(12) UK Patent Application (19) GB (11) 2 189 594 (13) A

(43) Application published 28 Oct 1987

(21) Application No **8608840**

(22) Date of filing **11 Apr 1986**

(71) Applicant
Integrated Photomatrix Limited

(Incorporated in United Kingdom)

The Grove Trading Estate, Dorchester DT1 1SY

(72) Inventor
Philip Geoffrey Claridge
Michael Anthony Vann

(74) Agent and/or Address for Service
Forrester, Ketley & Co.,
Forrester House, 52 Bounds Green Road, London N11 2EY

(51) INT CL⁴
G01B 11/00

(52) Domestic classification (Edition I):
G1A A2 D10 D1 EB G10 G12 G17 G1 G2 G7 P14 P17 R7 S10 T15 T25 T3 T8
U1S 2145 2146 2158 2170 G1A

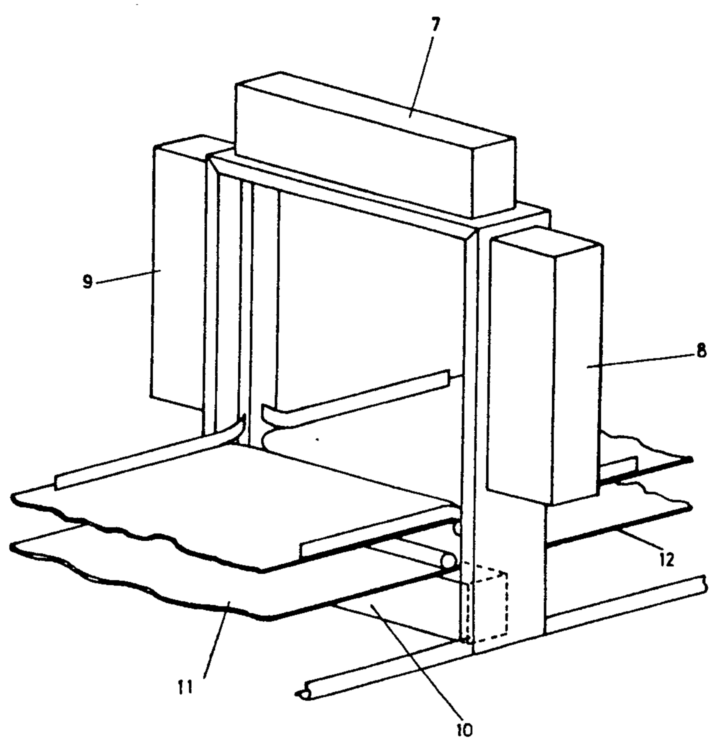
(56) Documents cited
GB A 2147996 **GB 1196274** **GB 1131411**
GB A 2078937

(58) Field of search
G1A
Selected US specifications from IPC sub-class G01B

(54) Optoelectronic measurement of package volume

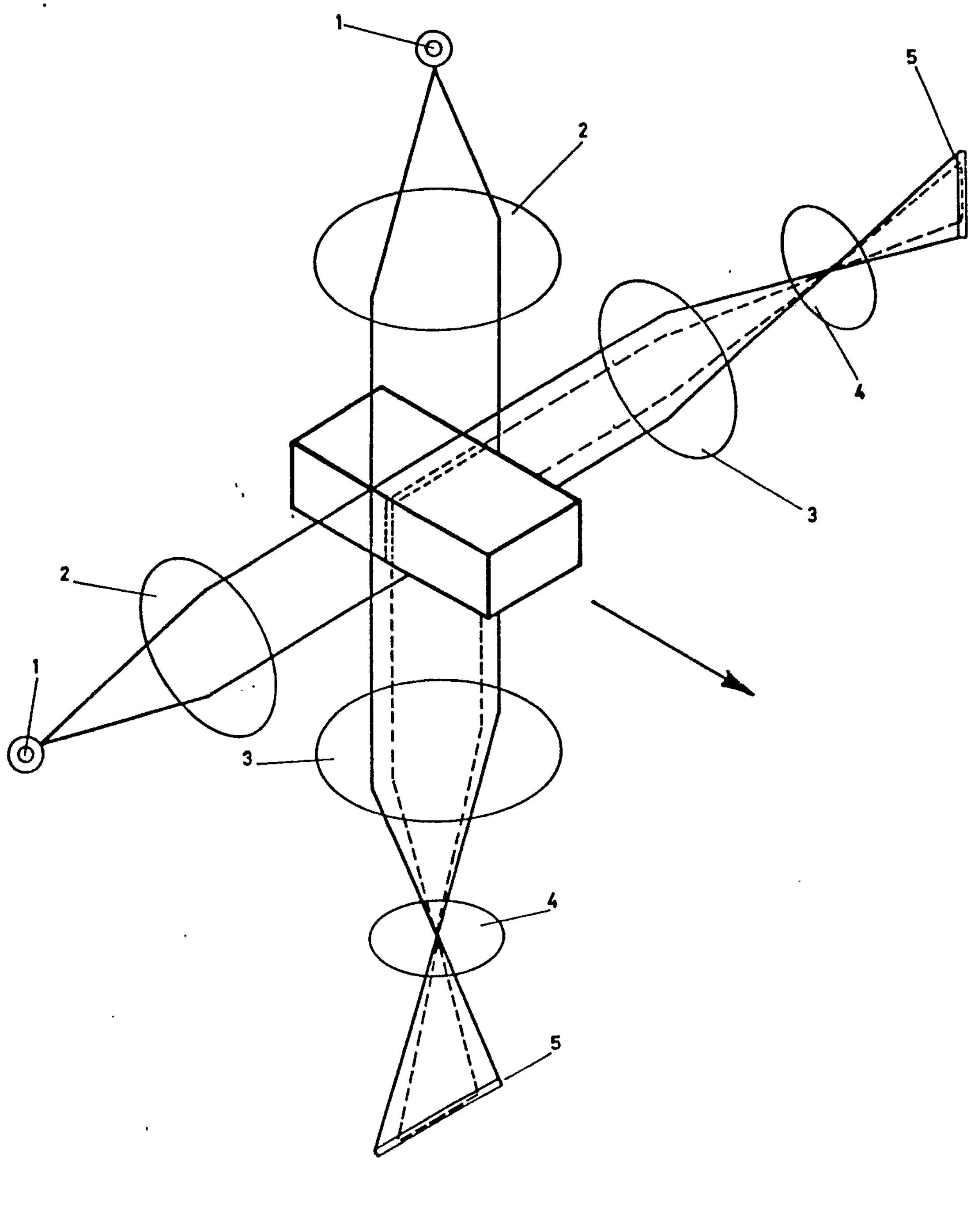
(57) To measure the volume of an arbitrarily shaped three-dimensional object, the object is passed through a scanning plane on conveying means 11, 12 and the respective dimensions of the object in two perpendicular measurement directions in the scanning plane are measured at intervals during the passage of the object through the scanning plane by two electro-optical systems 8, 9 and 7, 10. Means are provided for calculating the cubical volume of the object by determining the area of a rectangle of minimum area that fits around the profile in one measurement plane and multiplying the area of the minimum rectangle by the maximum dimension of the object perpendicular to the one measurement plane obtained from the profile in the other measurement plane.

FIGURE 3



GB 2 189 594 A

FIGURE 1



1 ... 040

FIGURE 2 D F A

2189594

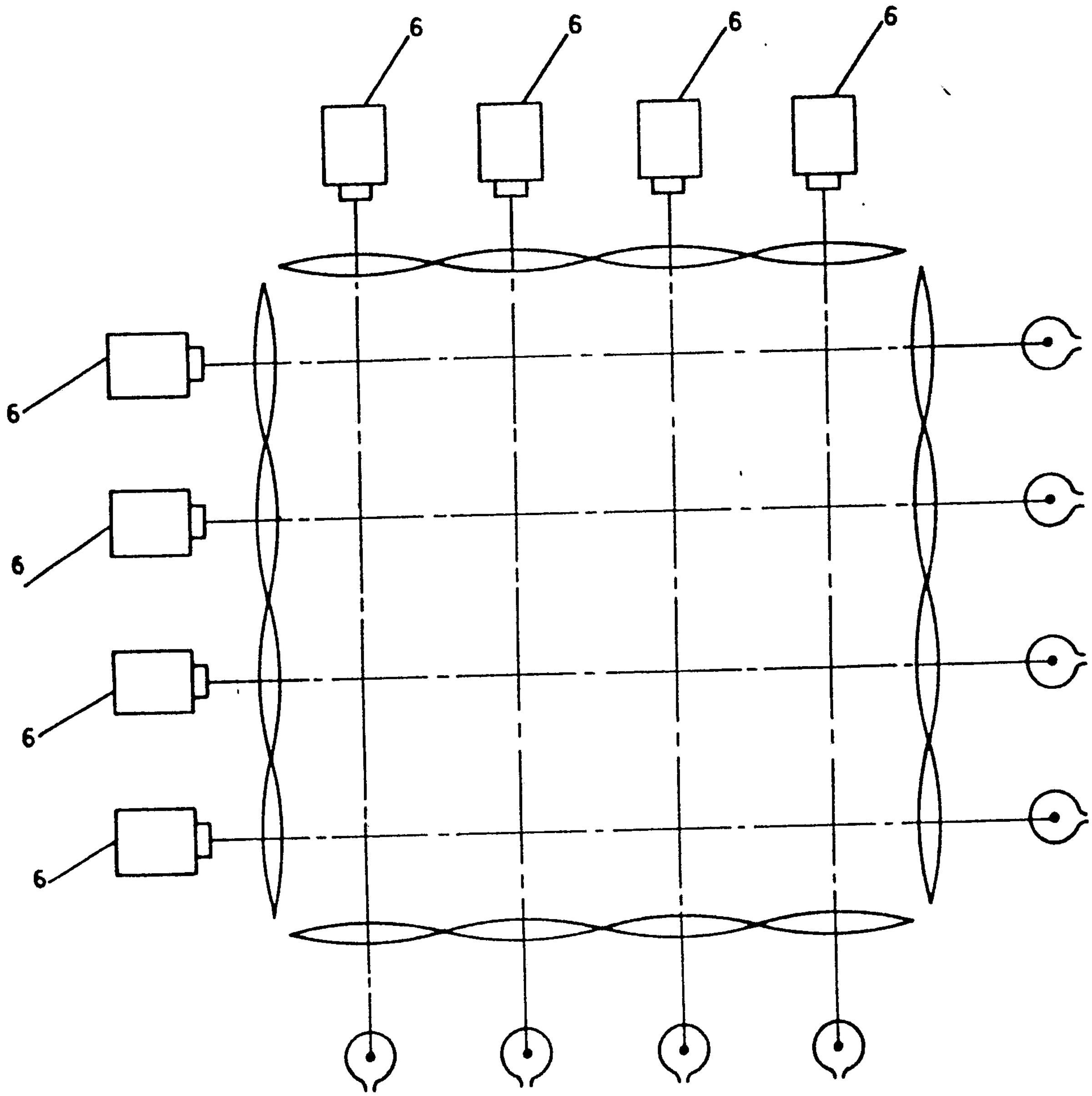
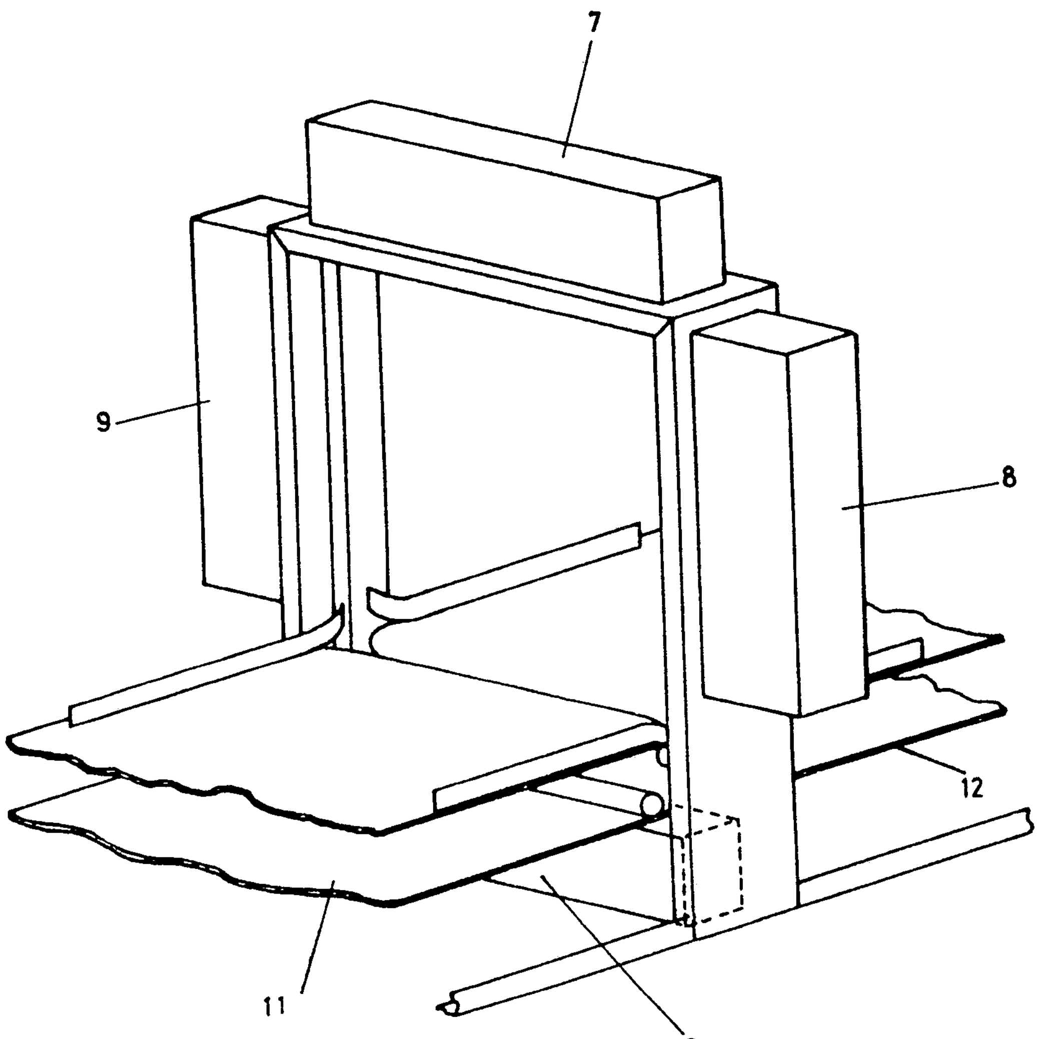


FIGURE 3

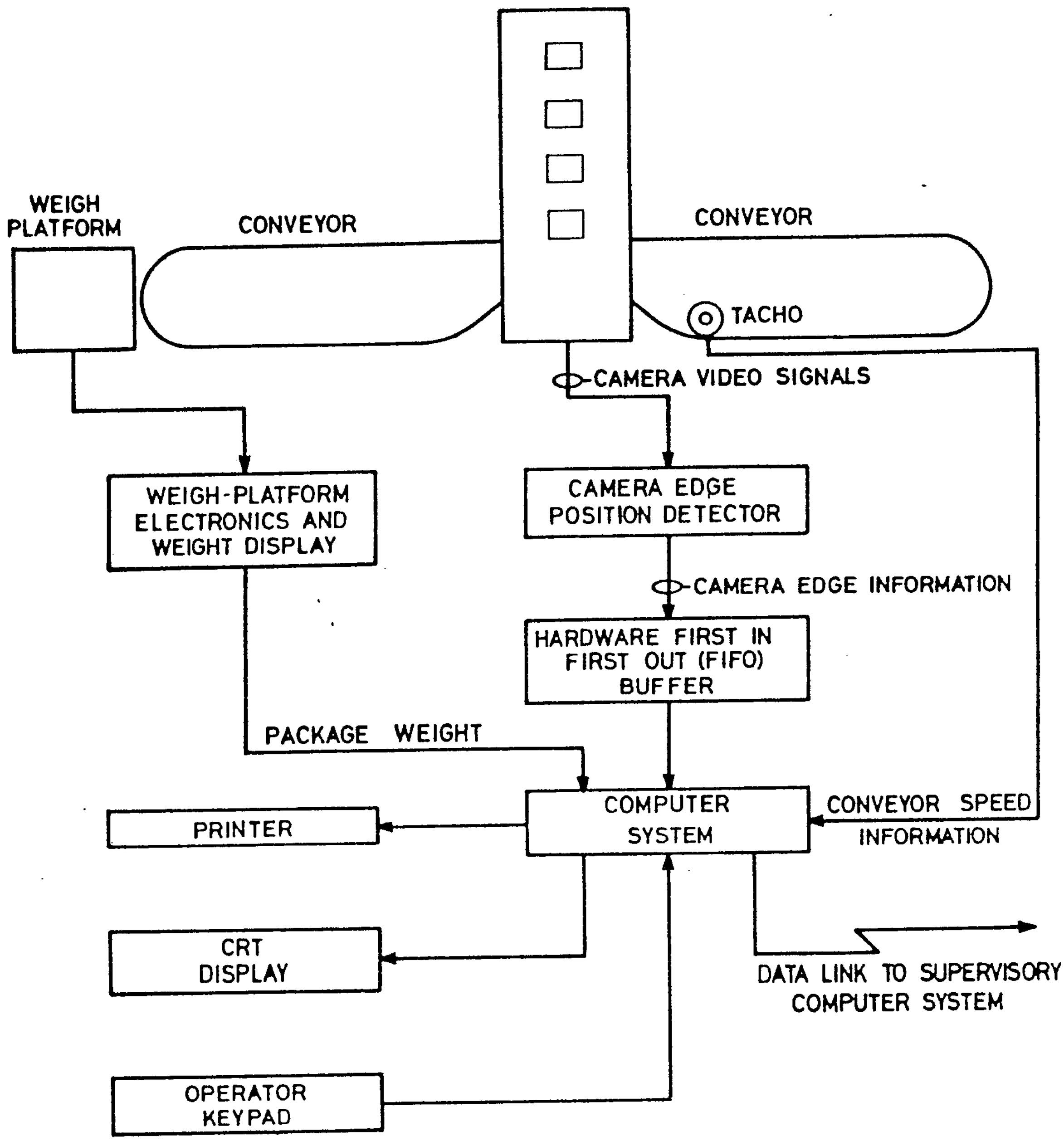
2189594



D F A

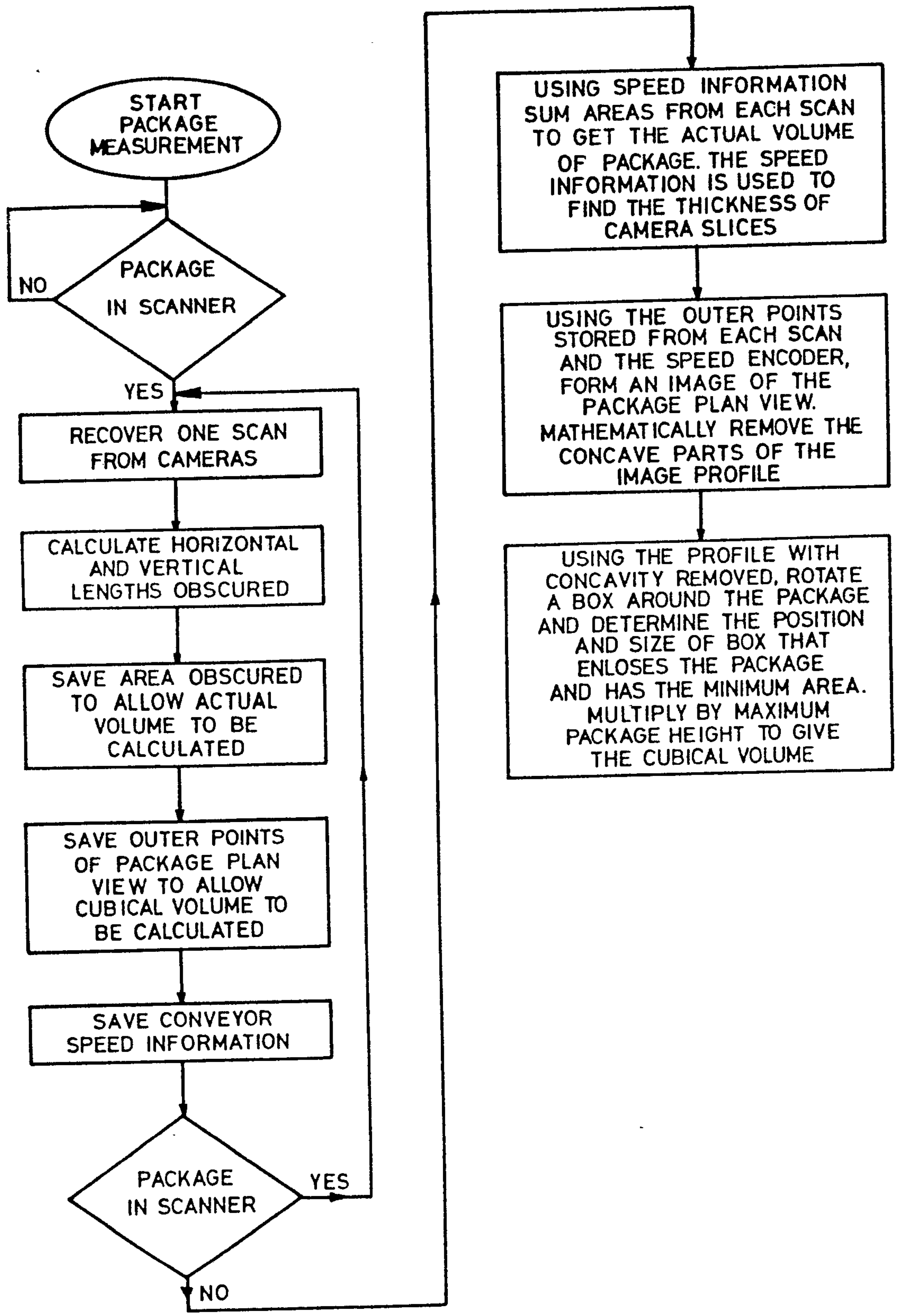
2189594

FIGURE 4



DFA

FIGURE 5


START PACKAGE MEASUREMENT
PACKAGE IN SCANNER
NO
YES
RECOVER ONE SCAN FROM CAMERAS
CALCULATE HORIZONTAL AND VERTICAL LENGTHS OBSCURED
SAVE AREA OBSCURED TO ALLOW ACTUAL VOLUME TO BE CALCULATED
SAVE OUTER POINTS OF PACKAGE PLAN VIEW TO ALLOW CUBICAL VOLUME TO BE CALCULATED
SAVE CONVEYOR SPEED INFORMATION
PACKAGE IN SCANNER
YES
NO
USING SPEED INFORMATION SUM AREAS FROM EACH SCAN TO GET THE ACTUAL VOLUME OF PACKAGE. THE SPEED INFORMATION IS USED TO FIND THE THICKNESS OF CAMERA SLICES
USING THE OUTER POINTS STORED FROM EACH SCAN AND THE SPEED ENCODER, FORM AN IMAGE OF THE PACKAGE PLAN VIEW. MATHEMATICALLY REMOVE THE CONCAVE PARTS OF THE IMAGE PROFILE
USING THE PROFILE WITH CONCAVITY REMOVED, ROTATE A BOX AROUND THE PACKAGE AND DETERMINE THE POSITION AND SIZE OF BOX THAT ENLOSES THE PACKAGE AND HAS THE MINIMUM AREA. MULTIPLY BY MAXIMUM PACKAGE HEIGHT TO GIVE THE CUBICAL VOLUME

SPECIFICATION

Optoelectronic measurement of package volume

This invention relates to a method and apparatus for the measurement of volume by an optoelectronic scanning technique.

In the field of freight and cargo handling it is customary for items to be charged on a dual basis, depending on their density. For packages above an arbitrarily established standard density, charges will be based on weight alone, at a specific rate per Kg. Packages below this density will be charged on their volume, assuming they are of the standard density. Packages below the standard density are regarded as having a 'volumetric equivalent weight' defined as the product of actual volume and the standard defined density. For example, if the standard density was 100 kg/m^3 and the package volume was 3m^3 it would be regarded as weighing 300 kg and charged accordingly although the true weight might be only 50 kg. Thus a very bulky package which weighs little will be charged at a realistic rate, commensurate with the amount of space it occupies in the transporting vehicle. For the purposes of charging, a notional volume is used known as 'cubical volume', defined as the product of the greatest length, greatest width and greatest height. This is the equivalent of fitting the smallest rectangular box around the package.

A further aspect of the volume measurement requirement relates to the problems of efficiently packing the freight in the transporting vehicle. It is common practice for miscellaneous packages to be assembled together in a large container scheduled for a specific destination. Such containers are constrained by an all-up weight limit, but if the carrier does not know the volume of the goods he is scheduling for transport it is easy to underfill with consequent loss of revenue, or attempt to overfill, in which case some freight must be re-routed or delayed in transit. For the purposes of freight packing, the carrier needs to know both the cubical volume and the actual volume of the packages he is dealing with. In the case of rectangular packages these values are the same. For non-rectangular packages the ratio of volumes provides a measure of the difficulty of packing.

To be able to operate a cargo handling system efficiently requires that the carrier has available to him a fast and accurate method of estimating volume, applicable over a wide range of package shapes and sizes.

In principle it is possible to estimate the volume of any piece of freight by calculation from manually measured linear dimensions. This procedure is orders of magnitude too slow to be of any use in a real cargo handling situation, with the result that such volume estimates are not normally undertaken.

It is the purpose of the present invention to provide an automated means of volume measurement, using opto-electronic scanning techniques, which is capable of operating at a high throughput rate, and of yielding both actual and cubical volume.

The principle upon which the invention is based is as follows: The volume of a solid object may be measured to a good approximation by cutting it up into a large number of thin parallel slices, multiplying the area of each slice by its thickness and summing over all the slices. If the object happens to be a rectangular solid this process is particularly easy since the area of each slice is simply the product of width and height. The above procedure lends itself to automation if the width and height of each slice is measured and recorded optoelectronically.

The present invention provides the means for forming optical images of the two cross-sectional dimensions referred to in the previous paragraph, together with photoelectric means for measuring these dimensions. It also provides means for moving the object being measured past the optical imaging system so that all cross-sectional dimensions of the object may be measured. Finally it provides electronic computing means for performing the calculations necessary to obtain the volume from the totality of measured dimensions.

The above mentioned slicing technique provides the actual volume of the package, which is a close approximation if the package is rectangular, and of lesser accuracy if the package is significantly non-rectangular. The profile information acquired can also be manipulated in the computer to extract the maximum overall dimensions, from which cubical volume may be calculated.

By way of example only, the operation of the invention will be described with reference to the accompanying Fig. 1. Fig. 1 shows a rectangular package situated in the fields of view of two identical optical systems which are disposed perpendicular to one another. The layout of these optical systems follows the well-known principles of gauge projection using parallel light which have been used in toolroom projectors for many years. Each optical system comprises a source of light 1, situated at the focus of a collimating lens 2. The subsequently parallel beam of light passes across the package and falls upon a decollimating lens 3. The light beam is then refocused in the region of a lens 4, and passes through to fall upon a photoelectric receiver 5. The combination of lenses 3 and 4 serves to form an image of the package cross-section in the plane of the photoelectric receiver, at a known magnification. The photoelectric receiver 5 is preferably a solid-state linear array of photodetectors in the form of a self-scanned photodiode array or a CCD array, but it may also be an electron tube such as a vidicon. The function of the receiver is to convert the image of the package cross-section into an analogue electrical signal from which may be obtained a linear dimension. In the preferred embodiment this dimension is obtained by electronically counting un-illuminated sensor elements according to known methods and applying a scaling factor derived from the known optical magnification.

The configuration of each lens system is that which is known as telecentric, wherein only narrow angle cones of rays parallel to the optical axis are permitted to pass from the object through the receiving optical assembly to form the final image. As is well known, this configuration confers a constancy of scale upon the final image such that the dimension measured by the photosensor array will be the same, irrespective of where the object lies between the collimating and decollimating lenses.

The two optical systems as shown in Fig. 1 are coplanar and serve to measure the two cross-sectional dimensions of the package at a specific point along its length. Means are provided (not shown) for translating the package past the measuring plane, in the direction of the arrow, so that all cross-sectional dimensions of the package may be obtained in sequence. The photosensor arrays are arranged to scan continuously at high speed, but only output their data on command after fixed increments of translational movement of the package. These fixed increments correspond to the slice thicknesses referred to previously, and when used in conjunction with the two measured cross-sections, enable the volume of the slice to be computed. The volume of the entire package is obtained as the sum of all the elementary slice volumes after the package has passed completely through the field of view of the optical system. It is not necessary for the package to pass squarely through the measuring plane since the slicing technique will operate accurately on a rectangular package skewed about either a vertical or a horizontal axis (but not both together).

The computation of volume is performed in an electronic processing unit which serves to drive the photosensor arrays, process and store the information from the arrays, monitor the movement of the package through the system and calculate and display the package volume from the incoming data.

The electrical signal obtained from each camera, hereafter referred to as the video signal, is passed to the processing unit where it is compared with a predetermined threshold level. By this means the analogue video is converted to binary video wherein unilluminated sensor elements below the threshold level are classed as 'dark' and illuminated sensor elements above the threshold level are classed as 'light'. This process defines one or more edge transitions which are points along the array of photosensors at which the video signal changes from light to dark, said transitions being regarded as defining the geometric boundaries of any opaque object in the field of view of the optical system. The position of any edge transition is determined by counting clock pulses from the start of array scan to the point where the transition occurs. Thus it is possible to obtain a numerical value for the proportion of the photosensor array which is obscured during any scan, expressed as a discrete number of photosensors. By applying the known optical magnification factor to this number, a real dimension is obtained, applicable in the object field.

Since the analogue image of an edge produced by the system is not completely sharp, and this sharpness decreases in the out of focus condition, it is evident that the apparent position of an edge or separation between two edges will be a function of video signal level. To counteract this situation the threshold setting is provided with an automatic level control (ALC) such that it can be adjusted to a predetermined percentage of the maximum illumination falling on the array and will track with this maximum if it varies from scan to scan.

As the package is mechanically transported through the fields of view of the optical systems shown in Fig. 1 the positions of the edge transitions are recorded as described above, at regular increments of travel. At each increment the package cross-sectional dimensions are obtained from the edge transition values and the volume of the elementary slice derived as the product of the vertical and horizontal dimensions, and the slice thickness. The slice thickness is obtained from a position pick-off on the mechanical transport. The slice volume is added to the sum of slice volumes previously computed so that by the time the package has passed out of the field of view the total package 'actual' volume has been calculated.

At this point in time, two complete package profiles are stored in the memory of the electronic processing unit. The cubical volume is calculated as follows. The package height is obtained from the side viewing camera, and is simply the highest point recorded during the package traverse through the system, relative to the datum plane defined by the mechanical transport. The length and width are calculated from the profile, or plan view, obtained by the overhead camera. This profile is manipulated by the system computer, using an algorithm which fits a rectangle to touch the profile on all four sides and then calculates the area of the rectangle. To allow for any random orientation of the package on the transport system, the process of rectangle fitting is iterative, a small rotation of the profile taking place between each iteration, until a full 90° has been covered. The minimum rectangular area resulting from this procedure is taken as the best fit and multiplied by the package height to give the cubical volume. To shorten the computation time involved in this iterative process, the number of points defining the profile is reduced to a relatively small number by an algorithm which removes points lying on any concave sections of the profile. The ends of each concave section are then joined up by notional straight lines. In this way a profile defined by several thousand points can be represented by a polygon of typically ten to twenty points.

The procedures described in the above two paragraphs are shown in block diagram form in Fig. 5.

The configuration shown in Fig. 1 is limited in the size of package it can accept by the physical size of lenses that it is possible to manufacture. Lenses 2 and 3 may be made of glass or, preferably, moulded plastic in the form of Fresnel lenses which allow diameters up to 250 mm or greater.

An embodiment of the invention will now be described which can deal with much larger packages. The description refers to the accompanying Figs. 2 and 3.

The limitation of the field of view imposed by a single optical system can be overcome by stacking a plurality of systems side by side, each with its own individual scanned array and light source. Fig. 2 shows schematically such an arrangement using a stack of four identical optical modules for each cross-sectional view capable of accepting packages up to 1.1 metre square. In each system lens 4 and array 5 are combined together in a linescan camera 6. Alternate modules are displaced, or staggered, perpendicular to the plane of Fig. 2 to allow individual camera fields of view to overlap slightly. The correspondingly displaced image data obtained when a package passes through the measuring plane is corrected for in the subsequent image processing.

Fig. 3 illustrates in outline an engineered embodiment of the multiple camera scanning system of Fig. 2. The light sources and collimating lenses are contained in illuminator housings 7 and 8, and the cameras and decollimating lenses in camera housings 9 and 10. These four housings are rigidly fastened together on a framework through which runs a conveyor system 11 and 12, which is split to allow the vertically scanning beams to pass between the illuminator housing 7 and camera housing 10. Packages are transported along the conveyor and scanned vertically and horizontally as they cross this gap. Longitudinal position information is derived from an encoder driven by the conveyor. The two halves of the conveyor system, 11 and 12 are mechanically coupled together so that they both run at the same speed.

Fig. 4 shows, in block diagram form, the components of a total volume measuring equipment incorporating the scanner of Fig. 3 and also an in-line electronic weighing platform feeding package weights to the system computer. This facility allows the machine to distinguish which packages should be charged according to weight and which should be charged according to volume, and also to calculate volumetric equivalent weight.

CLAIMS

1. A method of measuring the volume of an arbitarily shaped three-dimensional object, comprising passing the object through a scanning plane, measuring the respective dimensions of the object in two non-parallel measurement directions in the scanning plane at intervals during the passage of the object through the scanning plane to provide respective profiles of the object in respective measurement planes and calculating the cubical volume of the object by determining the area of a rectangle of minimum area that fits around the profile in one measurement plane and multiplying the area of the minimum rectangle by the maximum dimension of the object prependicular to the one measurement plane obtained from the profile in the other measurement plane.

2. A method according to Claim 1, comprising calculating the actual volume of the object by using pairs of corresponding measured dimensions to determine the volume of a corresponding elementary slice of the object parallel to the scanning plane and summing the volumes of the elementary slices to obtain the total actual volume.

3. A method according to claim 1 or 2, wherein the object is passed through the scanning plane at a uniform speed.

4. A method according to any one of claims 1 to 3, in which the two measurement directions are perpendicular.

5. Apparatus for measuring the volume of an arbitarily shaped three-dimensional object, comprising means for passing the object through a scanning plane, means for measuring the respective dimensions of the object in two non-parallel measurement directions in the scanning plane at intervals during the passage of the object through the scanning plane to provide respective profiles of the object in respective measurement planes, and means for calculating the cubical volume of the object by determining the area of a rectangle of minimum area that fits around the profile in one measurement plane and multiplying the area of the minimum rectangle by the maximum dimension of the object perpendicular to the one measurement plane obtained from the profile in the other measurement plane.

6. Apparatus according to Claim 5, comprising means for calculating the actual volume of the object by using pairs of correspondiing

measured dimensions to determine the volume of a corresponding elementary slice of the object parallel to the scanning plane and summing the volume of the elementary slices to obtain the total actual volume.

7. Apparatus according to claim 5 or 6, wherein the measuring means includes two optical systems each comprising a light source and a lens producing a parallel beam of light which passes across the path of the object to be measured, followed by a collecting lens and an imaging lens which forms an image of the object at a constant scale on an electronically scanned image detector.

8. Apparatus according to Claim 7, wherein the measuring means includes an electronic processing means which accepts the outputs of teh image detectors and, by applying an appropriate threshold level to the detector signals, generates information on the positions of edges within the fields of view, from which the instantaneous dimensions of the object in the measuring directions may be derived.

9. Apparatus according to Claim 8, wherein the calculating means comprises electronic storage means for storing the measured instantaneous dimensions during the passage of the object through the scanning plane until the respective complete profiles have been recorded, and electronic computing means for calculating the volume of the object from the stored profiles.

10. Apparatus according to any one of claims 7 to 9, wherein a plurality of the said optical systems are provided for each measurement direction so that larger objects may be measured than can be encompassed by a single optical system.

11. Apparatus according to any one of claims 7 to 10, wherein the electronically scanned image detectors are self-scanning solid state linear arrays of photosensors.

12. Apparatus according to any one of claims 7 to 10, wherein the electronically scanned image sensors are television camera tubes.

13. Apparatus according to any preceding claim, wherein the passage of the object through the scanning field is achieved by a conveyor system, from which is derived an encoder signal to monitor the movement of the object between scans and hence provide a measure of the slice thickness for volume calculation.

14. Apparatus according to Claim 13, wherein the conveyor system incorporates an electronic weighing platform, so that both weight and volume of objects are available to the computing system, in order that object density and volumetric equivalent weight may be calculated.

15. A method of measuring the volume of an arbitarily shaped three-dimensional object, substantially as hereinbefore described with reference to the accompanying drawings.

16. Apparatus for measuring the volume of an arbitarily shaped three-dimensional object, substantially as hereinbefore described with reference to the accompanying drawings.

17. Any novel feature or combination of features described herein.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon) Ltd, Dd 8991685, 1987. Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.