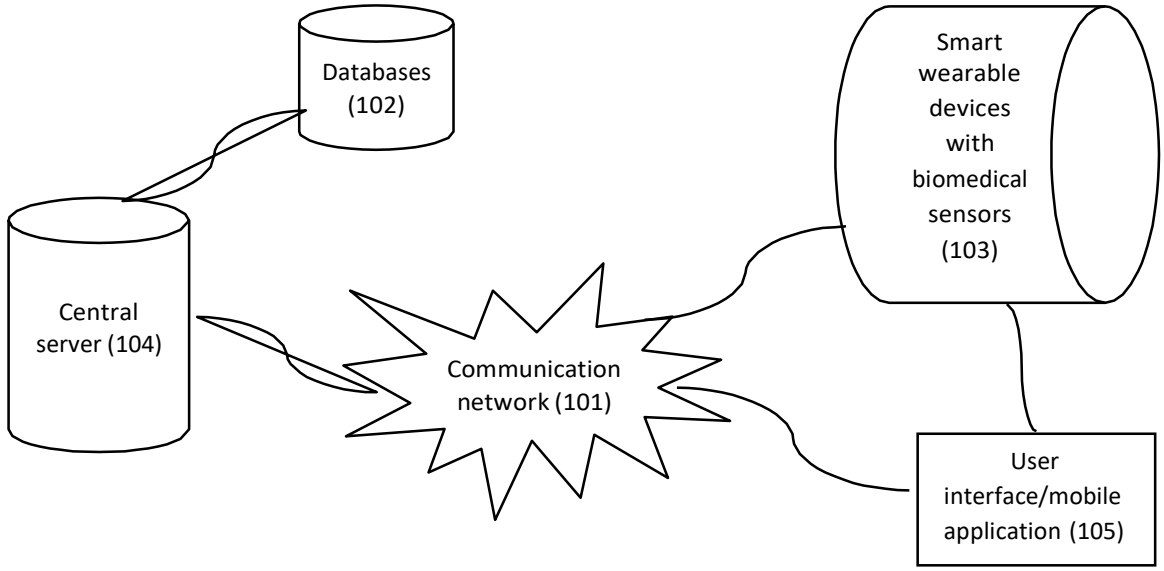


Figure 1: Block diagram of Machine learning based framework for observation of covid patient using Block Chain

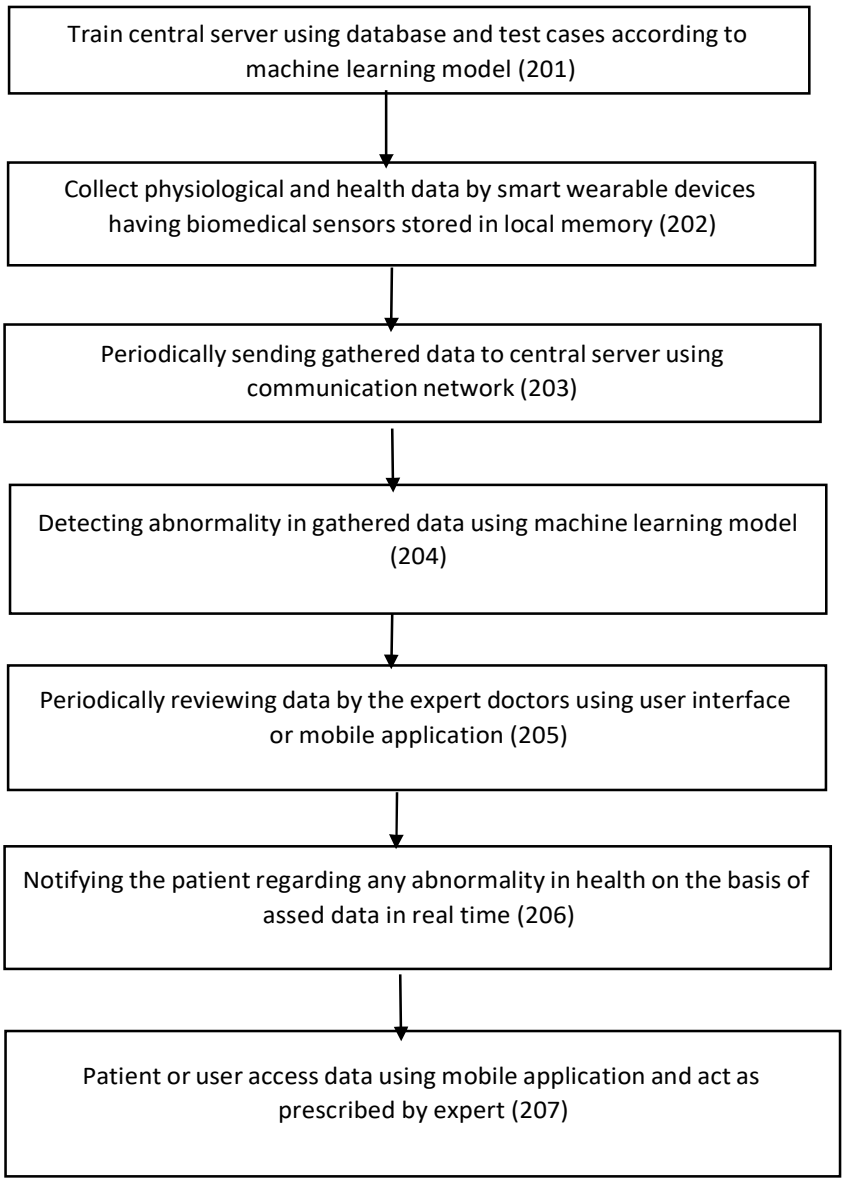


Figure 2 – Flow-diagram of Machine learning based framework for observation of covid patient using Block Chain