Optical Metrology Centre

OMC Technical Brief - Linear CCD 3-D Sensor

Linear CCD 3-D sensor systems measure the location of one or more LED targets by use of three cameras and triangulation

What do they do?

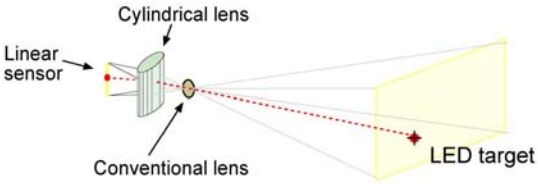
Measure distance to an infra-red light emitting diode over a range of 1.5 to 6 metres with a speed of up to 3,500 measurements points per second and an accuracy of around 0.02 mm

Where are they used?

- Wind tunnel testing where the angle of attack, captive trajectory, deformation and vibration of models can be determined in real time or with using post processing.
- Bio-mechanics - e.g. for use in analysis of sports.
- Medicine where the position and orientation of medical devices can be determined in real-time
- Robots - tracking of end effectors
- Human gait analysis
- Manufacturing industry - digitising probes allow use of the system as a portable CMM

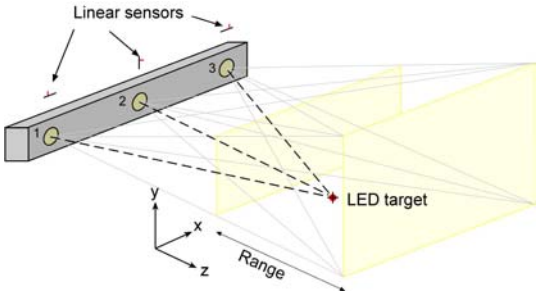
How do they work?

The key elements of this system are the lenses and linear CCD sensor



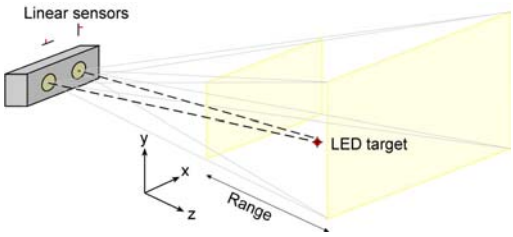
Configuration of target, lenses, and linear sensor

By using a cylindrical lens in the camera the sensor is able to measure the vertical position of an infra-red LED target at any horizontal position. Each camera system has a pyramid field of view. In one configuration three of these cameras are used as illustrated in the next figure.



A three-camera system

Each camera is able to measure one angle for each illuminated target in the object space. Cameras 1 and 3 in the figure provide horizontal measurement (**x**), and stereo depth (**z**), while the other camera (2) measures the angle of inclination which together with the depth produces the **y** co-ordinate. In another configuration a number of two camera systems are used.



A two-camera system

Each system acts like a conventional camera producing **x** and **y** co-ordinates but a much higher data rate due to the linear CCD being used instead of an area camera (approximately 100 times faster). By using several of these cameras a conventional photogrammetric algorithm can be used to provide 3-D estimates for each LED target.

What is the key technology?

Linear CCD sensors are used in a variety of applications from remotes sensing to desktop scanners, from optical triangulation probes to fax machines. In this application they are used to measure the location of the image of a target. They use the same technology as CCD area cameras used in video cameras but have only one

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line of light sensitive pixels. Because of this, although they may operate as similar speeds to CCD sensors (10-20 Mhz clock rate), each line of data is available much faster - 20,000 times per second in some cases. The sensors are geometrically stable and are manufactured to tight specifications. They are capable of measuring the location of an image of a target to a subpixel accuracy of between 1/5 to 1/50 of a pixel. The use of infra-red LED's with these systems allows optical filters to remove unwanted radiation from the sensor and produce high noise immunity so that these systems can be used in the day light without problems.

How are these system used?

Each of the targets is illuminated in sequence (up to 256 can be used). For each target the position of the image of the target is measured with at least three linear sensors at the same time. Many applications only require a few targets (10 -30). This means that the location and orientation of an object can be measured many times within a second. In some cases the targets will be attached to a model aeroplane being tested in a wind tunnel, in other cases the targets may be attached to a medical instrument.

How accurate?

For a 1 metre volume using one manufacturers systems an accuracy of 0.1 - 0.25 mm is quoted with a repeatability of 0.01 - 0.02 mm. At a 6 metre distance with a measurement volume of some 3x3 metres the accuracy is between 0.45 - 0.9 mm.

Advantages of this system

- Relatively high accuracy
- Non-contact
- Robust
- High speed 6 DOF measurements
- LED's can be viewed over a wide angle
- High degree of immunity from environment

Disadvantages of this system

- Lines of sight for instrument required
- Assumption of small movement between points
- LED's have to be attached and powered
- Measurement does not happen simultaneously

How to decide whether you need one of these systems

- You need to measure the position of points or an object at a distance of 1.5 - 6 metres away with an accuracy of 0.1 - 0.7 mm.
- You do not mind having LED targets attached to the object or points of interest and connecting wires to each of these points is not a problem
- You wish to measure the 3-D location of points in 1/3500 th of a second and repeat the measurement up to 600 times per second
- You need 6 degrees of freedom information in a high value or embedded application

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