We claim:

1. A system for mixing or compositing in real-time, computer generated 3D objects and a video feed from a film camera, such as a video camera, to generate real-time augmented reality video for TV broadcast, cinema or video games, in which:

(a) the body of the film camera can be moved in 3D and sensors in or attached directly or indirectly to the film camera provide real-time positioning data defining the 3D position and 3D orientation of the film camera, or enabling the 3D position and 3D orientation of the film camera to be calculated and

(b) that real-time positioning data is then automatically used by the system to create, recall, render or modify computer generated 3D objects and

(c) the resulting computer generated 3D objects are then mixed in or composited with the video feed from the film camera to provide augmented reality video for TV broadcast, cinema or video games.

2. The system of Claim 1 in which the computer generated 3D objects are mixed in or composited in real-time with the real-time video feed from the film camera.

3. The system of any preceding Claim in which real-time zoom, focus and iris settings of the film camera are measured, for example using conventional encoders, and used, together with the real-time positioning data, so that the 3D objects are correctly rendered in a desired location and orientation in a 3D scene

4. The system of any preceding Claim in which the sensors include an accelerometer, and a gyro (6DOF sensor).

5. The system of any preceding Claim in which the sensors include a 3-axis accelerometer measuring translational acceleration in 3D, a 3-axis gyro measuring angular velocity in 3D, and magnetometer measuring absolute heading in 3D, and hence constituting a 9DOF sensor.

6. The system of any preceding Claim in which the sensors include a 3D range sensor,

such as structured light or time-of-flight camera.

7. The system of Claim 6 in which the 3D range sensor captures the depth of each pixel in a video output from the camera.

8. The system of Claim 7 in which the depth of edges is refined by reprojecting the 3D range sensor depths onto the high resolution video feed of the film camera.

9. The system of any preceding Claim in which the sensors are formed into a unit that can be securely fixed to the film camera.

10. The system of Claim 9 in which the unit includes one or two witness cameras.

11. The system of Claim 9 in which the unit includes a 3D range sensor that captures the depth of each pixel in a video output.

12. The system of Claim 9 in which the unit can form a survey device which can be used to survey a complex scene and transmit data defining the 3D scene being surveyed wirelessly to a computer which then tracks or recovers tracking of the scene.

13. The system of any preceding Claim which includes one single witness camera (monoscopic case) or two witness cameras (stereocscopic case), equipped with lenses which may be 180 degree fish eye lenses.

14. The system of Claim 13 in which the witness camera(s) are off-set from the film camera and that off-set is obtained using a calibration chart including a first and second group of circles, each circle being in a known location with respect to one or more of the other circles and each circle being recognized using a blob image algorithm.

15. The system of any preceding Claim in which a lens of the film camera is calibrated for optical distortion using a calibration chart including several circles, each circle being in a

known location with respect to one or more of the other circles and each circle being recognized using a blob image algorithm.

16. The system of any preceding Claim in which the 3D position and orientation of the film camera is determined with reference to a 3D map of the real-world generated, in part, by using the real-time 3D positioning data from the sensors plus an optical flow in which witness camera(s) surveys a scene and software running on a processor detects natural markers in the scene ('feature points') that have not been manually or artificially added to that scene.

17. The system of any preceding Claim which utilizes one or two high-speed (such as at least 100 fps) witness cameras to enable the system to be fully initialized without a separate stage of purely surveying the scene to be tracked (called 'instant survey'), but instead surveying takes place continuously whilst the camera is being used to capture video.

18. The system of Claim 17 in which the two high speed witness cameras form a stereoscopic system that enables software to process the images and, even with the camera system not being moved at all, to generate an instant 3D point cloud (for example associating a large number of points in the scene to their position in a 3D space using knowledge of the separation between the two camera and epipolar geometry).

19. The system of Claim 17 in which the depth of each pixel in the 3D point cloud is obtained using corresponding 2D texture patches obtained from each stereoscopic witness camera and an epi-polar line search algorithm.

20. The system of any preceding Claim which runs a fusion algorithm that combines optical flow data from the witness camera system with the real-time positioning data from the hardware sensors.

21. The system of Claim 20 in which the fusion algorithm is based on an Extended Kalman Filter prediction/correction technique to integrate outputs from, and to re-calibrate,

all the sensors, which may include an accelerometer, a gyroscope, a magnetometer, a 3D range sensor, to determine the position and orientation of the camera.

22. The system of Claim 21 in which the Extended Kalman Filter fusion algorithm uses confidence level data, associated with the output from each sensor, when determining how to merge the data from each sensor.

23. The system of any preceding Claim in which keyframes generated by a or the witness camera(s) are part of the visual tracking process and are real-time images computed at 4 different resolution levels of the witness camera video feed.

24. The system of any preceding Claim which includes (a) a content generating computer that provides 3D computer generated animation of virtual figures, objects and places, and (b) a rendering computer (which may or may not be separate from the content generating computer), and in which the real-time positioning data defining the 3D position of the film camera is used by either or both of the content generating computer and the rendering computer to cause real-time, computer generated 3D objects to be generated that can in real-time be inserted and mixed with the video feed from the film camera to form a natural part of the scene shown in that video feed.

25. The system of any preceding Claim in which the computer generated 3D objects are animations that can move anywhere within the scene and can alter their shape and appearance in a manner determined by the content generating computer.

26. The system of any preceding Claim in which the computer generated 3D objects are animated figures of people or creatures that move (e.g. run, dance, walk, fight, fly, jump, …) in a realistic manner when mixed in the scene.

27. The system of any preceding Claim in which the camera positioning or tracking data is also made available for use in post-production to facilitate post-production CGI

28. The system of any preceding Claim in which a 3D range sensor is used to enhance the accuracy of a depth measurement associated with a reconstructed 3D point, or to reject that reconstructed 3D point.

29. The system of Claim 28 in which the 3D range sensor is used for real-time depth keying to enable dynamic occlusion and suppress the eventual use of a green stage.

30. The system of any preceding Claim which uses a small camera registration object, such as a board of known size and covered with a known pattern, placed in the scene so that a corner of the detected pattern is treated as the origin for the 3D point cloud (and thus the world).

31. The system of Claim 30 in which the camera registration object comprises at least two spheres of known size arranged in a true vertical and recognized using a blob image recognition algorithm.

32. The system of any preceding Claim which includes a magnetometer to indicate magnetic North, an accelerometer to indicate gravity direction (and thus giving true vertical), a gyro to indicate if the system is tilted up/down or has panned left or right or has been rotated about the optical axis, and a 3-axis accelerometer to enable translation in 3D from a start position to be inferred.

33. The system of any preceding Claim in which software attempts to generate a uniformly distributed point cloud in the 3D map to greatly reduce tracking losses and increase tracking accuracy (more parallax is generated, so the estimated camera position is more accurate).

34. The system of any preceding Claim in which a camera tracking system can be wirelessly connected to the film camera and can hence be rapidly moved around the set when generating the 3D point cloud.

35. The system of any preceding Claim providing a camera tracking system that combines real-time surveying of a 3D scene (monoscopic case) or instant survey (stereoscopic case) with tracking of the film camera as the director/cameraman tracks, pans, tilts the camera tracking system attached to the film camera.

36. The system of any preceding Claim that fully automates all aspects of film camera tracking, including rotation, translation, focus, iris, focal length; and automates the scaling, positioning and orientation of the 3D computer generated content to be mixed in with the video.

37. The system of any preceding Claim that enables real-time, continuous surveying of a scene to generate a more complete point cloud defining the scene.

38. The system of any preceding Claim that attaches rotation invariant descriptors, for example using ORB, to feature points detected in the scene to facilitate recovery of tracking.

39. The system of any preceding Claim that uses a constant velocity model associated with the information provided by the sensors to predict the next position of the film camera using the previously correctly computed or confirmed position.

40. The system of Claim 39 that uses that prediction to re-project a 3D point cloud onto the current frame, to enable a point matching algorithm to match points identified in the real-time video feed from the witness camera system and the projected points in the new, 3D point cloud.

41. The system of Claim 40 that uses a Levenberg-Marquardt minimization scheme for camera tracking to minimize the error between the points identified in the real-time video feed from the witness camera system and the projected points in the new, 3D point cloud.

42. The system of any preceding Claim in which a user can use a 3D point cloud generated by the camera tracking system to define 3D masks, such as 3D Garbage Matting

masks.

43. The system of any preceding Claim in which the 3D objects include static objects, dynamic animations, virtual worlds, virtual people, virtual buildings, virtual scenery, virtual film sets, and any data in an animation database.

44. The system of any preceding Claim in which the film camera and a witness camera are calibrated for frame acquisition delay using a modulated light source, such as by comparing light intensity curves associated with a flashing LED.

45. The system of any preceding Claim in which the film Camera is any of the following: crane camera; steady cam; hand-held-camera; dolly mounted camera, tripod-mounted camera, smartphone, augmented reality glasses.

46. A method of mixing or compositing real-time, computer generated 3D objects and a video feed from a film camera in which the body of the film camera can be moved in 3D and sensors in or attached to the camera provide real-time positioning data defining the 3D position and 3D orientation of the camera, or enabling the 3D position to be calculated.

47. A method for mixing or composting real-time, computer generated 3D objects and a video feed from a film camera, such as a video camera, to generate augmented reality video for TV broadcast, cinema or video games, in which:

(a) the body of the film camera can be moved in 3D and sensors in or attached directly or indirectly to the film camera provide real-time positioning data defining the 3D position and 3D orientation of the film camera, or enabling the 3D position and 3D orientation of the film camera to be calculated and

(b) that real-time positioning data is then automatically used by the system to create, recall, render or modify computer generated 3D objects and

(c) the resulting computer generated 3D objects are then mixed in or composited with the video feed from the film camera to provide augmented reality video for TV broadcast, cinema or video games.

48. Methods or systems as defined above and used to enable a director (or a director of photography) to frame-up the pre-production computer generated 3D assets in camera, typically previsualisation or visual effects assets, in real-time onto the live action film plate or video images as captured by the camera, enabling the director to explore possible camera angles and moves in real-time with the computer generated 3D assets being automatically mixed into the video as seen by the director.

49. Methods or systems as defined above in which the real-time positioning data is recorded and time-code stamped to provide match-move data for post-production processes.

50. Methods or systems as defined above and used to enable virtual objects or images to be inserted into a broadcast video stream.

51. Method or system as defined above to enable one or more of the following:

- Real-time tracking for studio cameras
- Real-time tracking for Steadicam
- Real-time tracking for Crane-mounted cameras
- Real-time tracking for Dolly-mounted cameras
- Real-time tracking for Steadicam
- Real time tracking for Oustside Broadcast (OB)
- Using real-time data (e.g. tracking data) for 2D post-production
- Using real-time data (e.g. tracking data) for post-conversion for 3D stereoscopic content
- Using real-time data (e.g. tracking data) for native 3D stereoscopic content
- 3D graphics insertion
- 3D graphics insertion for in-studio or on-set product placement
- 3D graphics insertion for OB
- 3D graphics insertion for other sponsored images
- 3D graphics insertion that is viewer-location specific
- 3D graphics insertion that is viewer-specific

- 3D graphics insertion that is time-specific
- 3D graphics insertion for filling out crowd scenes
- 3D graphics insertion for green screen replacement
- 3D graphics insertion of educational content to assist learning, in museums and interpretation centres in cultural, historic or natural sites.
- Measurement of the absolute or relative size of objects in the scene.

52. Methods or systems as defined above, where the film camera is one of the following:

- All cameras with a standard tether
- Cameras requiring tactical optical fibre connection
- Camera requiring RF/wireless connection

53. Method or systems as defined above, deployed in one of the following markets:

- Film/TV (not live)
- Commercial (not live)
- Commercials live
- Broadcast (not sports)
- Broadcast OB
- Sports studio based
- Sports OB based
- TV product placement live
- Internet usage (not live)
- Internet live
- Internet live territory based
- Interent product placement live
- Museum/heritage content
- Museum/heritage advertisements
- Architectural

- Games

54. Methods or systems as defined above and used to enable augmented reality images to be displayed by any display device, including a smartphone, and augmented reality glasses, the appearance of the augmented reality images being automatically altered in dependence on the real-time positioning data.

55. A film, movie, TV show or video game in which real-time, computer generated 3D objects are mixed with a video feed from a camera, in which the body of the camera can be moved in 3D and sensors in or attached to the camera provide real-time positioning data defining the 3D position of the camera, or enabling the 3D position to be calculated.

56. A scene surveying and tracking device adapted to be attached to a conventional camera, in which the body of the camera can be moved in 3D and hardware sensors in the scene surveying and tracking device provide real-time positioning data defining the 3D position of the camera, or enabling the 3D position to be calculated.

57. A hand-held or portable camera including sensors in or attached to the camera provide real-time positioning data defining the 3D position and 3D orientation of the camera relative to a 3D reference frame, or enabling, fully or as part of a system that analyses other data, such as optical flow data, the 3D position to be calculated.

58. A film camera including or attached to a stereoscopic witness camera system, the witness camera system generating wide-angle (e.g. 180 degree) stereoscopic images, enabling software to process the images and, without the camera system being tracked/moved at all, to generate an instant 3D point cloud.

59. A camera tracking system for attaching to a film camera, having the witness camera system generating stereoscopic images, enabling software to process the images and, without the camera system being moved at all, to generate an instant 3D point cloud and provide real-

time tracking (position, orientation, zoom, focus and iris) of the film camera.

60. Augmented reality glasses including sensors in or attached to the glasses provide real-time positioning data defining the 3D position and 3D orientation of the glasses relative to a 3D reference frame, or enabling, fully or as part of a system that analyses other data, such as optical flow data, the 3D position to be calculated.

Dated this 8th day of December, 2014