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(71) Applicant (for all designated States except US): **MIMOS BERHAD** [MY/MY]; Technology Park of Malaysia, 57000 Kuala Lumpur (MY).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **BODE MAULT, Tomas, Henrique** [PT/MY]; Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(74) Agent: **KAUR, Sushil**; No 2-12, Jalan PJU 8/3, Perdana Business Centre, Bandar Damansara Perdana, 47820 Petaling Jaya, Selangor (MY).

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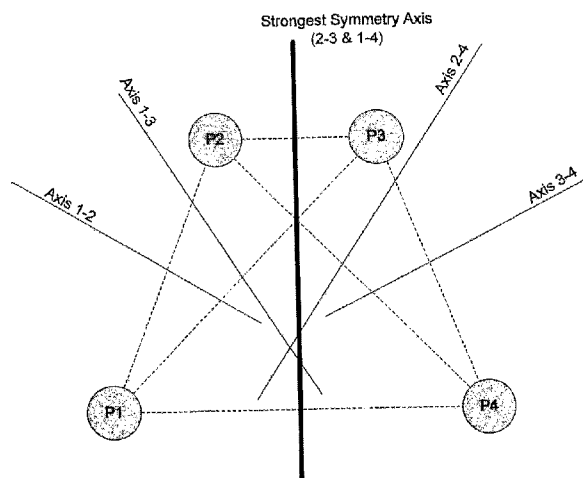


Figure 3

(57) **Abstract:** The present invention relates to a multiple object symmetry axis extractor for symmetry axis extraction characterized in that wherein is provided the extraction of symmetry axes from multiple objects in a 2D image which associates for each extracted axis an estimate of the underlying object's center, width and elongation along the axis and wherein the extraction is achieved via a second order neural network and wherein is further provided a voting structure consisting of a two-dimensional parameter space defined by (α , r) parameters, wherein each pair of which specifies a different line corresponding to a particular symmetry axis.

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A MULTIPLE OBJECT SYMMETRY AXIS EXTRACTOR

FIELD OF INVENTION

5 The present invention relates to an object symmetry axis extractor and more particularly the present invention relates to a multiple object symmetry axis extractor.

BACKGROUND OF THE INVENTION

10 The closest patented invention is that of Saito US Patent No 5,809,170 wherein candidate symmetry axes in a target pattern are tested sequentially until one with sufficient evidence is found (or not) and then used in order to register the said pattern. Apart from Saito no other patents were found pertaining to symmetry axis extraction.

15 The closest academic system is that of Fukushima et al. wherein axes of symmetry are extracted via a hierarchical neural network with preprocessing layers performing contrast and edge extraction.

20 Both the said prior arts have an implicit assumption that axes are being extracted from single objects. However, in the present invention, multiple objects are explicitly taken account of. Further to this, the present invention, contrary to both prior art documents, computes centrality, width and elongation estimates of underlying objects.

Further to this, the present invention uses Second Order Neural Networks wherein the present invention is not constrained by the use of edge orientation information (contrary to Fukushima). Further to that the present invention weighs axis votes based on factors such as feature rarity and salience.

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Therefore, it is an objective of the invention to allow symmetry axis extraction from multiple objects in the same image. It is another objective of the present invention to form estimates of the centers, widths and elongations of underlying objects.

10 **SUMMARY OF THE INVENTION**

The present invention relates to a multiple object symmetry axis extractor for symmetry axis extraction. The present invention provides therein an extraction of symmetry axes from multiple objects in a 2D image and associates for each extracted
15 axis an estimate of the underlying object's center, width and elongation along the axis. The extraction is achieved via a second order neural network and wherein is further provided a voting structure consisting of a two-dimensional parameter space defined by (α, r) parameters, wherein each pair of which specifies a different line corresponding to a particular symmetry axis.

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After receiving a static image as input the present invention proceeds to the initialization of a voting structure which is characterized by the parameter space of interest such as angles and distances of symmetry axes, and estimates of centroids,

widths and elongations of underlying objects. The present invention thereafter proceeds to compute a salience map of the inputted image.

The salience map is a representation of which image coordinates exhibit strong intensity variations and wherein the said salience map is used for sub-sampling the number of features that need to be considered when building second order representations. After computing the salience map, all pairs of salient points are compared, and those that are deemed to be sufficiently similar are selected for further processing.

Then each pair of matching salient points is used in order to compute a pair of symmetry axis parameters, a pair of centroid parameters and a width, all of which are used for voting. After all pairs of matching salient points have been considered, the maxima for the symmetry axes parameters are found and wherein based on said maxima, the centroids and widths of the corresponding symmetry axes are averaged. The elongation estimate for a particular symmetry axis is computed by averaging the distance between the centroids of all pairs of points contributing to that axis and the averaged centroid for that same axis.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a main process flow chart of an algorithm according to the present invention.

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Figure 2 shows a comparison between a Second Order Neural Network on the left with a general Higher Order Neural Network on the right.

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Figure 3 shows an illustration of four matching points (i.e. P1, P2, P3 and P4) and the symmetry axes that originate from their paired coupling.

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Figure 4 shows a simplified diagram of a second order neural network for the extraction of symmetry axes and the estimation of several geometric properties of underlying objects.

Figure 5 shows several examples of the invention's ability to extract symmetry axes.

Figure 6 shows a comparison of the present invention's ability to extract symmetry axes with that of a prior art, Fukushima et al.

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DETAILED DESCRIPTION OF THE PRESENT INVENTION

The present invention will now be described in detail with reference made to the accompanied drawings but the scope of the invention not limited thereto.

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The invention extracts symmetry axes from multiple objects in a 2D image. The invention also associates for each extracted axis an estimate of the underlying object's center, width and elongation along the axis. The extraction is achieved via a second order neural network. Refer to Figure 2 and Figure 4 for a diagrammatic and simplified depiction of the network, which compares pairs of features and votes for a particular axis contingent on a sufficient match being found for each pair. Figure 4 shows how node representing a symmetry axis is depicted in (a), while nodes (b), (c) and (d) represent width, centrality and elongation estimates respectively. Second order nodes are represented at (g). Several connection weights are depicted in (e). The clouds in (f) represent small temporal delays. The modulus of a difference is represented in (h) and divisive normalization is depicted at (i).

The voting structure consists of a two-dimensional parameter space defined by (α, r) parameters, each pair of which specifies a different line corresponding to a particular symmetry axis.

20

Reference is now made to Figure 1 wherein is summarized the main processes which characterize the functionality of the current invention.

After receiving a static image as input (e.g. a grayscale image of height H and width W), the algorithm proceeds to initialize a voting structure which is characterized by the parameter space of interest, i.e.: angles and distances (relative to the origin) of symmetry axes, and estimates of centroids, widths and elongations of underlying
5 objects. Following this, the algorithm proceeds to compute a salience map of the inputted image. A salience map is essentially a representation of which image coordinates exhibit strong intensity variations (e.g. edges).

The salience map is used for sub-sampling the number of features that need to be
10 considered when building second order representations. After computing the above map, all pairs of salient points are compared, and those that are deemed to be sufficiently similar (e.g. in terms of their grayscale values) are selected for further processing.

15 After this, each pair of matching salient points is used in order to compute a pair of symmetry axis parameters, a pair of centroid parameters and a width, all of which are used for voting. After all pairs of matching salient points have been considered, the maxima for the symmetry axes parameters are found. Subsequently, based on these maxima, the centroids and widths of the corresponding symmetry axes are averaged.

20 Finally, the elongation estimate for a particular symmetry axis is computed by averaging the distance between the centroids of all pairs of points contributing to that axis and the averaged centroid for that same axis.

The symmetry axis, centroid and width parameters for a particular pair of matching salient points are computed as follows. To simplify the explanation we will refer to the points as A and B and the origin as O . First the bisector between A and B is computed. The bisector is the symmetry axis, but its parameters will be defined as the length and angle of a vector starting at the origin and intersecting (and ending at) the bisector perpendicularly. The centroid is defined as the midpoint between A and B on the line AB . The width is defined as the distance between A and B . Refer to Figure 3 for an illustration of the symmetry axes computed for 4 points.

Reference could also be made to Figures 5 and 6 for comparison purposes. Figure 5 in (a) demonstrates the ability to extract axes from multiple objects. The subfigure in (b) demonstrates the invention's ability to extract the main symmetry axis of a face and the subfigure in (c) demonstrates the invention's ability to extract a further symmetry axis which is relevant to eye position. Figure 6 illustrates a comparison of the proposed invention's ability to extract symmetry axes with that of Fukushima et al. The invention's axes are incorporated with the patterns while those of Fukushima et al are in squares below each pattern.

CLAIMS

1. A multiple object symmetry axis extractor for symmetry axis extraction characterized in that wherein is provided the extraction of symmetry axes from multiple objects in a 2D image which associates for each extracted axis an estimate of the underlying object's center, width and elongation along the axis and wherein the extraction is achieved via a second order neural network and wherein is further provided a voting structure consisting of a two-dimensional parameter space defined by (α, r) parameters, wherein each pair of which specifies a different line corresponding to a particular symmetry axis.
2. A multiple object symmetry axis extractor for symmetry axis extraction as claimed in Claim 1 wherein after receiving a static image as input the present invention would proceed to initialize a voting structure which is characterized by the parameter space of interest such as angles and distances of symmetry axes, and estimates of centroids, widths and elongations of underlying objects.
3. A multiple object symmetry axis extractor for symmetry axis extraction as claimed in Claim 2 wherein the present invention would thereafter proceed to compute a salience map of the inputted image.
4. A multiple object symmetry axis extractor for symmetry axis extraction as claimed in Claim 3 wherein the salience map is a representation of which image coordinates exhibit strong intensity variations and wherein the said salience map is used for sub-

sampling the number of features that need to be considered when building second order representations.

- 5 5. A multiple object symmetry axis extractor for symmetry axis extraction as claimed
in Claim 4 wherein after computing the salience map, all pairs of salient points are
compared, and those that are deemed to be sufficiently similar are selected for
further processing.
- 10 6. A multiple object symmetry axis extractor for symmetry axis extraction as claimed
in Claim 3 wherein then each pair of matching salient points is used in order to
compute a pair of symmetry axis parameters, a pair of centroid parameters and a
width, all of which are used for voting.
- 15 7. A multiple object symmetry axis extractor for symmetry axis extraction as claimed
in Claim 3 wherein after all pairs of matching salient points have been considered,
the maxima for the symmetry axes parameters are found and wherein based on said
maxima, the centroids and widths of the corresponding symmetry axes are averaged.
- 20 8. A multiple object symmetry axis extractor for symmetry axis extraction as claimed
in Claim 1 wherein the elongation estimate for a particular symmetry axis is
computed by averaging the distance between the centroids of all pairs of points
contributing to that axis and the averaged centroid for that same axis.

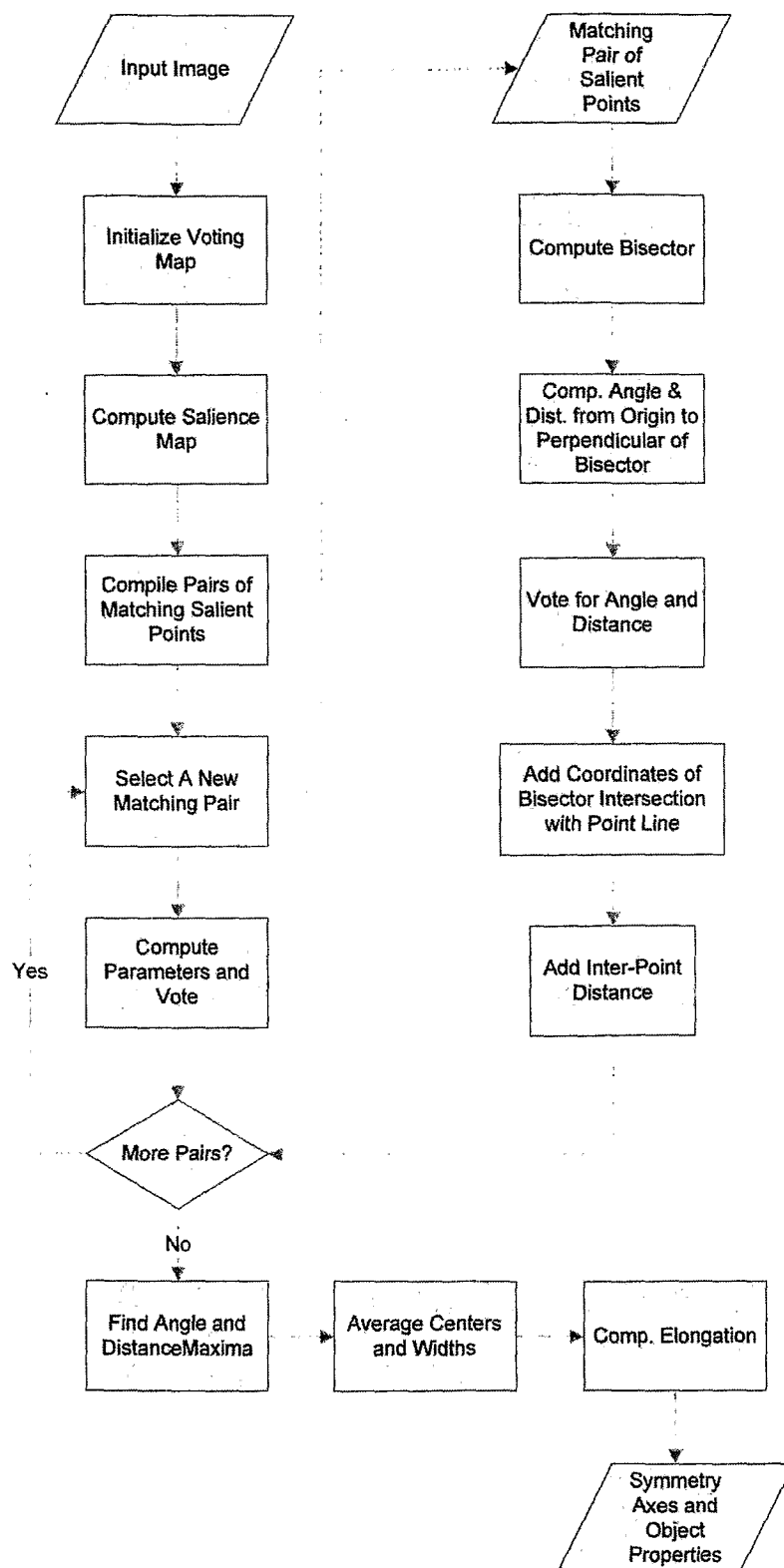


Figure 1

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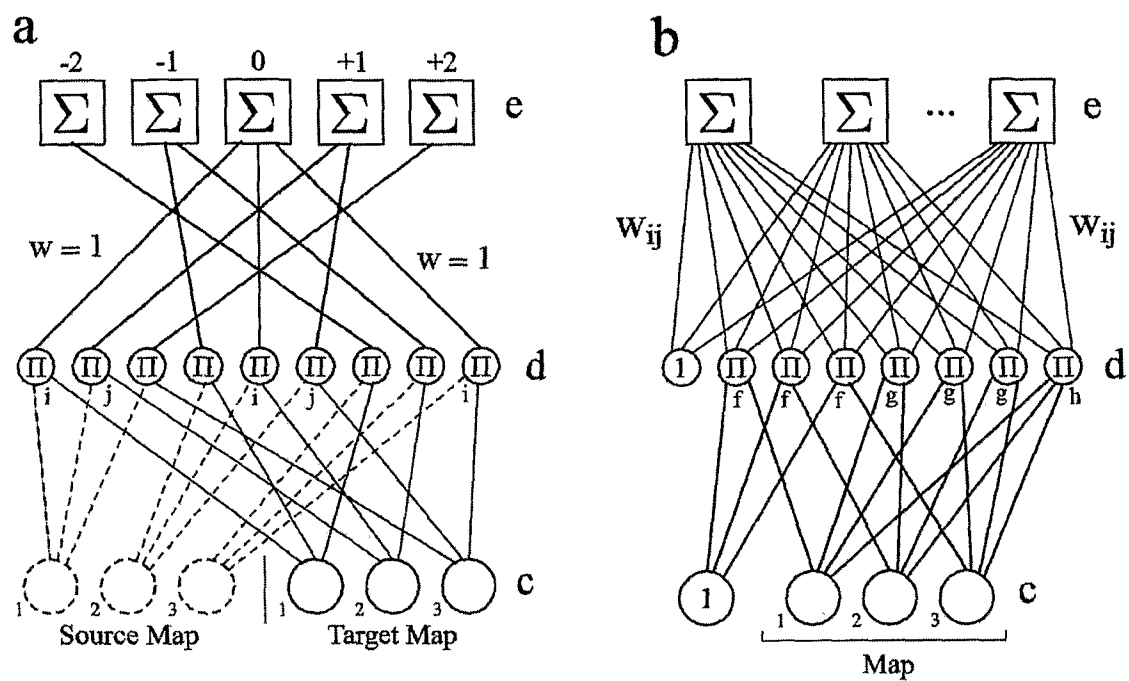


Figure 2

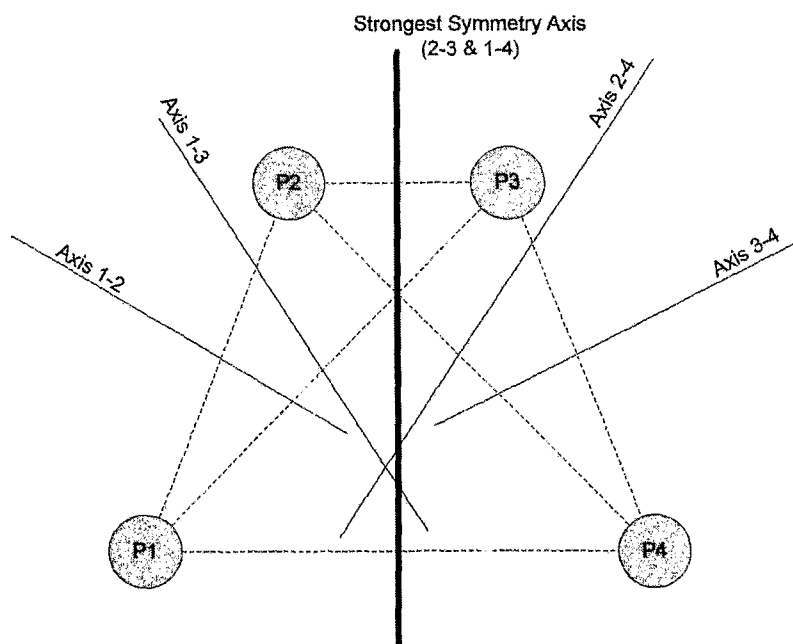


Figure 3

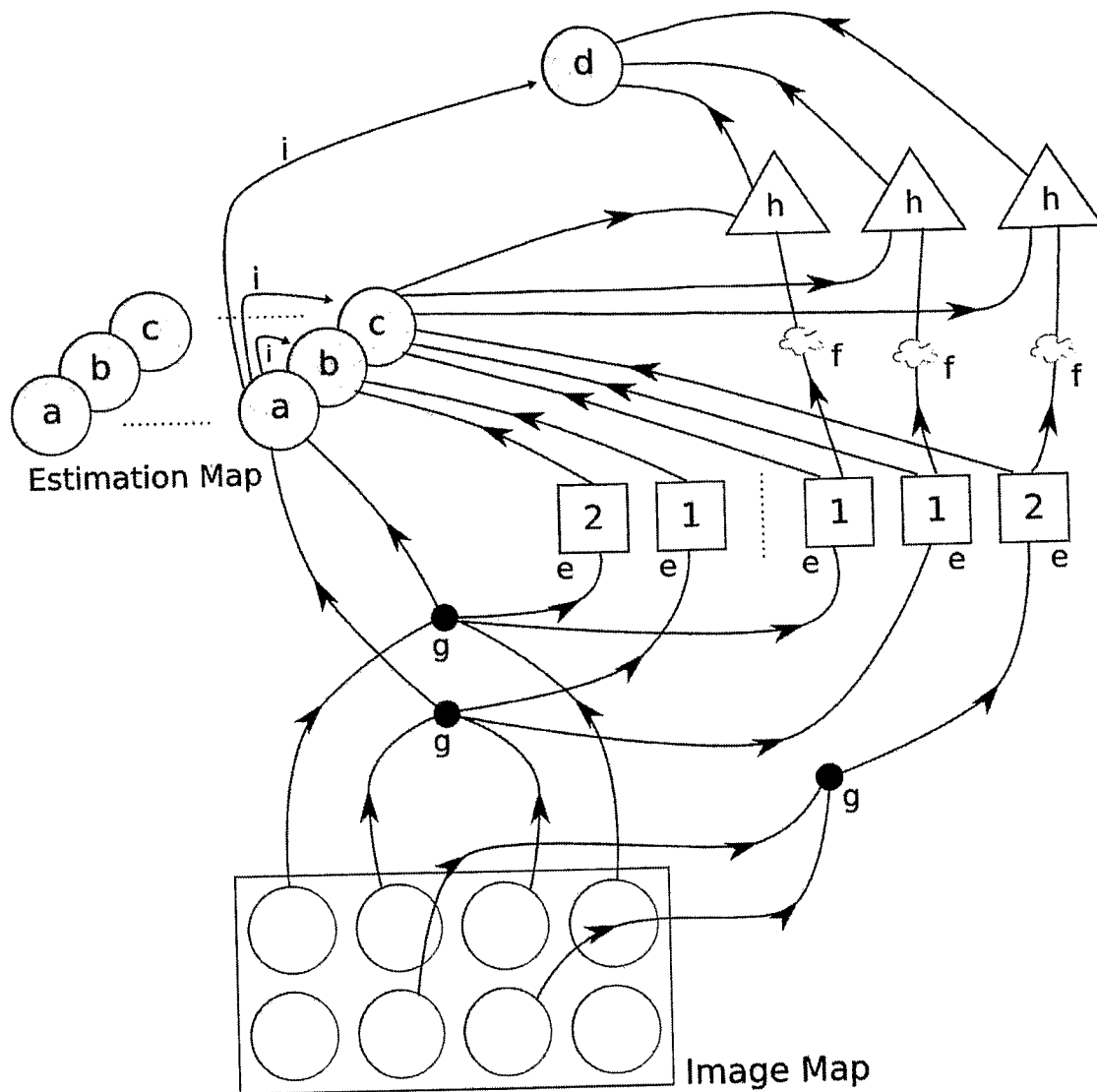


Figure 4

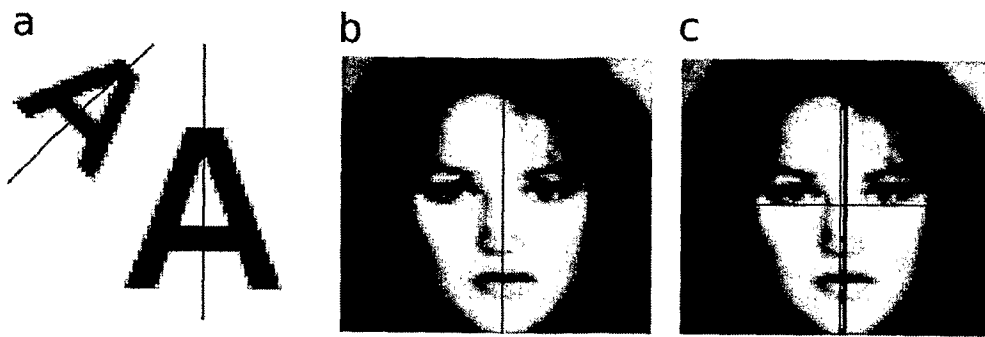


Figure 5

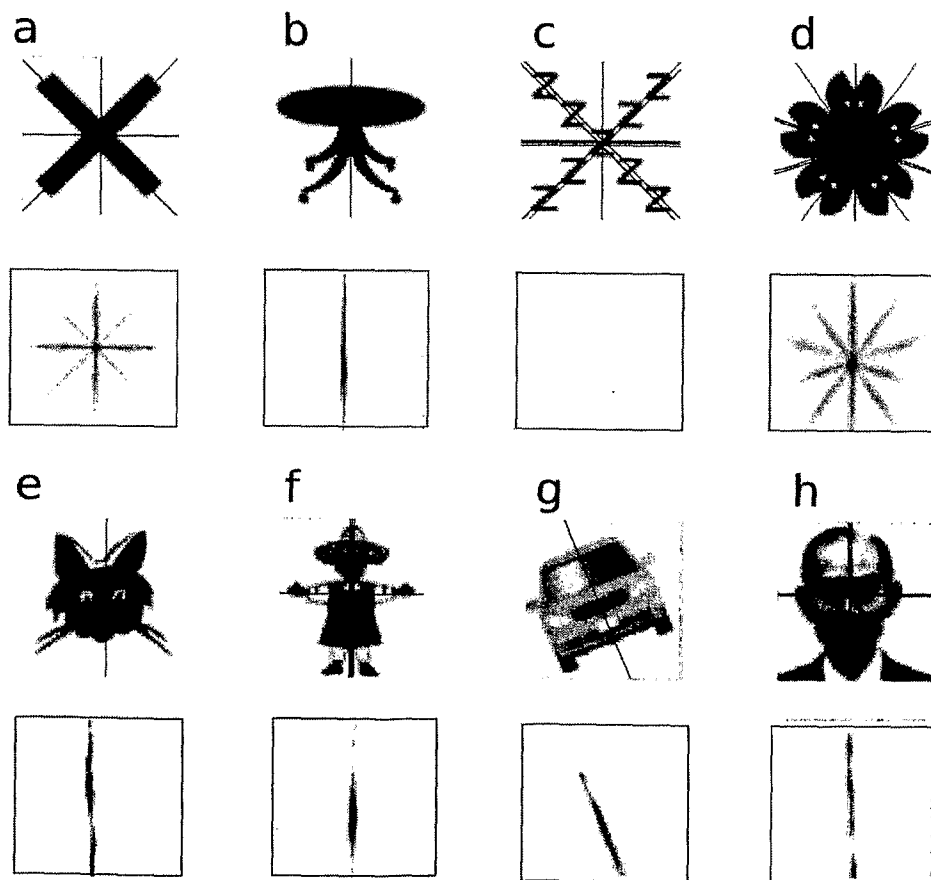


Figure 6