

5 CLAIMS

1. A method for deriving a 3D data from image data, comprising:
receiving, from at least one camera, image data representing an environment;
detecting, from the image data, at least one object within the environment;
10 classifying the at least one detected object, wherein the method comprises, for each
classified object of the classified at least one objects:
determining a 2D skeleton of the classified object by implementing a neural
network to identify features of the classified object in the image data
corresponding to the classified object; and
15 constructing a 3D skeleton for the classified object, comprising mapping the
determined 2D skeleton to 3D.
2. The method of claim 1, wherein each of said at least one object comprises a
plurality of associated sub-objects, and wherein, for each of said at least one object:
20 detecting at least one object comprises detecting each of the plurality of associated
sub-objects;
classifying at least one object comprises classifying each of the plurality of
associated sub-objects;
determining the 2D skeleton of the classified object comprises identifying features of
25 each of the plurality of classified sub-objects in the image data corresponding to the
classified sub-objects.
3. The method of claim 1 or claim 2, wherein, for each classified object, mapping the
determined 2D skeleton to 3D comprises:
30 implementation of a neural network; and/or
applying statistical and/or probabilistic methods to the determined 2D skeleton and
applying holonomic constraints to the statistical and/or probabilistic methods.
4. The method of claim 3, wherein classifying the at least one detected object
35 comprises classifying a first detected object of the at least one detected object as a human
object, and, when statistical and/or probabilistic methods are applied to the determined 2D
skeleton, the holonomic constraints comprise human anatomical holonomic constraints.

- 5 5. The method of claim 3 or claim 4, wherein the 3D skeleton comprises an anchor
point and a plurality of child points, each child point is defined by applying a transformation
to the anchor point or another child point of the plurality of child points, wherein the
holonomic constraints define the degrees of freedom of the transformation defining each
child point, and/or the range of possible values for each degree of freedom of the
10 transformation.
6. The method of any preceding claim, wherein classifying the at least one detected
object comprises classifying a second detected object of the at least one detected object as
a non-human object.
- 15 7. The method of any preceding claim, wherein the at least one camera comprises a
plurality of cameras;
 wherein detecting at least one object comprises detecting said at least one object in
image data collected from each camera;
20 classifying the at least one object comprises classifying said at least one object
detected in the image data from each camera;
 determining the 2D skeleton for each classified object comprises determining a
plurality of 2D skeletons, each of said plurality of 2D skeletons determined from identifying
features of the classified object in image data collected from a different camera of the
25 plurality of cameras; and
 wherein constructing the 3D skeleton comprises combining the determined plurality
of determined 2D skeletons.
8. The method of any preceding claim, wherein:
30 the image data comprises a time-ordered sequence of frames, the time-ordered
sequence of frames comprising frames collected from each camera of the at least one
cameras, and
 said detecting at least one object within the environment comprises detecting said at
least one object in each frame of the time-ordered sequence of frames,
35 said classifying the at least one detected objects comprises classifying the at least
one detected object in each frame of the sequence of frames; and
 each classified object of the classified at least one objects is tracked across the
time-ordered sequence of frames.

- 5 9. The method of claim 8, wherein each classified object is tracked across the time-ordered sequence of frames by implementing a recursive estimator; and, for each classified object, mapping the determined 2D skeleton to 3D comprises:
- determining a plurality of 3D skeletons to form a time-varying 3D skeleton, and
- applying a recursive estimator across the time-ordered sequence of frames to
- 10 determine a time-varying 3D skeleton for the classified object.
10. The method of claim 9, wherein the application of recursive estimators comprises applying time-dependent holonomic constraints.
- 15 11. The method of claim 10, wherein:
- the 3D skeleton comprises an anchor point and a plurality of child points, each child point is defined by applying a transformation to the anchor point or another child point of the plurality of child points;
- the time-varying 3D skeleton is defined by time-variable transformations for each
- 20 child point, and the time-dependent holonomic constraints define, for each point in time, the degrees of freedom of transformation defining each child point and/or the range of possible values for each degree of freedom of the transformation.
12. The method of any one of claims 8 – 11, wherein the at least one camera comprises
- 25 at least one first type of camera and at least one second type of camera, wherein each of the first type of camera captures image data at a first framerate, and each second type of camera captures image data at a second framerate that is different to the first framerate.
13. The method of any one of claims 8 – 12, further comprising constructing, from the
- 30 image data, a 3D model of the environment.
14. The method of claim 13, wherein the 3D environment model is constructed by
- applying Simultaneous Localisation and Mapping techniques to the image data to estimate a position and an orientation of each camera of the at least one camera and to
- 35 construct an environment map; and
- constructing the 3D model by mapping the environment map to a pre-determined 3D model of the environment.

- 5 15. The method of claim 13 or claim 14 further comprising integrating the time-varying 3D skeleton with the 3D environment model to construct a time-varying integrated environment.
- 10 16. The method of any preceding claim, the method further comprising, for each classified object of the classified at least one objects:
constructing a 3D avatar for the classified object comprising integrating the constructed 3D skeleton with a 3D model corresponding to the classified object.
- 15 17. The method of claim 16, wherein the method further comprises capturing the 3D model corresponding to the classified object at a higher resolution than the resolution of the image data.
- 20 18. The method of claim 13 or 14, further comprising:
for each classified object of the classified at least one objects: constructing a 3D avatar for the classified object comprising integrating the constructed 3D skeleton with a 3D model corresponding to the classified object, and
integrating the determined 3D environment model with the constructed 3D avatar for each of the classified objects to construct a 3D model of an integrated environment, said integrated environment comprising said environment and said objects within the
25 environment.
- 30 19. The method of claim 18, further comprising refining the construction of the integrated environment by applying time-dependent smoothing to the constructed 3D avatar, using filtering methods.
20. The method of claim 18 or claim 19, further comprising refining the construction of the integrated environment by constraining interactions between each constructed 3D avatar and the 3D environment model.
- 35 21. The method of any one of claims 18 – 20, wherein constructing a 3D avatar for each of the classified objects comprises constructing a plurality of 3D avatars, and the method further comprises refining the construction of the integrated environment by constraining interactions between the plurality of 3D avatars.

- 5 22. A method for deriving a 3D data from image data of a sporting environment for use
in determining compliance with an offside rule in a sporting match, said method comprising:
receiving, from at least one camera, image data representing the environment;
detecting, from the image data, a plurality of objects within the environment;
classifying a plurality of the detected objects as players,
- 10 wherein the method comprises, for each player:
determining a 2D skeleton of the player by implementing a neural network
to identify features of the payer in the image data corresponding to the player;
constructing a 3D skeleton for the player, comprising mapping the
determined 2D skeleton to 3D; and
- 15 integrating the constructed 3D skeleton with a 3D model corresponding to
the classified object to construct a 3D avatar for the player,
the method further comprising in response to a user-detected or automatically-detected
event:
defining a two-dimensional plane within the environment;
- 20 determining on which side of the two-dimensional plane predefined portions of the
avatars of the players may be found.
23. A method for deriving a 3D data from image data of a sporting environment for use
in determining compliance with an offside rule in a sporting match, said method comprising:
- 25 receiving, from at least one camera, image data representing the environment;
detecting, from the image data, a plurality of objects within the environment;
classifying a plurality of the detected objects as players,
wherein the method comprises, for each player:
determining a 2D skeleton of the player by implementing a neural network
- 30 to identify features of the payer in the image data corresponding to the player;
constructing a 3D skeleton for the player, comprising mapping the
determined 2D skeleton to 3D; and
the method further comprising in response to a user-detected or automatically-detected
event:
- 35 defining a two-dimensional plane within the environment;
determining on which side of the two-dimensional plane predefined portions of the
skeletons of the players may be found.

- 5 24. A computer comprising a processor configured to carry out the method of any preceding claim.
25. A computer program comprising instructions that, when executed by a processor, cause the processor to carry out the method of any of claims 1 – 23.

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