Chapter 4

1. For a 4-wheel vehicle with $L = 2$ m and width between wheel centres of 1.5 m
   a) compute the difference in wheel steer angle for Ackerman steering around curves of radius 10, 50 and 100 m.
   b) If the vehicle is moving at 80 km h^{-1} compute the difference in wheel rotation rates for curves of radius 10, 50 and 100 m.
2. Write an expression for turn rate in terms of the angular rotation rate of the two wheels. Investigate the effect of errors in wheel radius and vehicle width.
3. Implement the $\ominus$ operator used in Sect. 4.2.1 and check against the code for `angdiff`.
4. For Sect. 4.2.1 plot x, y and θ against time.
5. Pure pursuit example (page 74)
   a) Investigate what happens when the integral gain is zero. Now reduce the frequency of circular motion to 0.01 rev s^{-1} and see what happens.
   b) With integral set to zero, add a constant to the output of the controller. What should the value of the constant be?
   c) Modify the pure pursuit example so the robot follows a slalom course.
   d) Modify the pure pursuit example to follow a target moving back and forth along a line.
6. Moving to a pose (page 75)
   a) Repeat the example with a different initial orientation.
   b) Implement a parallel parking manoeuvre. Is the resulting path practical?

Chapter11

1. Create a central camera and a cube target and visualize it for different camera and cube poses.
2. Write a script to fly the camera in an orbit around the cube, always facing toward the centre of the cube.
3. Write a script to fly the camera through the cube.
4. Create a central camera with lens distortion and which is viewing a 10×10 planar grid of points. Vary the distortion parameters and see the effect this has on the shape of the projected grid. Create pincushion and barrel distortion.
5. Repeat the homogeneous camera calibration exercise of Sect. 11.2.1 and investigate the effect of the number of calibration points, noise and camera distortion on the calibration residual and estimated target pose.
6. Determine the solid angle for a rectangular pyramidal field of view that subtends angles θ_h and θ_v.
7. Do example 1 from Bouguet's Camera Calibration Toolbox.
8. Calibrate the camera on your computer.
9. For the camera calibration matrix decomposition example (Sect. 11.2.2) determine the roll-pitch-yaw orientation error between the true and estimated camera pose.
10. Pose estimation (Sect. 11.2.3)
    a) Repeat the pose estimation exercise for different object poses (closer, further away).

Chapter 12

1. Become familiar with `idisp` for greyscale and color images. Explore pixel values in the image as well as the zoom, line and histogram buttons.
2. Grab some frames from the camera on your computer or from a movie file and display them.
3. Write a loop that grabs a frame from your camera and displays it. Add some effects to the image before display such as "negative image", thresholding, posterization, false color, edge filtering etc.
4. Motion detection
   a) Write a loop that performs background estimation using frames from your camera. What happens as you move objects in the scene, or let them sit there for a while? Explore the effect of changing the parameter σ.
   b) Modify the *LeftBag* example on page 298 and highlight the moving people.
   c) Combine motion detection and chroma-keying, put the moving people from the lobby into the desert.
5. Convolution
   a) Compare the results of smoothing using a 21×21 uniform kernel and a Gaussian kernel. Can you observe the ringing artefact in the former?
   b) Why do we choose a smoothing kernel that sums to one?
   c) Compare the performance of the simple horizontal gradient kernel $K = (-0.5\ 0\ 0.5)$ with the Sobel kernel.
   d) Investigate filtering with the Gaussian kernel for different values of σ and kernel size.
   e) Create a 31×31 kernel to detect lines at 60 deg.
   f) Derive analytically the derivative of the Gaussian in the x-direction Eq. 12.2.
   g) Derive analytically the derivative of the Laplacian of Gaussian Eq. 12.6.
   h) Derive analytically the difference of Gaussian from page 310.
6. Show analytically the effect of an intensity scale error on the SSD and NCC similarity measures.

Chapter 13

1. Greyscale classification
   a) Experiment with `ithresh` on the images `castle_sign.png` and `castle_sign2.png`.
   b) Experiment with the Niblack algorithm and vary the value of k and window size.
   c) Apply `iblobs` to the output of the MSER segmentation. Develop an algorithm that uses the width and height of the bounding boxes to extract just those blobs that are letters.
   d) The function `imser` has many parameters: `'Delta'`, `'MinDiversity'`, `'MaxVariation'`, `'MinArea'`, `'MaxArea'`. Explore the effect of adjusting these.
   e) Apply the function `igraphcut` to the `castle_sign2.png` image. Understand and adjust the parameters to improve performance.

5. Corner detectors
   a) Experiment with the Harris detector by changing the parameters k, σ_D and σ_I.
   b) Compare the performance of the Harris, Noble and Shi-Tomasi corner detectors.
   c) Implement the Moravec detector and compare to Harris detector.

Chapter 14

1. Corner features. Examine the cumulative distribution of corner strength for Harris and SURF features. What is an appropriate way to choose strong corners for feature matching?
2. Feature matching. We could define the quality of descriptor-based feature matching in terms of the percentage of inliers after applying RANSAC.
   a) Take any image. We will match this image against various transforms of itself to explore the robustness of SURF and Harris features. The transforms are: *(a)* scale the intensity by 70%; *(b)* add Gaussian noise with standard deviation of 0.05, 0.5 and 2 greyvalues; *(c)* scale the size of the image by 0.9, 0.8, 0.7, 0.6 and 0.5; *(d)* rotate by 5, 10, 15, 20, 30, 40 degrees.
   b) For the Harris detector compare the performance for the structure-tensor-based feature and and the patch descriptor sizes of 3×3, 7×7 and 11×11 and 15×15.
   c) Try increasing the suppression radius for SURF and Harris corners. Does the lower density of matches improve the matching performance?
   d) The Harris detector can process a color image. Does this lead to improved performance compared to the greyscale version of the same image.
   e) Is there any correlation between outlier matches and strength of the corner features involved?
3. Write the equation for the epipolar line in image two, given a point in image one.

Chapter 15

4. Image-based visual servoing
   a) Run the IBVS example, either command line or Simulink® version. Experiment with varying the gain λ. Remember that λ can be a scalar or a diagonal matrix which allows different gain settings for each degree of freedom.
   b) Implement the function to limit the maximum norm of the commanded velocity.
   c) Experiment with adding pixel noise to the output of the camera.
   d) Experiment with different initial camera poses and desired image plane coordinates.
   e) Experiment with different number of target points, from three up to ten. For the cases where $N > 3$ compare the performance of the pseudo-inverse with just selecting a subset of three points (first three or random three). Can you design an algorithm that chooses a subset of points which results in the stacked Jacobian with the best condition number?
   f) Create a set of desired image plane points that form a rectangle rather than a square. There is no perspective viewpoint from which a square appears as a rectangle. What does the IBVS system do?
   g) Create a set of desired image plane points that cannot be reached, for example swap two adjacent world or image points. What does the IBVS system do?
   h) Use a different camera model for the image Jacobian (slightly different focal length or principal point) and observe the effect on final end-effector pose.