Abstract:
A payload weight calculation apparatus and method in which a load holder angle measuring apparatus is communicatively coupled to a weighing module (100) configured to calculate a weight value representative of a payload weight in respect of a loading machine comprising an arm (7) and a load holder (8) pivotally mounted at a distal end of said arm (7). The load holder angle measuring apparatus comprises an ultrasonic sensor (18) located at a distance from a pivot point between the load holder (8) and the arm (7) and configured to generate a distance signal representative of a distance between the sensor (18) and the pivot point (8b) and provide the distance signal, or data representative thereof, to the weighing module (100) for use in the calculation of the weight value.
PAYLOAD WEIGHING APPARATUS AND METHOD

This invention relates generally to apparatus configured to weigh a load and, more particularly but not necessarily exclusively, to apparatus configured to weigh a payload of a loading machine such as a wheeled excavator/material handling machine or wheeled loading shovel, for example.

Off-road machines, such as, for example, loaders, are typically used to transport a payload material, such as, for example, rock, sand, dirt, or gravel, from one location to another. According to a particular work cycle, the loader may use a work tool, such as a bucket, to capture a portion of the payload material and transfer the captured portion of material to another location. Alternatively, a work cycle may include use of the loader to fill a larger payload capacity machine, such as a haulage truck, which is used to transport the material. According to these work cycles and others, it may be desirable to calculate the weight, or mass, of the payload material that is moved within or transported from a work site. This payload weight or mass calculation may be used to evaluate efficiency, productivity, and profitability of the work site operations.

A typical excavator comprises a chassis on a carriage comprising tracks and a cab for housing the controls of the excavator. An operator can sit in the cab and control the excavator. The chassis can slew or rotate relative to the carriage. A boom extends from the chassis, the angle of which can be controlled by a hydraulic ram extending between the chassis and the boom. A stick is connected to the boom by a pivotable joint and can be arranged at various angles relative to the boom by a hydraulic ram. A bucket or other load holder is provided for scooping or grabbing, holding, transporting and dumping material or other payload. The load holder is connected to the stick by a pivotable joint, and a hydraulic ram enables the angle between the bucket and the stick to be varied as required. An operator can sit in the cab and operate the controls to alter the geometry of the boom, stick and load holder in order to manipulate the load holder and its payload in the desired manner. The boom and stick are generically termed as "linkages". The boom, stick and holder combination may be termed a lifting linkage.

The excavator also has a number of sensors to determine parameters for calculating a weight estimation. Typically, there is provided a first sensor for
measuring the angle between the boom and the chassis, a second sensor, located at
the pivot point between the boom and the stick, for measuring the relative angle
between the boom and the stick, and a third sensor for measuring the relative angle
between the load holder and the stick. The third sensor, hereinafter referred to as the
bucket angle sensor (although it will be appreciated that aspects of the present
invention may be used in relation to a loading machine having a load holder other than
a bucket), is located at, or as near as possible to, the pivot point between the load
holder and the stick. There is further provided at least one fourth sensor for measuring
the tilt of the chassis, and pressure sensors on the hydraulic actuator. It will be
appreciated that other sensors may also be provided for providing additional angle
and/or pressure measurements. Each of the sensors is connected via a cable to a
weighing module.

A weighing module samples each of the sensor signals received via the
respective cables and a computer program running in the weighing module applies a
known algorithm to calculate (or estimate) weight. Data representative of the
calculated/estimated payload weight value is fed to a user unit within the cab and
displayed to the user on a screen.

However, the cable connecting the bucket angle sensor to the weighing module
is required to extend along the length of the stick, alongside the hydraulic ram, as well
as the length of the boom, in order to be connected to the weighing module, which is
typically located at a convenient location on the chassis. Problems arise due to
movement of the hydraulic ram and stick, which can cause the bucket sensor cable to
become damaged and/or disconnected during use of the excavator.

The present invention seeks to alleviate this issue, and provides, in a first
aspect, a payload weight calculation apparatus comprising a load holder angle
measuring apparatus communicably coupled to a weighing module configured to
calculate a weight value representative of a payload weight in respect of a loading
machine comprising an arm and a load holder pivotally mounted at a distal end of said
arm, the load holder angle measuring apparatus comprising an ultrasonic sensor
located at a distance from a pivot point between said load holder and said arm and
configured to generate a distance signal representative of a distance between said
sensor and said pivot point and provide said distance signal, or data representative
thereof, to said weighing module for use in said calculation of said weight value.

In accordance with a second aspect of the present invention, there is provided a method of calculating a payload weight in a loading machine comprising an arm and a load holder pivotally mounted at a distal end of said arm, the method comprising generating an ultrasonic signal at a sensor point on or adjacent said arm and directing said signal toward a pivot point between said load holder and said arm, receiving ultrasonic energy reflected from said pivot point, and providing data representative of the distance between said sensor point and said pivot point to a weighing module configured to use said data to calculate a weight value representative of a payload weight of said machine.

The load holder angle measuring apparatus is configured to generate, using said distance signal, data representative of a relative angle between said arm and said load holder and provide said data to said weighing module for use in said calculation of said weight value.

In an exemplary embodiment, for a loading machine in which pivoting of said load holder is effected by an actuator provided between said arm and said pivot point, wherein the ultrasonic sensor may be mounted on a non-moving housing of said actuator.

In some exemplary embodiments, the arm comprises a boom and the load holder is pivotally mounted at a distal end of said boom.

In one embodiment, for a loading machine in which the actuator may comprise a hydraulic actuator, comprising a piston mounted for linear movement within a housing, a distal end of the piston being communicably coupled to said pivot point, wherein the ultrasonic sensor is mounted on the housing and configured to direct an ultrasonic signal toward said pivot point. In this case, the sensor may be configured to generate an electronic signal representative of the length of extension of the piston relative to the housing.

In one embodiment, the apparatus may be configured to generate a correction factor to match the output of said ultrasonic sensor to that of at least one other sensor provided in respect of said loading machine.
The apparatus may comprise a plurality of sensors for generating data for use by said weighing module in said calculation of said weight value, at least one of said sensors comprising an ultrasonic sensor for generating said electronic signal representative of a relative angle between said arm and said load holder.

Whilst the invention has been described above, it extends to any inventive combination of features set out above or in the following description. Although illustrative embodiments of the invention are described in detail herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to these precise embodiments. As such, many modifications and variations will be apparent to practitioners skilled in the art. Furthermore, it is contemplated that a particular feature described either individually or as part of an embodiment can be combined with other individually described features, or parts of other embodiments, even if the other features or embodiments make no mention of the particular feature. Thus, the invention extends to such specific combinations not already described.

An embodiment of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of an excavator in which an exemplary embodiment of the present invention can be used to measure the weight of a payload;

Figure 2 is a schematic diagram illustrating principal components of a payload weighing system according to an exemplary embodiment of the present invention; and

Figure 3 is a schematic diagram illustrating only the load holder sensor portion of the system of Figure 2.

An exemplary embodiment of the invention relates to a method for calculating an estimation of the weight of a payload in a load holder of an excavator during a lift sequence. A first embodiment of the present invention also relates to an apparatus for carrying out the method. The apparatus comprises a processor and inputs for receiving signals from sensors. It optionally comprises the sensors themselves. The apparatus could be adapted to be retro-fitted to an excavator for enabling the calculation of a weight estimation of a payload. This enables payload weight
estimation to be carried out in accordance with the invention in relation to an existing excavator that does not have any weight calculation functionality. Alternatively, the apparatus could be incorporated/built into an excavator at manufacture time. In the preferred embodiment, weight estimations can be output to a user as they operate the excavator in the normal manner.

Figure 1 shows an excavator 1 in schematic form. It comprises a chassis 2 on a carriage comprising tracks or other conveying means 3 and a cab 4 for housing the controls of the excavator. An operator can sit in the cab and control the excavator 1. The chassis can slew or rotate relative to the carriage. A boom 5 extends from the chassis 2, the angle of which can be controlled by a hydraulic ram 6 extending between the chassis 2 and the boom 5. A stick 7 is connected to the boom by a pivotable joint and can be arranged at various angles relative to the boom by a hydraulic ram 9. A load holder 8 is provided for scooping or grabbing, holding, transporting and dumping material or other payload. Preferably the load holder is a bucket or grapple. Alternatively, it could be any other type of holding means for holding or retaining a payload, such as an electromagnet. The load holder 8 is connected to the stick 7 by a pivotable joint, and a hydraulic ram 10 enables the angle between the bucket and the stick to be varied as required. An operator can sit in the cab 4 and operate the controls to alter the geometry of the boom 5, stick 7 and load holder 8 in order to manipulate the load holder and its payload in the desired manner. The boom 5 and stick 7 are generically termed as "linkages". The boom 5, stick 7 and holder 8 combination may be termed a lifting linkage.

Referring to Figure 2 of the drawings, the excavator also has a number of sensors to determine parameters for calculating a weight estimation. These sensors can form part of the existing excavator, or can be retro-fitted to the excavator as part of the first embodiment of the invention.

A first sensor 11 is attached over (or as close as possible to) the pivot point between the boom 5 and chassis 2. The first sensor 11 constantly outputs a signal that corresponds to the angle between the boom and chassis. The information represented by this signal could be derived in several different ways, as will be apparent to a person skilled in the art, for example from the extension of the actuator operating between the boom and chassis, or it may be an available output of the
control system of the excavator. However, the present invention is in no way intended to be limited in this regard.

A second sensor 12 is attached over (or as close as possible to) the pivot point between the boom and stick. This sensor constantly outputs a signal that corresponds to the relative angle between the boom and the stick. Again, the information represented by this signal could be derived in several different ways, as will be apparent to a person skilled in the art, for example from the extension of the actuator operating between the boom and stick, or it may be an available output of the control system of the excavator. However, the present invention is in no way intended to be limited in this regard.

A third sensor 18 is attached to the outer body of the hydraulic ram 9. The sensor 18 is an ultrasonic sensor which is arranged and configured to emit an ultrasonic signal 18a in the direction of the pivot point 8b between the load holder 8 and the stick 7. The purpose of the ultrasonic sensor 18 is to measure the extension of the hydraulic ram 10, i.e. the by measuring the distance of the sensor 18 from the pivot point 8b, which is directly proportional to the relative angle between the load holder 8 and the stick 7. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object. It will be appreciated that ultrasonic sensors are known, and any known type of ultrasonic sensor can be used for this purpose in the present invention.

Referring additionally to Figure 2 of the drawings, a first tilt sensor 13 is optionally located directly over the centre of rotation of the chassis. The tilt sensor may be, for example, a pendulum sensor. The tilt sensor constantly outputs a signal which corresponds to the inclination angle or tilt of the machine, for example as a result of working on unstable or uneven ground. Other forms of inclinometer or accelerometer could be used as an alternative. One or more further tilt sensors 13b may be provided on the chassis for measuring, for example, slew rate of the chassis.

Two pressure sensors 14, 15 are mounted on the hydraulic actuator that controls the pivoting of the boom relative to the chassis. The sensors are fitted to "tee off" points on both the lift and return pressure lines for the cylinder. The first
sensor 15 measures the pressure on the lift side of the actuator. The second sensor
14 measures the pressure on the return side of the actuator.

The pressure sensors are a transducer system which constantly outputs a
pair of signals, each directly related to the hydraulic oil pressures on each side of the
actuator. These can be used to determine torque. Where the actuator is not a
hydraulic actuator other approaches to determining the actuation force would be
necessary. For example electrical current measurements may be suitable for an
electrical actuator, or the forces could be measured more directly using a strain
gauge or load cell.

Cables 11b, 12b, 13b, 14b, 15b and 18b connect each of the respective
sensors 11, 12, 13, 14, 15 and 18 to a weighing module 100, samples each of the
sensor signals received via the respective cables 11b, 12b, 13b, 14b, 15b, 18b and a
computer program running in the weighing module applies a known algorithm to
calculate (or estimate) weight. Data representative of the calculated/estimated
payload weight value is fed to a user unit 102 within the cab and displayed to the
user on a screen.

Thus, referring to Figure 3 of the drawings, which shows the load holder sensor
18 in isolation, the cable 18b feeding the sensor, and carrying signals back to the
weighing module, only needs to extend along an upper portion of the stick and does
not need to extend alongside the moving portion of the hydraulic ram 9, thereby
reducing the potential for the cable 18b to become damaged or disconnected during
normal operation of the excavator.

Some algorithms for calculating or estimating the payload weight using
the measurement signals are known, and the present invention is not necessarily
intended to be limited in this regard. However, a novel example will now be
described in further detail, for completeness.

Thus, a requirement for the system described above might be to achieve
accurate compensation at nominal bucket angles. Such angles are, for example, +/-
25° from bucket level. Changing the bucket angle from level with the ground can
create a large error, sometimes up to 10% with a tilt of 20° (from level), thus a table
of corrections is created, based on angle from bucket level.
Up to, say, three methods might be required, depending on the design of attachment used:

- Lifting the Bucket as if it full of water. The bucket has to remain level during the lift. *(Measuring the angle of the bucket with reference to ground)*

- Lifting the Bucket, but with the bucket only being level at the weighing point, but being level at different Dipper Positions. *(Measuring the angle of the bucket with reference to the Boom)*

- Fixed Bucket position. *(Measuring the angle of the bucket with reference to the Dipper Arm or "stick")*

As a secondary function to bucket angle compensation, there is the option to have a "weighing inhibition function" if the angle of the bucket is out of position from a set weighing point, in which case an alarm may be caused to sound during weighing if the bucket is not in the chosen weighing position (+/- 5°).

The following list of bucket factors may be displayed to a user via the control unit in the cab of the machine:

- **BucketSensorMode** - this provides two options in accordance with an exemplary embodiment of the present invention:
  
  1. Inhibit only: bucket position must be maintained at this point within +/- 5°. If not, the bucket alarm will sound. No weight compensation is provided in this mode, it simply inhibits weighing until the bucket is in the correct position.

  2. Compensation: the system compensates for the angle of the bucket. In this case, no inhibit function is required, and no alarm will sound.

- **BucketWeighingPosition** - indicates the point at which the bucket will weigh without causing an inhibit alarm. Used only when the above-mentioned Inhibit mode is selected.

- **BucketPositionCalculation** - enables the type of calculation for measuring the bucket angle to be selected. In this exemplary embodiment, there are three types:
- With Ground:

\[(\text{Bucket raw sig} \times \text{Bucket Sig Gain Factor}) + \text{Dipper Sig} + (\text{Boom}/1.5) + (\text{Chassis}/1.5)\]

- With Boom:

\[(\text{Bucket raw Sig} \times \text{Bucket Sig Gain Factor}) + \text{Dipper Sig}\]

- With Dipper (Stick):

\[(\text{Bucket raw Sig} \times \text{Bucket Sig Gain Factor})\]

Note: (Boom/1.5) and (Chassis/1.5) are calculations used in order to balance the boom and chassis 120° signals with the 180° dipper sensor signal.

BucketZeroPoint - Combined signal that is calculated when the bucket is level. The signals used to calculate this factor are dependent on the above-mentioned Bucket Position Calculation setting.

BucketSignalGainFactor - The multiplier to "balance" the difference between the bucket signal and the dipper (stick) sensor signal, i.e. if the bucket signal is half of the dipper over the same angle change, the factor is "2" to balance the gain outputs (calculated from the Inclinometer sequences which will be described in more detail later).

BucketAngleCompensationFactor - The compensation factor to correct the pressure calculation (after all other corrections) in respect of the bucket angle from level.

The signal from the ultrasonic sensor installed on the hydraulic cylinder is non-linear compared with the angle change of the bucket. For simplicity, the signal should ideally be a linear relationship. Also, the signal does not match that of the dipper arm and boom (varies between machines). Therefore, the system according to this exemplary embodiment provides a routine to solve this, to create a known true bucket sensor angle.

Thus, the algorithm may include the following calibration sequence:

(Set) Dipper to min
Level bucket to ground

Log Dipper sig and Bucket Raw sig

(Set) Dipper to max

Level bucket to ground

Log Dipper sig and Bucket raw Sig

From these logged points, the Bucket Signal Gain Factor can be calculated:

Bucket Signal Gain Factor =

\[-1 \times (\text{Bucket raw Sig@max Dipper} - \text{Bucket raw Sig@min Dipper})\]

Next, the Bucket Zero Point is calculated:

Dipper to mid point

Level bucket to ground

Log Dipper signal + Bucket Signal + Boom + Chassisx

This gives a temporary store of pressure points.

BucketZeroPoint:

If Bucket Position calculation with Ground is set use calculation:

\((\text{Bucket raw Sig} \times \text{Bucket Sig Gain Factor}) + \text{Dipper Sig} + (\text{Boom}/1.5) + (\text{Chassisx}/1.5)\)

If Bucket Position calculation with Boom is set use calculation:

\((\text{Bucket raw Sig} \times \text{Bucket Sig Gain Factor}) + \text{Dipper Sig}\)

If Bucket Position calculation with Dipper is set use calculation:

\((\text{Bucket raw Sig} \times \text{Bucket Sig Gain Factor})\)

Once the ultrasonic sensor output has been corrected to match the output of the dipper sensor, the true angle of the bucket at any dipper position is known. A routine
can then be used to calibrate the effect of load centre effects due to the bucket angle changing:

With a half full bucket

Boom to horizontal, Dipper midway, Bucket Level (bucket must be within 3 degrees of level)

Temporarily save static live pressure when user presses "ok"

Open up bucket to +25°, stop

Temporarily save bucket angle and static live pressure - save to a temporary table

Bucket Compensation factor = Live Pressure Out - Live Pressure Level

(i.e Combined Bucket Sig out - Combined Bucket Sign Level)

Notes: the Combined bucket signal is dependent on the Bucket Position Calculation set (e.g With Ground, with Boom or with Dipper); Live pressure is based on the normal static weighing calculation.

The following calculation may be used to provide correction when weighing in use (after segment corrections):

Corrected pressure - (Bucket Angle Comp Factor)*(Combined Bucket Angle - Bucket Zero Point)

It will be apparent to a person skilled in the art that modifications and variations can be made to the described embodiment of the invention without departing from the scope of the present invention as claimed. For example, whilst the present invention has been described above in relation to a wheeled excavator or similar material handling machine, it is equally applicable for use in measuring receptacle position for a weigh transfer compensation system in a wheeled loading shovel or the like.
CLAIMS

1. A payload weight calculation apparatus comprising a load holder angle measuring apparatus communicably coupled to a weighing module configured to calculate a weight value representative of a payload weight in respect of a loading machine comprising an arm and a load holder pivotally mounted at a distal end of said arm, the load holder angle measuring apparatus comprising an ultrasonic sensor located at a distance from a pivot point between said load holder and said arm and configured to generate a distance signal representative of a distance between said sensor and said pivot point and provide said distance signal, or data representative thereof, to said weighing module for use in said calculation of said weight value.

2. Apparatus according to claim 1, wherein said load holder angle measuring apparatus is configured to generate, using said distance signal, data representative of a relative angle between said arm and said load holder and provide said data to said weighing module for use in said calculation of said weight value.

3. Apparatus according to claim 1 or claim 2, for a loading machine in which pivoting of said load holder is effected by an actuator provided between said arm and said pivot point, wherein the ultrasonic sensor is mounted on a non-moving housing of said actuator.

4. Apparatus according to any of claims 1 to 3, wherein said arm comprises a boom, and said load holder is pivotally mounted at a distal end of said boom.

5. Apparatus according to claim 2, for a loading machine in which the actuator comprises a hydraulic actuator comprising a piston mounted for linear movement within a housing, a distal end of the piston being communicably coupled to said pivot point, wherein the ultrasonic sensor is mounted on the housing and configured to direct an ultrasonic signal toward said pivot point.
6. Apparatus according to claim 5, wherein the sensor is configured to generate an electronic signal representative of the length of extension of the piston relative to the housing.

7. Apparatus according to any of the preceding claims, configured to generate a correction factor to match the output of said ultrasonic sensor to that of at least one other sensor provided in respect of said loading machine.

8. Apparatus according to any of the preceding claims, comprising a plurality of sensors for generating data for use by said weighing module in said calculation of said weight value, at least one of said sensors comprising an ultrasonic sensor for generating said electronic signal representative of a relative angle between said arm and said load holder.

9. A method of calculating a payload weight in a loading machine comprising an arm and a load holder pivotally mounted at a distal end of said arm, the method comprising generating an ultrasonic signal at a sensor point on or adjacent said arm and directing said signal toward a pivot point between said load holder and said arm, receiving ultrasonic energy reflected from said pivot point, and providing data representative of the distance between said sensor point and said pivot point to a weighing module configured to use said data to calculate a weight value representative of a payload weight of said machine.

10. A payload weight calculation apparatus substantially as herein described and/or with reference to the accompanying drawings.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. E02F9/26 G01G19/08

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02F G01G B66C G01F B66F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>Y</td>
<td>US 6 518 519 BI (CRANE III CARL D [US] ET AL) 11 February 2003 (2003-02-11) claim 1; figure 1 column 19, line 4 - line 10</td>
<td>1, 3-6, 9</td>
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<td>Y</td>
<td>JP 2003 184131 A (HITACHI CONSTRUCTION MACHINERY) 3 July 2003 (2003-07-03) paragraphs [0064], [0065], [0057]; figure 1</td>
<td>1, 3-7, 9</td>
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<tr>
<td>Y</td>
<td>FR 2 671 625 AI (TOSI MAURICE) 17 July 1992 (1992-07-17) page 4, line 22 - line 32; figure 2</td>
<td>1, 3-7, 9</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

A: document defining the general state of the art which is not considered to be of particular relevance

B: earlier application or patent but published on or after the international filing date

L: document which may throw doubts on priority claim(s) or which may establish the publication date of another citation or other special reason (as specified)

O: document referring to an oral disclosure, use, exhibition or other means

P: document published prior to the international filing date but later than the priority date claimed

X: later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

Y: document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y: document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

8: document member of the same patent family

Date of the actual completion of the international search: 13 July 2015

Date of mailing of the international search report: 22/07/2015

Name and mailing address of the ISA:

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax. (+31-70) 340-3016

Authorized officer: Bul tot. Coral i e
**INTERNATIONAL SEARCH REPORT**

**Box No. II** Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. **Claim Nos.:**
   - **10**
   - because they relate to subject matter not required to be searched by this Authority, namely:
     - Claim 10 is not expressed in terms of technical features of the invention, but it is defined with references to the description and the drawings. The whole subject-matter for which protection is sought in claim 10 is therefore unclear (Art. 6 PCT and Rule 6.2(a)) and a meaningful search is here not possible.

2. **Claim Nos.:**
   - because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. **Claim Nos.:**
   - because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III** Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. **As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.**

2. **As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.**

3. **As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:**

4. **No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:**

**Remark on Protest**

- The additional search fees were accompanied by the applicant’s protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

Form PCT/ISA/21 0 (continuation of first sheet (2)) (April 2005)
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<td>WO 2008/140336 Al (ACTRONIC LTD [NZ]; HSU HSIN-PAI [NZ]; KING JENNI FER CAROL [NZ]; CORDER) 20 November 2008 (2008-11-20) abstract; figure 1</td>
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