

SYSTEM AND METHOD FOR CATEGORISING A COIN**TECHNICAL FIELD**

[001] The present disclosure relates to a system and method for categorising coins. In particular, the system and method may employ image analysis techniques to analyse coins to determine whether they are acceptable, e.g. for recirculation.

BACKGROUND

[002] Globally, currency is produced in accordance with particular standards. The choice of materials and the proportions of those materials are limited, as are the choices of size and shape of currency.

[003] These limitations mean there is similarly a limited number of choices when designing new currency. As a result, currency formulation (i.e. mixtures, compound, and combinations of materials) and sizing has reached saturation point. There are now some currencies that are indistinguishable from other currencies using conventional size and compound or mixture detection technologies.

[004] Currencies are also occasionally updated to exchange expensive material combinations for more affordable combinations, or to recognise new milestones in the progress of a nation, a new monarch or leader, a new denomination or other change. As a result, a single nation may have multiple series of currency in circulation at any one time, where two or more series have exactly the same combination of materials, size and shape.

[005] Conventional minting quality assurance and detection technologies are typically used for newly minted coins. These technologies confirm the peripheral edge of the coin is intact, to ensure blanks are of the appropriate shape, and also confirm the constituent materials are in the correct proportions.

[006] Such technologies cannot distinguish between different series of coins, nor can they identify when a coin is too dirty to re-enter circulation.

[007] It is desirable therefore to provide a system and/or a method that removes one or more of the abovementioned disadvantages in the prior art, or at least provides a useful alternative.

SUMMARY OF THE PRESENT DISCLOSURE

[008] Disclosed herein is a system for categorising a coin, comprising:

one or more image capture devices positioned to capture at least one image of a surface of the coin;

memory comprising master coin data of at least one master coin; and

at least one processor, wherein the at least one processor is configured to:

identify the surface in the at least one image, the surface being one of an obverse and a reverse of the coin;

measure one or more data describing a portion of the surface within a peripheral edge of the coin;

compare the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data; and

categorise the coin as acceptable if the amount of deviation is below a predetermined threshold, and otherwise categorise the coin as unacceptable.

[009] The one or more image capture devices may be positioned to capture at least one image of the reverse of the coin.

[010] Measuring one or more data describing a portion of the surface may comprise selecting a portion of the surface comprising a relief and comparing the one or more data with the master coin data may comprise determining if the central portion matches master coin data describing a central portion, comprising a relief, of a surface of the master coin. Comparing the one or more data with the master coin data may further comprise orienting the central portion of the surface to match an orientation of the central portion of the master coin.

[011] Comparing the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data may comprise determining whether a relief of the coin matches a relief of the master coin.

[012] Measuring one or more data describing a portion of the surface may comprise determining a reflectance of the portion of the surface of the coin. Comparing the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data may comprise calculating a difference in reflectance between the reflectance of the surface of the coin and a reflectance of a surface of the master coin.

[013] The system may further comprise a light source for illuminating the coin during capturing of the at least one image. The light source may be configured to illuminate the coin using light of a predetermined wavelength. The light source may be configured to illuminate the coin using light having a wavelength within a predetermined spectrum.

- [014] The one or more image capture devices may be positioned to capture at least one image of each of the obverse and reverse of the coin.
- [015] Identifying the surface in the at least one image may comprise identifying both the obverse and reverse in respective images of the at least one image.
- [016] Measuring one or more data describing a portion of the surface may comprise:
selecting a portion of the surface comprising a relief; and
determining a reflectance of the portion of the surface of the coin; and
comparing the one or more data with the master coin data may comprise:
determining if the central portion matches master coin data describing a central portion, comprising a relief, of a surface of the master coin; and
calculating a difference in reflectance between the reflectance of the surface of the coin and a reflectance of a surface of the master coin.
- [017] The coin may be classified as acceptable only if the central portion matches master coin data describing the central portion of the master coin, and the difference in reflectance is below the predetermined threshold.
- [018] The system may further comprise a separator configured to locate the coin in a first location if the coin is acceptable, and to locate the coin in a second location if the coin is unacceptable.
- [019] The system may further comprise:
a transparent plate; and
a coin delivery device for delivering the coin across the transparent plate, the a first side of the coin, being one of the obverse and reverse of the coin, faces away from the plate and a second side of the coin, being another of the obverse and reverse of the coin, is visible through the transparent plate,
wherein the at least one image capture device is positioned to capture at least one image of both the first and second sides of the coin.
- [020] The at least one image capture device may comprise a first image capture device arranged to capture at least one image of the first side of the coin, and a second image capture device arranged to capture at least one image of the second side of the coin.
- [021] The system may comprise a first surface mirror positioned above the transparent plate, to reflect the first side of the coin towards the at least one image capture device. The system may comprise a second surface mirror positioned below the transparent plate, to reflect the second side of the coin towards the at least one image capture device. The, or

each, mirror may be angled to enable the at least one image capture device to be positioned to laterally with respect to the transparent plate.

[022] The system may further comprise an edge capture mirror positioned to reflect an image of the peripheral edge of the coin towards the at least one image capture device. A surface of the edge capture mirror facing the coin may be concave. The edge capture mirror may be located below the transparent plate.

[023] The coin delivery device may comprise a coin hopper and an upstream conveyor, the upstream conveyor being arranged to receive the coin from the hopper and deliver the coin across the transparent plate from an upstream side of the transparent plate.

[024] The system may further comprise a downstream conveyor arranged to receive the coin on a downstream side of the transparent plate, to convey the coin away from the transparent plate. The, or each, conveyor is located above a run, such that the coin is sandwiched between the conveyor and run.

[025] The, or each, conveyor may comprise one or more spring-loaded rollers, wherein the spring of the respective roller becomes compressed as a coin passes between the roller and the run.

[026] The run may comprise opposite or opposing bumpers, at least one of the bumpers being adjustable laterally to change a width of the run. The height of the bumpers may be adjustable.

[027] The run under the downstream conveyor may comprise a kicker, the kicker being activated, if the coin is classified as unacceptable, to kick the coin from said run.

[028] The system may further comprise at least one edge detector for determining at least one of:

- (i) when the coin is passing across the transparent plate; and
- (ii) when the coin has passed across the transparent plate.

[029] The present disclosure further provides a method for categorising a coin, comprising:

capturing at least one image of a surface of the coin;

identifying the surface in the at least one image, the surface being one of an obverse and a reverse of the coin;

measuring one or more data describing a portion of the surface within a peripheral edge of the coin;

comparing the one or more data with master coin data of at least one master coin to determine an amount of deviation of the one or more data from the master coin data; and

categorising the coin as acceptable if the amount of deviation is below a predetermined threshold, and otherwise categorising the coin as unacceptable.

[030] Measuring one or more data describing a portion of the surface may comprise selecting a portion of the surface comprising a relief, and comparing the one or more data with the master coin data may comprise determining if the central portion matches master coin data describing a central portion, comprising a relief, of a surface of the master coin.

[031] Comparing the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data may comprise determining whether a relief of the coin matches a relief of the master coin.

[032] Measuring one or more data describing a portion of the surface may comprise determining a reflectance of the portion of the surface of the coin. Comparing the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data may comprise calculating a difference in reflectance between the reflectance of the surface of the coin and a reflectance of a surface of the master coin

[033] The method may further comprise delivering the coin across a transparent plate, and wherein capturing at least one image of a surface of the coin comprises capturing an image of both an obverse and reverse surface of the coin, the image of one of the obverse a reverse surface of the coin being captured through the transparent plate

BRIEF DESCRIPTION OF THE DRAWINGS

[034] Some embodiments of systems and methods for categorising coins in accordance with present teachings will now be described, by way of non-limiting example only, with reference to the accompanying drawings in which:

FIG. 1 illustrates a process or method for categorising coins in accordance with an embodiment of the present invention;

FIG. 2 shows a reverse and obverse of the same coin;

FIG. 3 depicts an interface with lines used to identify the location of a coin;

FIG. 4 depicts an interface in which modified lines are used to identify a portion of the surface of the coin;

FIG. 5 is a schematic diagram of a system for categorising a coin, in accordance with some embodiments;

FIG. 6 is a partial flowchart highlighting a portion of the method of Figure 1;

FIG. 7 is a side view of an alternative embodiment of an apparatus for categorising a coin in accordance with present teachings;

FIG. 8 is a partial, cross-section view of the apparatus of FIG. 7; and

FIG. 9 is a plan view of an upstream end of a run of the system of FIG. 7.

DETAILED DESCRIPTION

[035] In some embodiments, the invention enables categorisation of coins as acceptable or unacceptable based on whether the coin is of the correct series, has been damaged during use, the surface relief or legend is worn, the coins are dirty and other characteristics.

[036] A method 100 for categorising a coin is shown in Figure 1. The method 100 broadly comprises:

Step 102: capturing one or more images of a surface of the coin

Step 104: identifying the surface of the coin in the one or more images captured at step 102;

Step 106: measuring data describing a portion of the surface of the coin identified at step 104;

Step 108: comparing the data measured at step 106 with master coin data; and

Step 110: categorising the coin.

[037] The method 100 can thus enable categorising of a coin as acceptable or unacceptable by taking at least one image of the coin (step 102) and identifying the coin, or part of the coin, in the image(s) to enable the coin to be analysed. The surface of the coin is identified (step 104) and analysed to extract features from the image that identify, for example, whether the coin is dirty or damaged, the series of the coin and other parameters such as reflectance (step 106). Once the coin has been analysed, the results of the analysis are compared to relevant parameters of a master or benchmark coin (step 108). The master or benchmark coin is usually a freshly minted acceptable coin – e.g. a clean, undamaged coin of the correct series, that is not worn. Depending on the results of the comparison, the coin is either accepted if it is sufficiently similar to the master coin to re-enter circulation, or rejected otherwise. The method and system can be applied repeatedly, to multiple coins.

[038] The step of capturing at least one image of a surface of the coin – step 102 – enables a relevant portion of the coin to be identified in later steps.

[039] The “relevant portion” may be entirety of the obverse side of the coin, the entirety of the reverse side of the coin, or both. The “relevant portion” may instead be a substantial part, or an identifying part of the relevant surface. In this context, a “substantial part” of a

surface is a sufficiently large portion of the surface that the cleanliness of the surface or damage or wear to the surface can be assessed. Also in this context, an “identifying part” of a surface is a portion of that surface that enables the coin to be distinguished from one or more other coins or currencies, or enables the coin to be uniquely identified as being of a particular denomination and of a particular currency.

[040] The “relevant portion” may instead show properties of the coin, such as a reflectivity spectrum, or reflectance, enabling materials or cleanliness of the coin to be determined.

[041] Step 104 involves identifying the surface in the one or more images. The surface is either an obverse of the coin, a reverse of the coin or both. Where both surfaces are captured, two or more image capture devices may be used. Thus image capture step 102 may involve capturing an image or images or both the obverse and reverse of the coin.

[042] As shown with reference to Figure 2, the reverse 200 is the rear side or tails of a coin. Similarly, the obverse 202 is the front side or heads of a coin. The periphery of the coin is the edge 210. In some circumstances, the edge 210 is considered the third side of the coin – along with the obverse and reverse sides – and can take any desired design, such as a plain or smooth edge, a reeded or milled edge, a lettered edge or a decorated edge. The edge 210 adjoins, but is a distinct feature from, the rim 208. The rim 208 is a raised or protruding lip around the periphery of the coin. A rim 208 may be provided on both sides of the coin as shown, on a single side of the coin or may be entirely omitted. The rim 208 protects the design of the coin, e.g. the relief 204, from wear and damage. A relief 204 is a design applied to the obverse or reverse of the coin. In the present case, the reverse relief 204 of the reverse 200 is a maple leaf and the obverse relief 204 of the obverse 202 is a side view of a bust of Queen Elizabeth II. The coin also exhibits a legend 214 which is the principle inscription or lettering on a coin, a field 212 which is the flat portion of the coin usually between the rim 208 and relief 204, and a mint mark 206. The field 212 usually has no design applied, and the mint mark 206 identifies the location of the mint where the coin was minted.

[043] To improve image capture or to ensure certain properties (e.g. cleanliness, material mixture) of the coin are identifiable, the method 100 may further involve illuminating the coin during capturing of the at least one image – step 112. Illumination may involve illuminating the coin using a particular wavelength of light, or a particular light spectrum, to ensure one or both of reflectance and reflectivity spectrum can be measured. The particular wavelength or spectrum emitted by the light source may therefore be predetermined to optimise the wavelength or spectrum for detecting particular characteristics or properties of

the coin. For example, in some circumstances blue light may produce substantial noise in the one or more images, so other wavelengths should be considered. It may be that illuminating step 112 should involve illuminating with a white light source in the shape of a ring, circle or annulus so that an image capture device – e.g. a camera – can be centrally positioned concentrically in the middle of the light source, and the light source can thereby uniformly illuminate the area in front of the camera.

[044] Step 112 may also involve positioning the light source a predetermined distance from the coin, or at an angle to the coin, to optimise or improve image capture – e.g. when compared with illuminating perpendicularly to the surface of the coin. Similarly, step 102 may involve positioning the one or more images captured devices to optimise the viewing angle and improve image capture – e.g. when compared with illuminating perpendicularly to the surface of the coin.

[045] The measuring step, step 106, involves measuring one or more data describing a portion of the surface. The portion of the surface is within a peripheral edge of the coin. This enables the portion of the surface to be used to identify certain characteristics such as the series, currency, cleanliness or state of wear or damage of the coin.

[046] In some embodiments, such as those in which coins move past the image capture device or devices or vice versa, it may first be desirable to identify the coin or a surface of the coin in the captured image(s). An interface for identifying a coin is shown in Figures 3 and 4.

[047] Figure 3 shows an example interface 300 for user interaction with a system 500 (see Figure 5) for categorising a coin. The interface 300 is shown to enable coin identification in an image, and to reduce the proportion of the image that is considered for analysis steps.

[048] The interface 300 comprises user input regions 302, 304, 306. Input region 302 is for setting camera parameters such as shutter speed. The camera parameters will be set according to the rate at which the method 100 is to be applied to coins. For example, if the rate of coin analysis (e.g. 600 coins per minute) is high, the shutter speed will need to be rapid. Conversely, the shutter speed may be slowed where coins are analysed at a lower rate.

[049] Input region 304 sets capture parameters such as the size of the area or region of the field of view that is captured. The area that is captured in an image can be adjusted based on the size of the master coin. For example, if the master coin is large, the size can be increased. If the master coin is small, the size can be decreased. This may enable smaller coins to be analysed faster, or at higher resolution, on the basis that the data transfer for the

smaller capture region will be quicker, or can be the same speed with higher resolution, when compared with a larger capture region.

[050] Input region 306 enables the image colours to be balanced. Notably, different types of image capture devices may be used, which will have different parameters for adjustment. For example, the system 500 may include two or more monochrome cameras for capturing appearance characteristics of the coin, and two or more cameras for capturing reflectance or colour spectrum. The two or more of each type of camera may photograph the obverse and reverse of a coin. The monochrome cameras need not have options for adjusting red, green, blue (RGB) camera parameters – hence region 306 is deactivated as shown in Figure 3 – whereas the other cameras may require the RGB capture parameters to be optimised to easily identify wear, damage or dirt.

[051] Input region 308 shows a field of view of the image capture device. The field of view is bounded by upper and lower lines 314. Thus, portions of the field of view that are not between these lines 314 may not be captured or, if the camera is motion triggered, motion in these regions may not result in image capture.

[052] The field of view 308 may be captured as a series of vertical and horizontal scan lines. Presently, the image resolution is 512 (vertical lines) x 480 (horizontal lines). The image in the field of view may be searched for a coin, and the portion of the image used for measurement step 106 may therefore be reduced to a region of the field of view containing the coin or part of the coin.

[053] To reduce data analysis and transfer times, thereby enabling higher coin processing or categorising rates, the search region, bounded by box 310, is less than the entire field of view 308. In particular, the search region 310 is limited to portions of the field of view 308 through which coins can be expected to pass.

[054] In some embodiments, the portion of the coin that needs to be analysed to enable unique identification of cleanliness, series, wear or damage is less than the entire obverse or reverse of the coin. Thus the search region 310 is further reduced, vertically, by lines 312. This means that a central portion of the coin – i.e. a portion of the coin that is less than a full obverse or reverse side, that includes the geometric centre of the relevant side – will be used for steps 104 onwards.

[055] In this manner, the search region 310 is reduced based on the typical position of a coin, to speed up processing time.

[056] Figure 4 shows an alternative arrangement in which only a central, small portion of the side of the coin is taken for analysis. The search region 402 may remain the same as for

the examples described with reference to Figure 3. However, the pattern region or “relevant portion” 404 is strategically taken to limit that portion of the image analysed to a portion that is sufficient for differentiating between, for example, different series of a currency.

[057] In the present examples, both the obverse and reverse will be captured and analysed. In some embodiments, however, only the reverse may be captured and analysed. Such embodiments may apply where one side of the coin is sufficient for differentiation – whether the coin is positively identified (i.e. as a particular currency, denomination and series), or simply identified as not being an acceptable coin. Analysis of the other side of the coin – e.g. the obverse – may be avoided since the desired outcome has been achieved through analysis of a single side only. With reference to Figure 6, illustrating a partial method for categorising a coin, the system 500 may capture an image of the reverse (step: U0002:Back), determine whether the reverse is sufficient to enable identification of the currency series (step: U0007:IF already...) and bypass obverse image capture (step: U0003:Face) if so. Or, if the reverse is not sufficient to enable identification of the series, the obverse is captured and the images are joined in analysis (step: U0008:Join).

[058] In the example shown, step 106 involves selecting a portion of the surface of the coin that includes the relief of the coin.

[059] Step 106 may also involve determining a reflectance of the portion of the surface of the coin that is selected for analysis. The reflectance can be used to determine whether the coin is clean or not. A clean coin will reflect more light than a dirty coin.

[060] Step 106 may also involve measuring image features of the relief for comparison with image features of the relief in the master coin.

[061] After measuring the parameters or characteristics of the coin, the measurements are compared with master coin data to determine an amount of deviation of the measurements from similar measurements of the master coin – step 108. For example, comparing step 108 may involve determining if the central portion, that includes the relief, matches master coin data describing a central portion, comprising a relief, of a surface of the master coin. The image of the coin may be rotated to substantially the same orientation as the data representing the master coin against which the comparison is being made.

[062] The coin is then accepted if the deviation between the measurements for the coin and those for the master coin are below a predetermined threshold – step 110.

[063] In determining an amount of deviation between the measurements or data taken from the coin, and the similar measurements or data of the master coin, the method 100 may determine if the coin matches the master coin. Where the relief of the coin is compared

to the relief of the master coin, a match may be found where a minimum matching percentage has been reached – e.g. that 65% (by area) of the relief of the coin matches the relief of the master coin. This comparison enables the coin to be identified as being of a particular series or currency. If there is a match, then the coin is accepted. Otherwise, the coin is found unacceptable.

[064] A different comparison may be required where cleanliness is being assessed. For example, the reflectance measured from the coin may be compared to the reflectance measured from the master coin. If the deviation of the reflectance from the coin exceeds a predetermined threshold from the reflectance of the master coin, then the coin is deemed unacceptable. Otherwise, the coin is accepted. Notably, where reflectance is being considered, the threshold may relate to a lower bound only, since it is unlikely that the coin will become more reflective during use.

[065] Figure 5 is a block diagram showing an exemplary system 500 for executing the method 100, for categorising a coin. The system 500 may be a stationary plant including a traditional coin sorting ramp, or may include parts of a system manufactured by Keyence® such as SmartTrax®.

[066] The system 500 broadly comprises:
one or more image capture devices (e.g. cameras) 513 – shown here concentrically positioned within a ring-shaped, white light source 514;
non-volatile (non-transitory) memory 504; and
at least one processor or central processing unit (CPU) 510.

[067] The system 500 also includes:
a display 502 – which may display an interface such as that shown in Figures 3 and 4;
random access memory ("RAM") 508;
a transceiver component 512 that includes N transceivers;
user controls 515; and
sorter 509.

[068] All of the above may be in communication via a bus 506.

[069] Although the components depicted in Figure 5 represent physical components, Figure 5 is not intended to be a hardware diagram. Thus, many of the components depicted in Figure 5 may be realized by common constructs or distributed among additional physical components. Moreover, it is certainly contemplated that other existing and yet-to-be developed physical components and architectures may be utilized to implement the functional components described with reference to Figure 5.

- [070] The display 502 generally operates to provide a presentation of content to a user, and may be realized by any of a variety of displays (e.g., CRT, LCD, HDMI, micro-projector and OLED displays). The display 502 may also be a touch screen, enabling the user controls 515 to be incorporated thereinto.
- [071] The memory 504 includes master coin data of at least one master coin. Notably, where reference is made to the master coin and comparisons thereof with the coin being categorised, the skilled person will appreciate that reference is being made to data representing the master coin rather than the master coin itself, and similarly for the coin being categorised. Moreover, the master coin data may be for multiple coins, enabling a single coin to be categorised as acceptable if it deviates only within an acceptable threshold from at least one coin represented in the master coin data.
- [072] In general, the non-volatile data storage 504 (also referred to as non-volatile memory) functions to also store (e.g., persistently store) data and executable code. The data and executable code include instructions enabling operation of the CPU 510 and other components – e.g. cameras 513.
- [073] In some embodiments for example, the non-volatile memory 504 includes bootloader code, modem software, operating system code, file system code, and code to facilitate the implementation components, well known to those of ordinary skill in the art, which are not depicted nor described for simplicity.
- [074] In many implementations, the non-volatile memory 504 is realized by flash memory (e.g., NAND or ONENAND memory), but it is certainly contemplated that other memory types may be utilized as well. Although it may be possible to execute the code from the non-volatile memory 504, the executable code in the non-volatile memory 504 is typically loaded into RAM 508 and executed by one or more processors or CPU 510.
- [075] The one or more processors or CPU 510 in connection with RAM 508 generally operate to execute the instructions stored in non-volatile memory 504. As one of ordinary skill in the art will appreciate, the one or more processors or CPU 510 may include a video processor, modem processor, DSP, graphics processing unit (GPU), and other processing components. For example, the one or more processors or CPU 510 may be a XG-X2800 controller for fast processing, with a 7-core DSP.
- [076] The one or more processors or CPU 510 are configured to perform the steps of method 100. The one or more processors or CPU 510 may perform step 106 by selecting a portion of the surface comprising a relief. Alternatively, the one or more processors or CPU

510 may perform step 106 by determining a reflectance of the portion of the surface of the coin.

[077] Depending on the manner in which the one or more processors or CPU 510 performed step 106, the one or more processors or CPU 510 may then perform step 108 by:

determining if the central portion matches master coin data describing a central portion, comprising a relief, of a surface of the master coin. Comparison step 108 may also involve orienting the central portion of the surface to match an orientation of the central portion of the master coin. Moreover, this determination may involve comparing the relief of the coin being categorised, to the relief of the master coin; or

calculating a difference in reflectance between the reflectance of the surface of the coin and a reflectance of a surface of the master coin.

[078] The one or more processors or CPU 510 may alternatively perform both forms of analysis. This may require different types of cameras. For example, the one or more processors or CPU 510 may:

perform step 106 by:

selecting a portion of the surface comprising a relief; and

determining a reflectance of the portion of the surface of the coin; and

perform step 108 by:

determining if the central portion matches master coin data describing a central portion, comprising a relief, of a surface of the master coin; and

calculating a difference in reflectance between the reflectance of the surface of the coin and a reflectance of a surface of the master coin.

[079] Thus the one or more processors or CPU 510 will classify the coin as acceptable only if the central portion matches master coin data describing the central portion of the master coin, and the difference in reflectance is below the predetermined threshold.

[080] The system 500 also includes a separator 509. The separator 509 is configured to separate acceptable coins from unacceptable coins. The separator 509 may also separate one acceptable coin from other acceptable, but different, coins. For example, the separator may separator an acceptable 5^c coin from an acceptable 10^c coin. In these embodiments, the separator 509 will locate the coin in a first location (e.g. the, or one of the, acceptable coin bins) if the coin is acceptable, and to locate the coin in a second location if the coin is unacceptable. Separation technology is known for newly minted coins and can be applied similarly in the present context.

[081] The one or more processors or CPU 510 may take instructions about categorising

specific currencies from a remote server, via the transceiver component 512. The transceiver component 512 includes N transceiver chains, which may be used for communicating with external devices via wireless networks. Each of the N transceiver chains may represent a transceiver associated with a particular communication scheme. For example, each transceiver may correspond to protocols that are specific to local area networks, cellular networks (e.g., a CDMA network, a GPRS network, a UMTS networks), and other types of communication networks.

[082] The system 500 may also be able to execute applications 518 or receive external inputs to refine operation. Such applications 518 may be specific to a particular currency, or a feature of that currency (e.g. an assessment of holographic features).

[083] The transceiver component 512 is also adapted to receive external inputs such as inputs from apps 518, and to transmit results to a remote server or client server.

[084] The image capture device(s) 513 are positioned to capture at least one image of a surface of the coin. The image capture devices may be designed to capture various properties of the coin, such as reflectance, electromagnetic signature (for identifying constituent metals from which the coin is fabricated), and the relief and other design features on the coin.

[085] Any number of image capture devices 513 may be used. Presently, each is a 21 mega pixel camera, and there are 4 cameras in the system 500. The cameras are each CA-HX048M, which is a 16 times speed monochrome camera with maximum 786 x 596 pixels. The transfer time from capture of image to receipt at the CPU 510 is 2.9ms. Each image capture device 513 is positioned to capture at least one image of the reverse of the coin. In some cases, an image capture device may capture multiple images and aggregate them (e.g. form an average) or select the clearest image for subsequent processing.

[086] The light source 514 is a multi-angle white ring light, CA-DRW8M, used to achieve a bright and uniform illuminated image. The light source 514 illuminates the coin during capturing of the images. As discussed above, the light source may also be configured to illuminate the coin using light of a predetermined wavelength or wavelength within a predetermined spectrum.

[087] The distance of the light source 514 and camera 513 to the coin can also be adjusted to optimise categorising. Similarly, the angle of projection for the light source 514, and of viewing for the camera 513, can be adjusted to optimise registration of surface and compound features of the coin.

[088] It should be recognized that Figure 5 is merely exemplary and in one or more exemplary embodiments, the functions described herein may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be transmitted or stored as one or more instructions or code encoded on a non-transitory computer-readable medium 504. Non-transitory computer-readable medium 504 includes both computer storage medium and communication medium including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a computer.

[089] In an exemplary embodiment, the tool utilized for coin inspection leverages off software available in the market (market software) that uses profile information extracted from the target during search. The target can be searched stably even if changes occur such as chips, contrast reduction and size changes. This tool offers high search performance also as a position adjustment reference for other tools. Hence, the outline of the face and back of the coin is highlighted for comparison. Each coin may undergo two inspections by the market software, namely new coin face and new coin back. If the coin fulfils the matching percentage of either new coin face or new coin back, it is accepted as a new coin, otherwise rejected as an old coin.

[090] The current market software tool only registers an outline of the coin. This is not useable for separating between currencies of the same size and shape, but of different series. This technology has been extended by methods disclosed herein to register an outline feature of a pattern region and move that pattern at certain intervals or by set increments within a specified range (search region) to find a portion that matches the corresponding feature (e.g. relief) in the master coin data to the highest degree. The position and angle values of the portion having the highest degree of matching are output as the measurement results. Minimum matching percentages may be set or fine-tuned with sample coins to sort new and old coins. Parameters such as search sensitivity (e.g. resolution of images and thus of data) and fine search accuracy (e.g. the degree to which the coin needs to match the master coin – e.g. 80% versus 60% of the portion of the surface that was measured at step 106) can be fine-tuned to modify the accuracy of outline feature.

[091] The one or more processors or CPU 510 may also be configured to ignore irrelevant imperfections such as image contrast and surface damage, in some examples. For example, where distinguishing between series of currency, some surface damage may be disregarded in lieu of analysing the more important features that enable the series of a coin to be determined. Thus a higher level of acceptance accuracy can be achieved.

- [092] Similarly, distortions can be resolved using image processing techniques. For example, if each edge of the detection candidate (i.e. the coin being categorised) is not aligned with the registered pattern due to the lens angle or work tilting, the edges are detected as edges during a fine feature search provided it is a distortion of within a predetermined margin or number of pixels.
- [093] In another illustrative example, the system can be embodied as shown in the schematic in FIG. 7. The system 700 is used for categorising a coin (see coins 702, 704, 706). That categorisation may be that the coin is acceptable or unacceptable, or that it belongs to a particular series. The system 700 comprises a transparent plate 708, and a coin delivery device generally designated 710.
- [094] The coin delivery device 710 delivers the coin across the transparent plate 708. When passing across the transparent plate 708, the coin is not being driven by the delivery device 710. Therefore, the coin may be considered to be thrown across the transparent plate 708.
- [095] The coin has a first side 712, that is one of the obverse and reverse of the coin, and a second side 714 that is the other of the obverse and reverse. The first side 712 faces away from the plate 708 and the second side 714 is visible through the plate due to the transparency of the plate.
- [096] The system 700 includes an image capture device for capturing at least one image of both the first and second sides. To facilitate capture of both the first and second sides of the coin, the image capture device presently comprises two cameras 716, 718. A first camera 716 captures the first, or top side of the coin – i.e. that facing away from the transparent plate 708, and the second camera 718 captures the second, or bottom side of the coin – i.e. that visible through the transparent plate 708.
- [097] The cameras 716, 718 may be disposed normal to the transparent plate 708 – e.g. directly, perpendicularly above and below the plate 708 – or, as shown in FIG. 8, be positioned laterally with respect to the transparent plate 708. The term "laterally" in the present context refers to be positioned at one side of the transparent plate 708. This reduces the height of the system 700 when compared with having cameras disposed vertically above and below the transparent plate 708.
- [098] Since the cameras 716, 718 do not perpendicularly face the upper or lower surface of the transparent plate 708, they similarly will not perpendicularly face the surfaces of the coin 724 passing across that plate 708. To enable the image capture device to be positioned laterally with respect to the transparent plate, and to direct clear, perpendicular image

towards the cameras 716, 718, the system 700 comprises a first mirror 720 positioned above the transparent plate, to reflect the first side of the coin 724 towards the image capture device – namely, camera 716. The system 700 also comprises a second mirror 722 positioned above the transparent plate, to reflect the second side of the coin 724 towards the image capture device – namely, camera 718. In some embodiments, there may be a single camera positioned to receive the reflected images from both the first and second mirrors. However, to enable faster processing of the images the present embodiment employs two separate cameras for capturing respective surface images. At least one, and presently both, of the mirrors is angled (with respect to the surface of the transparent plate 708 – by angle α or β , which may be equal angles or different) so that a view from the camera of the surface of the coin 724 appears substantially perpendicular to the coin surface – e.g. appears as shown in FIG. 2 or 4.

[099] In some cases it can be desirable to inspect an image of the edge of the coin – e.g. edge 726 of coin 706. To facilitate this, the system 700 further comprises an edge capture mirror 728. The edge capture mirror is positioned to reflect an image of the peripheral edge of the coin 724 towards the at least one image capture device – presently, a third camera being edge capture camera 730. The present edge capture mirror 728 is concave with respect to the surface facing the coin 724, and is below the transparent plate 708. Being below the transparent plate 708 ensures a highly consistent distance between the second surface of the coin and the edge capture mirror 728, regardless of the thickness of the coin 724

[100] The edge capture mirror 728 may, instead of being concave, be shaped in another manner to facilitate clear visibility of the edge of the coin 724 during image capture by camera 730. Moreover, the camera 730 may be located to ensure clarity of the captured image – presently, camera 730 is angled with respect to the edge capture mirror 728, and is aligned along arrow Y, though could alternatively be aligned along arrow Z or in another direction. Similarly, the edge capture mirror 728 may be angled towards or away from the camera – e.g. rotated in the same direction as angle α or β .

[101] The coins may pass across the transparent plate 708 at a rate of hundreds per minute, or faster. It is therefore critical that the image capture device knows when to capture images. In many cases, it will be crucial that the surface of the coin is fully shown in the captured image rather than being cut off at an edge of the image. Therefore, timing of image capture can be critical.

[102] To assist with timing, the system 700 comprises one or more coin detectors to trigger image capture. There may only be a single coin detector though, presently, there are two. One coin detector 732 detects entry of a coin onto the transparent plate 708 – i.e. when a coin is passing across the transparent plate 708. A second coin detector 734 detects exit of the coin from the transparent plate 708 – i.e. when the coin has passed across the transparent plate 708. Since, the coin delivery device 710 delivers coins at a known speed across the transparent plate 708, the timing of the coin being detected by detector 732 can be used to trigger image capture at precise timing.

[103] The coin detectors are presently embodied by laser edge detectors 732, 734. The laser edge detectors 732, 734 detect a leading edge of the coin, though may equally be configured to detect a trailing edge. The coin detector(s) deliver a message to a processor (e.g. processor 510) that a coin has been detected, and the processor then triggers image capture at a time that ensures the surface of the coin is substantially centred in the capture image – "substantially centred" refers to the image of the surface of the coin being entirely within, and thus not overlapping, an edge of the image.

[104] The coin delivery device 710 includes a coin hopper 736 and an upstream conveyor 738. The upstream conveyor 738 is arranged to receive a coin, or series of coins, from the hopper 736 and to deliver the coin across the transparent plate 708 from an upstream side (A) of the transparent plate 708. The upstream conveyor 738, may be positioned below the coin. However, in the present embodiment the conveyor 738 is positioned above an upstream run 740. Coins being driven by the upstream conveyor 738 towards the transparent plate 708 are therefore sandwiched between the conveyor 738 and run 740. Positioning the coin on a fixed surface of the run 740 – where the conveyor 738 would have a degree of flex – reduces undesirable movement of the coin that may reduce clarity of the captured images.

[105] Similarly, on the downstream side (B) – upstream (A) and downstream (B) referring to being on the delivery and exit sides of the transparent plate 708 respectively – a downstream conveyor 742 is arranged to receive the coin on a downstream side of the transparent plate 708, and to convey the coin away from the transparent plate 708. As with upstream conveyor 738, downstream conveyor 742 may be located below the coin. however, to ensure smooth control of the coin the downstream conveyor 742 is located above a run 744 to sandwich coins therebetween.

[106] The conveyors 738, 742 propel the coins longitudinally towards, across and away from the transparent plate 708 in the direction of arrow X. The conveyors 738, 742 are each

driven either by the same motor or by separate motors, where the speed of the motor or motors may be controllable depending on the type of coins being processed or the speed at which processing is desired to occur. To ensure the coins (which will generally lie flat in the runs or on the belts in some embodiments) remain on the runs 740, 744, each run comprises opposing bumpers 746 – shown in FIG. 7 in broken lines and in FIG. 8 in solid lines. The bumpers may continue along the length of the system 700, across the transparent plate 708. However, in the present embodiment, the bumper has been separated into two bumpers 746 that extend away from the transparent plate 708 on either side thereof. This ensures a clear line of sight between the mirrors, image capture devices and coin. The bumpers may also be opaque, translucent or transparent and will generally be transparent (e.g. glass) so as to minimise interference with image capture.

[107] As shown in FIG. 9, the ends 748 of the bumpers 746 may be fluted at the transparent plate 708. Fluting may only be provided on the bumpers 746 on the downstream side (B) of the transparent plate 708. This ensure the bumpers 746 do not inadvertently bump the coin out of the system 700 if the trajectory of the coin across the transparent plate 708 is not directly in line with arrow X.

[108] The system 700 can be adjusted to enable processing of coins of various widths and thicknesses. To ensure the coins travel straight along the runs 740, 744, at least one, and presently both, bumpers 746 are adjustable. Adjustment mechanism 750 enables one or both of the height of the bumper 746 to which it is attached to be adjusted – e.g. to match the thickness of the coin – or the distance between bumpers 746 to be adjusted depending on the coin width. It will be appreciated that adjusting the lateral location (i.e. across the image shown in FIG. 8) will bring one of the bumpers 746 towards or away from the opposite bumper 746. Thus, there may be no need to adjust both bumpers 746 for changes in coin width.

[109] In addition, to enable the conveyors 738, 742 to grab and propel coins of varying thickness, the rollers 756 of the conveyors 738, 742 are spring-loaded. To rollers 756 are mounted by spring-loaded supports 758 to a support frame 760. The support frame 760 can be raised or lowered to adjust for variations in coin thickness. Alternatively, the spring-loaded supports 758 may be placed under pre-compression or released from compression to adjust for variations on coin thickness. Therefore, an optimal downward force applied by the conveyor 738, 742 to the coins on the runs 740, 744 can be maintained for various coin thicknesses.

- [110] The system 700 is for categorising coins. To enable one type of coin – e.g. an unacceptable coin – to be separated from other types of coins – e.g. acceptable coins – the system 700 comprises a coin rejection device. The coin rejection device is presently embodied by a kicker 752. The kicker 752 is in the run 744 under the downstream conveyor 742. The kicker 752 is activated if the coin 704 is classified as unacceptable or otherwise is need of separation from other coins, to kick the coin 704 from the run 746.
- [111] The coin rejection device or kicker 752 is embodiment by a solenoid activated ram. The kicker 752 protrudes through an aperture 754 in the run 744. The aperture 754 is laterally offset from a centre of the run 744. As such, when a coin passes over the kicker 752 and is to be rejected, the kicker 752 dislodges a side of the coin from the run 744 which results in the coin being flung, either under its own inertia or through continued propulsion from the conveyor 742, from the run 744. The coin may land in a collection bin or similar.
- [112] To time rejection of the coin, a further edge detection device may be provided. However, the present embodiment makes use of the spring-loaded mounts 758. The spring-loaded mount 762 immediately upstream of the kicker 752, or the spring-loaded mount 764 directly above the kicker (if the kicker is directly below a roller 756, which it may not be) may detect compression of the spring-loaded mount and thereby detection the coin located between the respective roller and run 744. As shown in FIG. 7, coins passing under the rollers slightly raise the rollers since the rollers ensure some downward force is always applied to the coin. Thus, coins passing beneath the rollers cause a small amount of compression of the springs of the spring-loaded mounts, which compression can be detected to detect the presence of a coin. The system 700 (e.g. using processor 510) can then determine when the coin 704 is directly above the kicker 752 and activate the kicker 752.
- [113] Activation of the kicker 752 causes the belt of the conveyor 742 to raise, as shown above kicker 752 in FIG. 7. The belt is narrow – i.e. not the full width of the run 744. Thus, kicking up one side of the coin 704 causes the belt to throw the coin clear of the run 744, resulting in it being discarded. Other forms of coin rejection device may be used as appropriate for a particular application – e.g. a solenoid kicker may laterally displace a coin into a chute, and there may be multiple such kickers located along run 744 so that coins can be simultaneously sorted for multiple different coin classifications – e.g. different series, dirtiness, and so forth. Notably, in some cases it may be desirable to pre-process coins to ensure they are all of the same series, or of similar materials but minted with different images or are unclear or damaged etc.

- [114] In addition, the system 700 may include a light source configured to emit light at a predetermined wavelength, wavelengths or spectrum, such that reflectance from the coin can be captured by the one or more image capture devices and used to determine coin material composition, dirtiness and other conditions as described above. The light source can be located over, under or near the transparent plate 708 or in a downstream (or upstream) station of the system 700. The processor 510 can apply an algorithm to the captured reflected light to determine if the colour is, for example, greater than a predetermined threshold of intensity and/or covers more than a predetermined area of the coin in which case the coin is accepted or, if under one or both thresholds, the coin is classified as unacceptable.
- [115] Coin classification and image analysis can be performed as described above.
- [116] Many modifications will be apparent to those skilled in the art without departing from the scope of the present invention.
- [117] Throughout this specification, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

CLAIMS

1. A system for categorising a coin, comprising:
 - at least one image capture devices positioned to capture at least one image of a surface of the coin;
 - a transparent plate;
 - a coin delivery device for delivering the coin across the transparent plate, a first side of the coin, being one of an obverse and a reverse of the coin, faces away from the transparent plate and a second side of the coin, being another of the obverse and the reverse of the coin, is visible through the transparent plate;
 - an edge capture mirror positioned to reflect an image of a peripheral edge of the coin towards the at least one image capture device;
 - wherein the at least one image capture device is positioned to capture at least one image of both the first and second sides of the coin while the coin is on the transparent plate;
 - memory comprising master coin data of at least one master coin; and
 - at least one processor, wherein the at least one processor is configured to:
 - identify the surface in the at least one image, the surface being one of an obverse and a reverse of the coin;
 - measure one or more data describing a portion of the surface within a peripheral edge of the coin;
 - compare the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data; and
 - categorise the coin as acceptable if the amount of deviation is below a predetermined threshold, and otherwise categorise the coin as unacceptable.
2. The system of claim 1, wherein the one or more image capture devices are positioned to capture at least one image of the reverse of the coin.
3. The system of claim 1 or 2, wherein:
 - measuring one or more data describing a portion of the surface comprises selecting a central portion of the surface comprising a relief; and
 - comparing the one or more data with the master coin data comprises determining if the central portion matches master coin data describing a central portion of a surface of the master coin, the central portion of the master coin comprising a relief.

4. The system of claim 3, wherein comparing the one or more data with the master coin data further comprises orienting the central portion of the surface to match an orientation of the central portion of the master coin.

5. The system of claim 3 or 4, wherein comparing the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data comprises determining whether a relief of the coin matches a relief of the master coin.

6. The system of any preceding claim, wherein measuring one or more data describing a portion of the surface comprises determining a reflectance of the portion of the surface of the coin.

7. The system of claim 6, wherein comparing the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data comprises calculating a difference in reflectance between the reflectance of the surface of the coin and a reflectance of a surface of the master coin.

8. The system of any preceding claim, further comprising a light source for illuminating the coin during capturing of the at least one image.

9. The system of claim 8, wherein the light source is configured to illuminate the coin using light of a predetermined wavelength.

10. The system of claim 8, wherein the light source is configured to illuminate the coin using light having a wavelength within a predetermined spectrum.

11. The system of any preceding claim, wherein the one or more image capture devices are positioned to capture at least one image of each of the obverse and reverse of the coin.

12. The system of claim 11, wherein identifying the surface in the at least one image comprises identifying both the obverse and reverse in respective images of the at least one image.

13. The system of claim 11 or 12, wherein:

measuring one or more data describing a portion of the surface comprises:

selecting a portion of the surface comprising a relief; and

determining a reflectance of the portion of the surface of the coin; and

comparing the one or more data with the master coin data comprises:

determining if the central portion matches master coin data describing a central portion, comprising a relief, of a surface of the master coin; and
calculating a difference in reflectance between the reflectance of the surface of the coin and a reflectance of a surface of the master coin.

14. The system of claim 13, wherein the coin is classified as acceptable only if the central portion matches master coin data describing the central portion of the master coin, and the difference in reflectance is below the predetermined threshold.

15. The system of any preceding claim, further comprising a separator configured to locate the coin in a first location if the coin is acceptable, and to locate the coin in a second location if the coin is unacceptable.

16. The system of claim 15, wherein the at least one image capture device comprises a first image capture device arranged to capture at least one image of the first side of the coin, and a second image capture device arranged to capture at least one image of the second side of the coin.

17. The system of claim 15 or 16, further comprising a first surface mirror positioned above the transparent plate, to reflect the first side of the coin towards the at least one image capture device.

18. The system of any one of claims 15 to 17, further comprising a second surface mirror positioned below the transparent plate, to reflect the second side of the coin towards the at least one image capture device.

19. The system of claim 17 or 18, wherein the first or second mirror is angled to enable the at least one image capture device to be positioned laterally with respect to the transparent plate.

20. The system of claim 1, wherein a surface of the edge capture mirror facing the coin is concave.

21. The system of claim 20, wherein the edge capture mirror reflects an entirety of the peripheral edge.

22. The system of claim any one of claims 18 to 21, wherein the edge capture mirror is located below the transparent plate.

23. The system of any one of claims 13 to 22, wherein the coin delivery device comprises a coin hopper and an upstream conveyor, the upstream conveyor being arranged to receive the coin from the hopper and deliver the coin across the transparent plate from an upstream side of the transparent plate.

24. The system of claim 23, further comprising a downstream conveyor arranged to receive the coin on a downstream side of the transparent plate, to convey the coin away from the transparent plate.

25. The system of claim 23 or 24, wherein the or each conveyor is located above a run, such that the coin is sandwiched between the conveyor and run.

26. The system of claim 25, wherein the or each conveyor comprises one or more spring-loaded rollers, wherein the spring of the respective roller becomes compressed as a coin passes between the roller and the run.

27. The system of claim 25 or 26, wherein the run comprises opposing bumpers, at least one of the bumpers being adjustable laterally to change a width of the run.

28. The system of claim 27, wherein a height of the bumpers is adjustable.

29. The system of claim 23, wherein the run under the downstream conveyor comprises a kicker, the kicker being activated, if the coin is classified as unacceptable, to kick the coin from said run.

30. The system of any one of claims 13 to 29, further comprising at least one edge detector for determining at least one of:

- (i) when the coin is passing across the transparent plate; and
- (ii) when the coin has passed across the transparent plate.

31. A method for categorising a coin, comprising:

delivering the coin across a transparent plate;

capturing at least one image of a surface of the coin, wherein capturing at least one image of a surface of the coin comprises capturing an image of both an obverse and reverse surface of the coin, the image of one of the obverse and reverse surface of the coin being captured through the transparent plate by using an edge capture mirror positioned to reflect an image of a peripheral edge of the coin towards the at least one image capture device;

identifying the surface of the coin in the at least one image, the surface being one of the obverse and the reverse of the coin;

measuring one or more data describing a portion of the surface within a peripheral edge of the coin;

comparing the one or more data with master coin data of at least one master coin to determine an amount of deviation of the one or more data from the master coin data; and

categorising the coin as acceptable if the amount of deviation is below a predetermined threshold, and otherwise categorising the coin as unacceptable.

32. The method of claim 31, wherein:

measuring one or more data describing a portion of the surface comprises selecting a central portion of the surface comprising a relief; and

comparing the one or more data with the master coin data comprises determining if the central portion matches master coin data describing a central portion of a surface of the master coin, the central portion of the master coin comprising a relief.

33. The method of claim 31 or 32, wherein comparing the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data comprises determining whether a relief of the coin matches a relief of the master coin.

34. The method of any one of claim 31 to 33, wherein measuring one or more data describing a portion of the surface comprises determining a reflectance of the portion of the surface of the coin.

35. The method of claim 34, wherein comparing the one or more data with the master coin data to determine an amount of deviation of the one or more data from the master coin data comprises calculating a difference in reflectance between the reflectance of the surface of the coin and a reflectance of a surface of the master coin.

36. The method of claim 31, wherein a surface of the edge capture mirror facing the coin is concave.