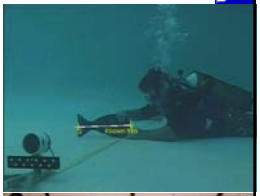
HELSINKI UNIVERSITY OF TECHNOLOGY
Department of Surveying

RMIT UNIVERSITY

UCL University College London

TKK Graduate School Course in Geomatics 2009



How to use video sequences to make accurate measurements from images in air or under water

Prof Mark Shortis, RMIT University,
Melbourne, Australia

Prof Stuart Robson, University College London,
England

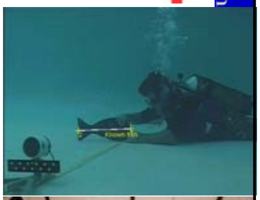
Session Outline: Day 2

- Session 1 — Design Factory
  - Introduction to stereo/multi-camera systems and tracking
  - Coverage/resolution/geometry/target/initial state/stability issues
  - Relative orientation computations for stereo/multi-camera systems
- Session 2 — Design Factory
  - Set up of experiment for the multi-camera system
  - Image capture for self-calibration and tracking of the remotely controlled electric helicopter
  - Demonstration of processing for tracking of a parachute
- Session 3 — M240 PC Lab
  - Hands-on processing of tracking sequence data from session 2
- Session 4 — Design Factory
  - Examples of other tracking applications
  - Review of workshop and guide to more information

HELSINKI UNIVERSITY OF TECHNOLOGY
Department of Surveying

RMIT UNIVERSITY

UCL University College London



Day 2 - Session 1

Tracking Design for Stereo and Multi-camera Systems

Photogrammetric data processing using targets

Setting up

- **Design set up:** position the cameras and targets
- **Measure images**: identification of known targets and measurement of other imaged targets
- **Location of cameras***:* given appropriate spatial information the location and pointing direction (orientation) of each camera is determined at the time the image was taken.
- **Identification and location of targets**: Given camera orientations the identities and locations of new targets are established.

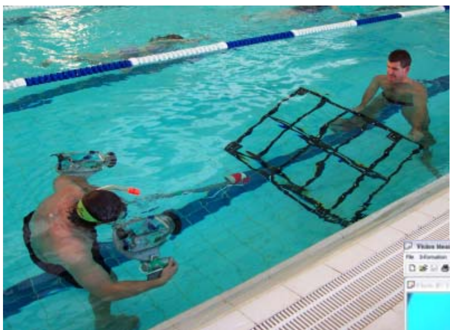
Repeated

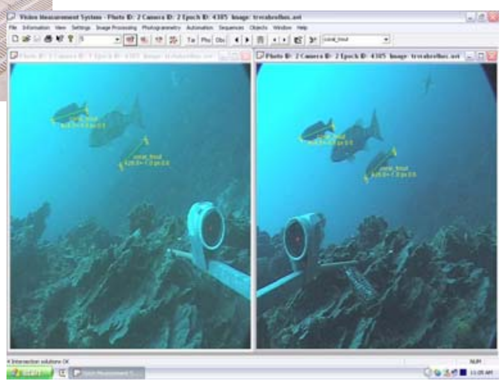
- **Compute parameters of interest:** for example the attitude of the object or motion parameters. This is may be carried out in association with a statistically rigorous network solution
- **Re-compute the solution for the next set of images:** Using, for example, target tracking to enable a very rapid update of the parameters of interest.

Design Question 1: Stereo or Multi-camera?

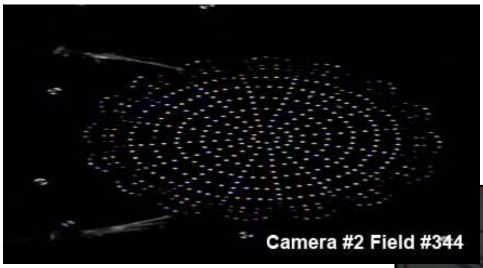
- Stereo is the minimum configuration for 3D information
- Multiple cameras require more set-up time, additional connections and may be more affected by ambient lighting
- Advantages of multi-camera are:
  - –redundancy provides reliability
  - –coverage can be optimised to concentrate on the area of primary interest but also include peripheral areas
  - –coverage may reduce the loss of retro-response because of different view angles
- Four cameras is a logical minimum to permit error detection
- Both approaches may be affected by changes in the shape of the object

Stereo-Camera





Multi-Camera



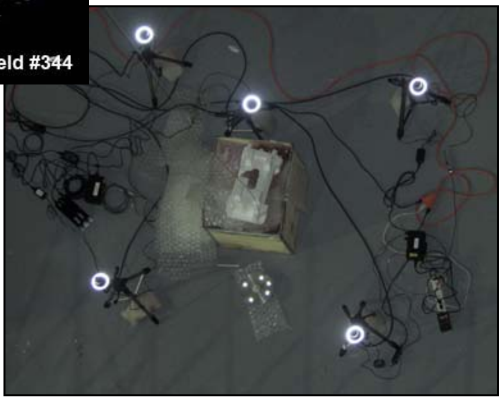


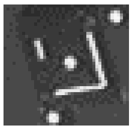
Image Capture and Synchronisation

- The distances to the object for calibration and measurement are often different due to physical constraints – the exposure must be managed so that retro-targets are visible and there is sufficient depth of field to ensure the objects are in focus at the same focus and zoom settings
- Image resolution and image quality settings must be consistent between calibration and measurement images
- Movies captured in MP4 or H.264 formats must be converted to AVIs for VMS
- Beware of recompression from one codec to another

- Cameras must be synchronised to avoid systematic errors for objects in motion
- Synchronisation can be provided by:
  - frame grabber/capture hardware
  - purpose-built flashing LED
  - external events eg bottom strike or flash gun
- Hardware synchronisation should always be tested using a short-duration event
- Image sequences may “drift” requiring re-synchronisation – this is a common problem for older camcorders recording to DV tape

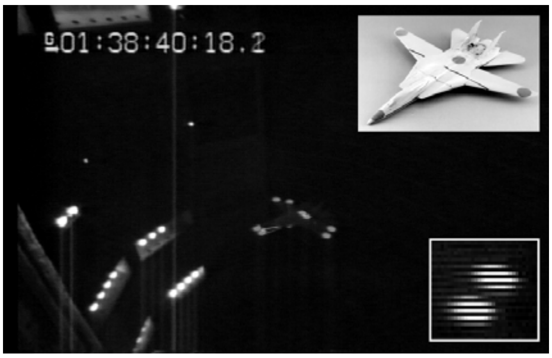
Design Question 27: Image Resolution and Quality

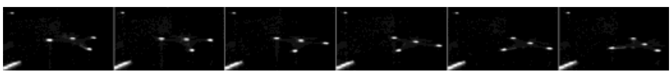
- Image resolution and target diameter should result in target images of 5-10 pixels in diameter
- The quantisation and MTF of the lens will spread the target images over a larger diameter than that predicted from simple theory
- Coded targets must be large enough to be able to separate the code markings
- Coaxial lighting is required for retro-targets
- Target image intensities should be at least 50 levels above the ambient background
- High resolution images lead to greater storage requirements, slower processing and (possibly) very large target images
- Image compression can reduce file sizes but should **not** impact on the precision and accuracy of target image measurement – previous research has shown that only high compression levels result in significant degradations



Frame Rates and Interlace

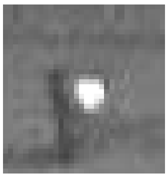
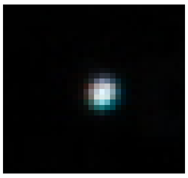
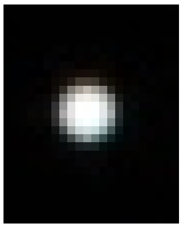
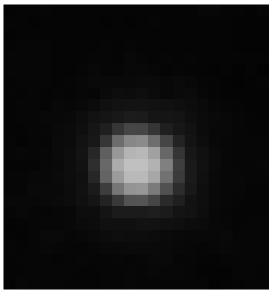
- The frame rate must be adequate to sample the motion
- Broadcast quality camcorders record interlaced images at 30 frames per second (fps)
- De-interlaced images avoid motion effects and sample at 60 fields per second, but halves the vertical resolution
- Progressive scan, digital cameras can record at up to 200 fps
- Specialised cameras can record at 1000+fps

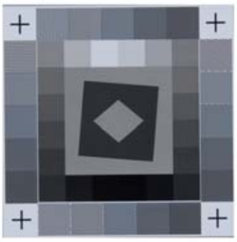
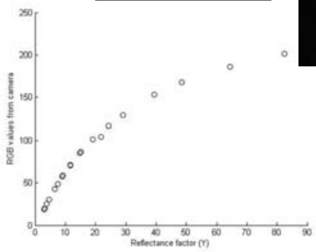




Examples of Target Image Quality and Radiometry

Watec (IR) 0.4MP   Nikon D70 6MP   Nikon D700 20MP   Hasselblad H3D (40MP)

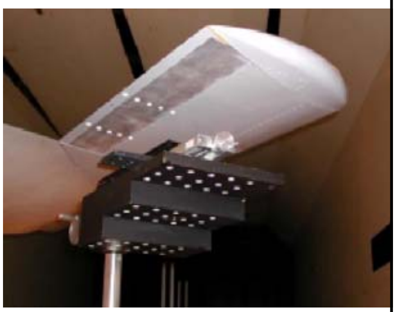
Tone curve for Nikon D200 camera derived from ISO 16067 test chart

-- Remember ! --

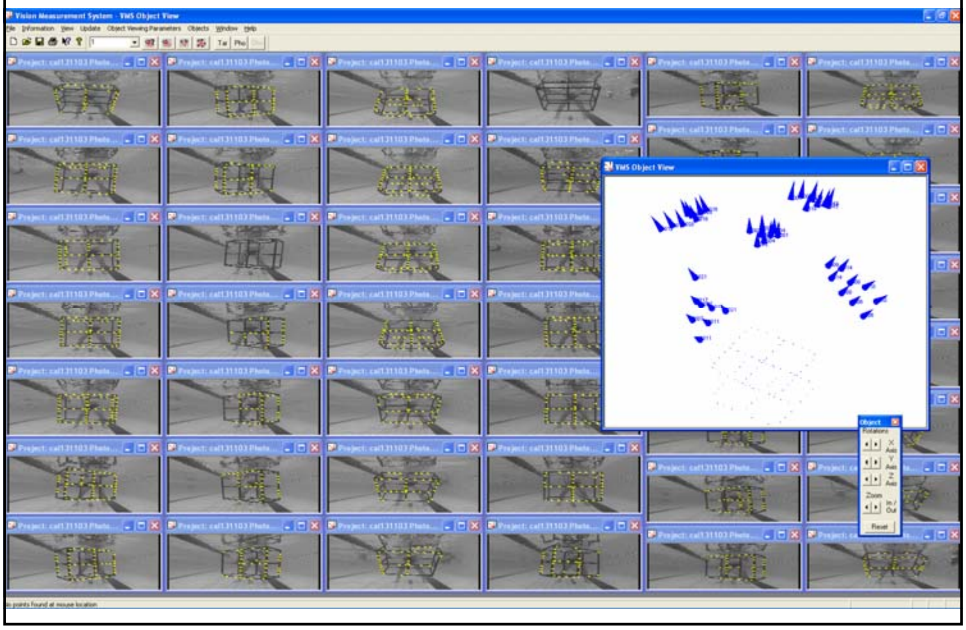
- Target diameter
- Target image diameter
- Image brightness and contrast
- Lens aperture
- Lens angle of view
- Axial illumination
- Range from camera to target

Stereo or Multi Camera Calibration

- Cameras may be pre-calibrated using a test range or in the laboratory
- However optimum accuracy requires in-situ calibration, especially if there is any question regarding camera stability, focus or zoom settings
- A portable calibration fixture is positioned within the field of view of all cameras to allow simultaneous self-calibration
- Rotations of the calibration fixture emulate the multi-camera, convergent network
- An essential requirement is to calibrate the entire measurement volume

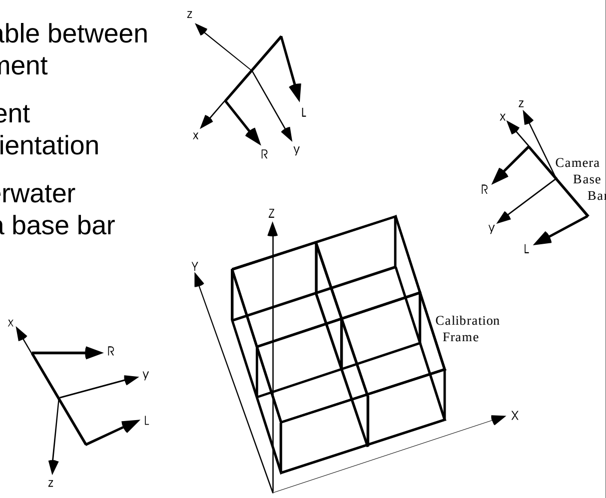



Calibration Image Set



Design Question 99: Relative Orientation or Resection?

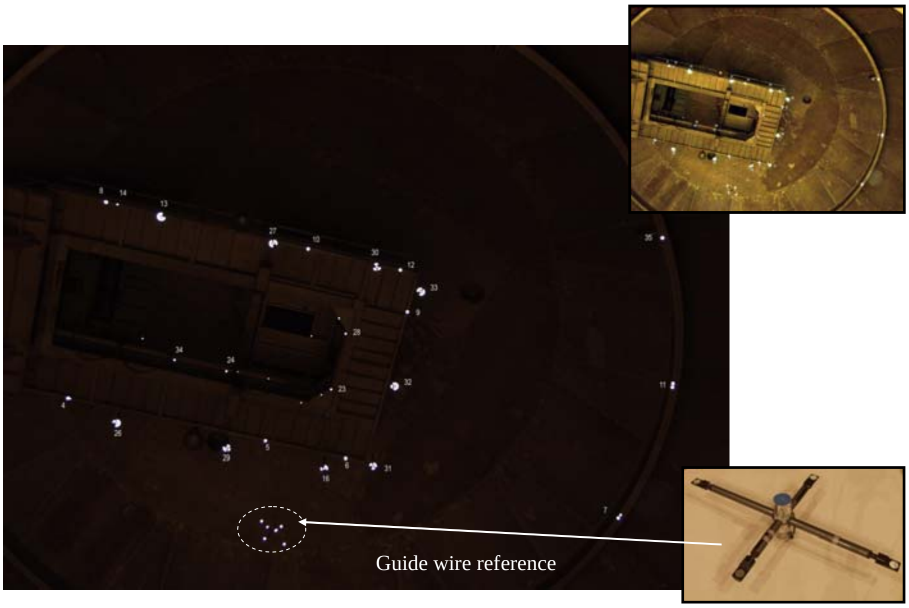
- Relative orientation can be derived as a post-process from an in-situ self-calibration of fixed cameras
- The cameras must be stable between calibration and measurement
- Any instability or movement invalidates the relative orientation
- Commonly used for underwater stereo-cameras fixed to a base bar



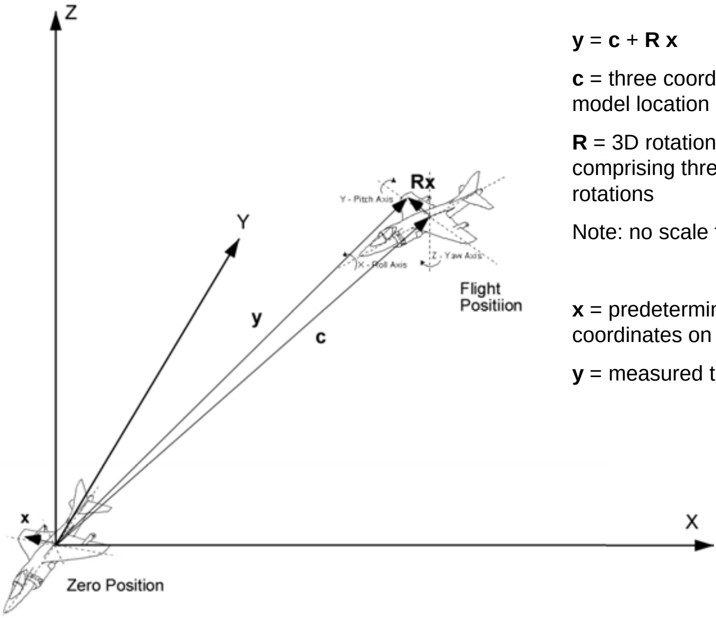
Reference Targets and Resection

- More reliable option if camera stability is in question
- Mandatory if cameras have to be disturbed to record
- Reference targets require an independent survey to establish the 3D coordinates
- Coded targets allow rapid set-up
- Reference targets are measured on every image in the captured sequences by tracking or back driving
- This allows all cameras to be resected for every image set
- Disadvantage may be that the reference targets are not optimally positioned relative to the measurement volume

Ceiling Reference Targets (40m Parachute Drop)



6dof = 3D Transformation = Absolute Orientation



y = **c** + **R x**

c = three coordinates of the model location

R = 3D rotation matrix comprising three orthogonal rotations

Note: no scale factor

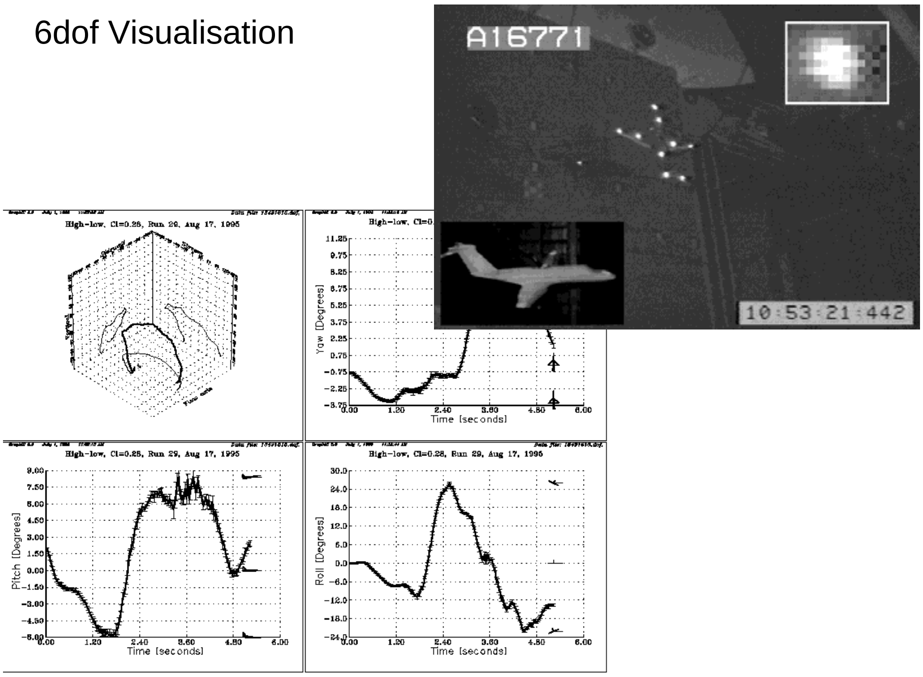
x = predetermined target coordinates on model

y = measured target locations

6dof Computation

- 6dof = 6 degrees of freedom and refers to three coordinates and three rotations of the object
- the 6dof parameters are relative to the initial or zero position of the object
- for example an aerospace model will have an initial position and orientation (usually straight and level flight relative to the airflow)
- the 6dof parameters are computed from a LSE solution to the 3D transformation from the zero position to the current position, based on targets on the object
- the precision of the 6dof parameters is dependent on the number and span of the targets

6dof Visualisation



HELSINKI UNIVERSITY OF TECHNOLOGY
Department of Surveying

RMIT UNIVERSITY

UCL University College London

Day 2 - Session 2

Helicopter Tracking

Set up for calibration and measurement