Exam / 31392 / May 2020

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Question 0 (0.0% of the exam)

Welcome to the Exam of the course 31392: Perception for Autonomous Systems!

This exam will take 4 hours. There are 34 questions (excluding this!). Each question has a different weight on your final grade; the weight of each question (as a percent) is indicated in the question description.

In this link you will find all the files (materials and datasets) needed to complete ALL the "numerical" exercises in this exam: link (alternate link)

The folder structure (after you unzip the file) contains the appropriate files per **Question number.**

Note: You can alternatively find the question-specific materials and datasets linked in the respective questions.

	Yes	No
Do you understand that you can either download all the files now or one-by-one in each question?	✔	○
Do you understand that in both cases you will have access to the exact same files?	✔	○

Question 1 (2.0% of the test grade):

Consider the matrix below. Assume that we want to convolve an image with this matrix. What will be the outcome?

0	0	0
0	0	0
0	1	0

- [x] The image will be shifted downwards by 1 pixel
- [ ] The image will remain unaffected
- [ ] The image will be blurred
- [ ] The image will be sharpened
- [ ] The image will be shifted to the right by 1 pixel
- [ ] The image will be shifted upwards by 1 pixel

Question 2 (2.0% of the test grade):

What is the output of a smoothing, linear spatial filter?

- [ ] Median of pixels
- [ ] Maximum of pixels
- [ ] Minimum of pixels
- [x] Average of pixels

Question 3 (2.0% of the test grade):

Which of the following filters response is based on ranking of pixel values?

- [x] Nonlinear smoothing filters
- [ ] Linear Smoothing Filters
- [ ] Sharpening Filters

Question 4 (2.0% of the test grade):

Consider that we are using the following kernel to perform convolution and correlation on an image. Do you expect the results of the two operations to be different or identical and why?

0.2	0	0.2
0	0.2	0
0.2	0	0.2

- ○ The result will be different because none of the kernel elements is larger than 0.5
- ✔ The results will be identical because the kernel is symmetric
- ○ The results will be identical because all the elements of the kernel add up to 1
- ○ The results will be different because convolution and correlation are two different operations

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Question 5 (2.0% of the test grade):

Can we perform corelation using convolution?

- ✔ Yes, by tweaking the kernel
- ○ Yes, by using different input image
- ○ No, correlation and convolution are fundamentally different
- ○ No, we can only perform convolution using correlation, but not the inverse

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Question 6 (2.0% of the test grade):

With regards to **Harris Detector**, select TRUE or False for each one of the following statements?

	True	False
The Harris detector is used in computer vision to detect Corners	✔	○
The Harris detector is used in computer vision to detect Edges	✔	○
Harris detector uses the eigenvallues of the Hessian Matrix of the Image	✔	○
Assuming λ1 and λ2 the eigenvalues of the Hessian Matrix M, points where λ1>>λ2 are considered edges	○	✔
Assuming λ1 and λ2 the eigenvalues of the Hessian Matrix M, points where λ2>>λ1 are considered edges	✔	○
Assuming λ1 and λ2 the eigenvalues of the Hessian Matrix M, points where λ1>>λ2 are considered corners	○	✔
Assuming λ1 and λ2 the eigenvalues of the Hessian Matrix M, points where λ1~λ2 and large are considered corners	✔	○

Question 7 (2.0% of the test grade):

With regards to the **SIFT** algorithm, select TRUE or False for each one of the following statements?

	True	False
The detection is based on the Difference of Gaussians	✔	○
The detection is based on the Gradient of the Image	○	✔
The description is based on the Difference of Gaussians	○	✔
The description is based on the Gradient of the Image	✔	○
The fingerprint of the SIFT algorithm is vector with 64 values	○	✔
The fingerprint of the SIFT algorithm is vector with 128 values	✔	○

Question 8 (2.0% of the test grade):

With regards to the **Hough transform**, select TRUE or False for each one of the following statements?

	True	False
The Hough transform can be used to detect lines	✔	○
The Hough transform can be used to detect circles	✔	○
The Hough transform is a model fitting algortihm	○	✔
The Hough transform is only used in Computer Vision	✔	○
Hough transform can't handle outliers	✔	○
RANSAc should be used as an alternative to the Hough transform when the dimension of feature is high	✔	○

Question 9 (2.0% of the test grade) - Numerical - Hough Line Detection

Using the following image: Link (Alternative Link), do the following

- Convert it to grayscale (do not change the size!).
- Apply Canny edge detection (cv2.Canny) with the parameters "threshold1=100" and "threshold2=200".
- Apply HoughLines (cv2.HoughLines) with the parameters "rho=1", "theta=0.0017", "threshold=200".

How many lines are detected?

- [ ] 16
- [x] 32
- [ ] 64
- [ ] 128

Question 10 (2.0% of the test grade) - Numerical - Harris Corner Detection

Using the following image: Link (Alternative Link), do the following:

- Convert the image to grayscale (do not change the size!).
- Apply Harris corner (cv2.cornerHarris) to the image with the parameters "blockSize=2", "ksize=3", "k=0.04".

From the result of Harris Corners, how many values are above 0.01?

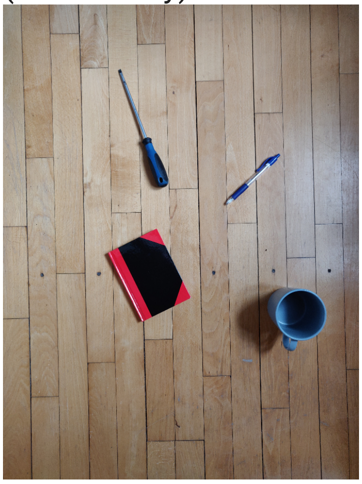
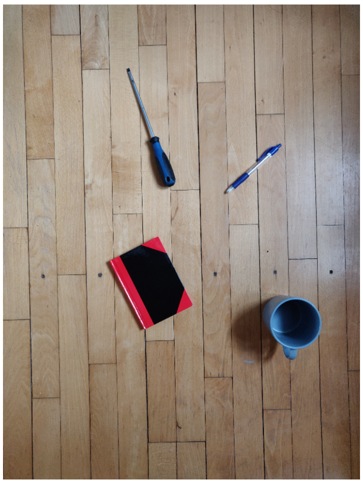
- ○ 128
- ○ 158
- ○ 188
- ○ 208

Question 11 (2.0% of the test grade) - Numerical - Optical Flow

Using the following **2 images**: Link 1 (Alternate Link 1), Link 2 (Alternate Link 2), do the following:

- Load the two images and convert them to grayscale (do not change the size!).
- Use cv2.goodFeaturesToTrack to find features on the first image (things1.png) using the parameters "maxCorners=100", "qualityLevel=0.3", and "minDistance=7".
- Apply sparse optical flow using the function ccv2.calcOpticalFlowPyrLK()

What is the maximum amount of pixels moved for any object in the x direction (horizontally)?

- ~15.5
- ~12.5
- ~20.5
- ~22.5

Question 12 (4.0% of the test grade):

You have measured a series of sensor intensities using a laser range finder and you are trying to find a specific object in this series.
The series you have measured is: [47, 211, 38, 53, 204, 116, 152, 249, 143, 177]
You know the shape of the object should follow the intensities: [39, 55, 207]

To do this you have decided to use SAD template matching. What is the best matching triplet in your measurements with your known object shape and what is the SAD for this match?

	Correct	Wrong
The best matching triplet is: [47, 211, 38]	○	○
The best matching triplet is: [116, 152, 249]	○	○
The best matching triplet is: [38, 53, 204]	○	○
The SAD score for the best matching triplet is: 6	○	○
The SAD score for the best matching triplet is: 2	○	○
The SAD score for the best matching triplet is: 0	○	○
The SAD score for the best matching triplet is: 333	○	○

Question 13 (2.0% of the test grade):

A rectified stereo system is a simplified version of the general stereo case. Which of the following statements are correct and which are wrong?

	Correct	Wrong
Epipolar geometry can be used to describe both unrectified and rectified stereo cases	○	✔
The rectified stereo case is computationally simpler to treat	✔	○
We can obtain rectified stereo image pairs in practice by physically mounting the two sensors on a common plane	✔	○
Epipoles do not exist in rectified stereo, because all epipolar lines are parallel	○	✔
The disparity value of a point grows with its depth	✔	○
We cannot obtain depth from stereo without knowing the system's focal length and baseline	✔	○

Question 14 (2.0% of the test grade):

Which of the following statements about stereo correspondece algorithms are correct and which are wrong?

	Correct	Wrong
Local algorithms typically produce inferior disparity maps, compared to global algorithms	✔	○
Bigger windows for calculating dis-similarity metrics such as SAD or SSD result always in better disparity results, at the expense of more calculations	✔	○
Bigger windows for calculating dis-similarity metrics such as SAD or SSD result always in worse disparity results, but calculation is faster	○	✔
Smaller windows are typically preferred for images with finer and more complicated texture	○	✔

Question 15 (2.0% of the test grade):

Could convolution be used to implement (dis-)similarity calculations in stereo matching?

- ◯ Yes, but with proper considerations for formulating the kernel
- ◯ No, it is correlation that expresses (dis-)similarity
- ◯ Yes, because in (dis-)similarity calculations the considered kernel is symmetric
- ◯ No, because in convolution the kernel needs to be smaller than the image

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Question 16 (2.0% of the test grade):

With regards to **the monocular camera Projection and Calibration**, select TRUE or False for each one of the following statements?

	TRUE	FALSE
The projection matrix includes instrinsic parameters	◯	◯
The projection matrix includes extrinsic parameters	◯	◯
The Homography is used to project a point from 3D to 2D	◯	◯
When using a flat calibration pattern we can employ the homography to perform calibration	◯	◯
Lens distortion is modeled as a polynomial	◯	◯

Question 17 (2.0% of the test grade):

With regards to **the stereo camera Projection and Calibration**, <u>select TRUE or False</u> for each one of the following statements?

	TRUE	FALSE
The Fundamental Matrix describes only extrinsic parameters	○	○
The Essential matrix contains only extrinsic parameters	○	○
The camera matrix can be calculated from the Fundamental Matrix	○	○
The Fundamental matrix projects **image points** from one image of the stereo pair to the other	○	○
The epipoles of a stereo pair are found at the intersection of the epipolar lines	○	○
The epipoles of the stereo system are found at the intersection of the baseline with the camera planes	○	○

Question 18 (6.0% of the test grade): - Numerical - Stereo Calibration

One property of stereo rectified images is that epipolar lines are parallel, and that the points on an epipolar line in one image plane can be found on the corresponding epipolar line in the other image plane. Therefore, it is necessary to know the equation for the epipolar in order to optimize the performance of any later template matching.

Determine the approximate coefficients of the epipolar lines in the imageset left.png and right.png by taking the average of all the epipolar lines. You should use **2000** of the best matching sift keypoints to compute the epipolar lines.

Note: opencv computes the epipolar lines in the form ax+by+c=0.

Using the following images: link to left.png (Alternative link to left.png), link to right.png (Alternative link to right.png)

Please select the average epipolar lines that are closer to the ones you calculated

 

- [-1.69333264e-02 7.97691572e-01 -0.26727486e+02]
  [17.0291542e-02 -7.9747336e-01 0.2541019e+02]

- [-6.69333264e-02 9.97691572e-01 -1.26727486e+02]
  [7.0291542e-02 -9.9747336e-01 1.2541019e+02]

- [-11.69333264e-02 17.97691572e-01 -1.06727486e+02]
  [11.0291542e-02 -17.9747336e-01 1.0541019e+02]

- [-2.69333264e-02 3.97691572e-01 -0.06727486e+02]
  [1.0291542e-02 -3.9747336e-01 0.0541019e+02]

Question 19 (3.0% of the test grade):

The number of iterations k that RANSAC needs in order to achieve a good (outlier-free) model with probability p
is defined by the formula: $k = \frac{log(1-p)}{log(1-w^2)}$
where k is the number of iterations, p is the probability of RANSAC having chosen a set of points free of outliers, w is the proportion of inliers with respect to all the points in the dataset.

SUB-QUESTION A

- Assume that we want a probability of success at least 98% and we know that 75% of the points are inliers. How many iterations does RANSAC need to achieve this?

SUB-QUESTION B

- How would the number of needed iterations change if the size of our dataset (number of points) doubled, but all other aspects of our scenario remained the same?

	Correct	Wrong
The number of needed iterations is: k = 3	○	○
The number of needed iterations is: k = 5	○	○
The number of needed iterations is: k = 14	○	○
The number of needed iterations is: k = 64	○	○
With a dataset twice as big, the number of required iterations would be half	○	○
With a dataset twice as big, the number of required iterations would be the same	○	○
With a dataset twice as big, the number of required iterations would be double	○	○

Question 20 (3.0% of the test grade):

The Iterative Closest Point (ICP) algorithm is often used during point cloud registration.
Which of the following statements about ICP are correct and which are wrong?

	Correct	Wrong
ICP is a deterministic algorithm	✔	○
ICP is guaranteed to converge (within a reasonable accuracy) no matter what the initial relative pose of the two point clouds is.	○	✔
ICP is one of the underlying algorithms for implementing the Kabsch algorithm	✔	○
In ICP, all intermediate transformations until convergence are applied always to the same of the two point clouds	✔	○
ICP could employ either Spin Images or FPFH for finding the interediate transformations until convergence	✔	○
ICP is not particularly robust to outliers	✔	○
When using ICP, one needs to choose either the Kabsch algorithm or the Procrustes analysis	✔	○

Question 21 (1.0% of the test grade):

In Point Cloud Registration, local alignment usually takes place first, and global alignment second.
Is the statement correct or wrong?

- ○ Correct
- ✔ Wrong

Question 22 (1.0% of the test grade):

The Kabsch algorithm is typically used both for Local and Global alignment.

- ✔ Yes, the Kabsch algorithm is used in both cases
- ○ No, the Kabsch algorithm is only used for Local alignement
- ○ No, the Kabsch algorithm is only used for Global alignment

Question 23 (10.0% of the test grade):

Apply K-means and PCA on a provided dataset and select the correct answers the following questions.
Required material and guidelines are provided in this archive: [link] *(alternative link to the same archive [link]).*

SUB-QUESTION A

- Use the elbow method to find how many clusters are optimal for this dataset.
  - Follow the guidelines and use the material found in the provided archive.

SUB-QUESTION B

- Perform PCA on the provided dataset and determine the minimum number of components required to express 95% of the variance.
  - Follow the guidelines and use the material found in the provided archive.

SUB-QUESTION C

- Perform K-means on the PCA transformed data and calculate the Inertia (sum of squared differences of samples to the closest centroid)
  - Use the value of K found in SUB-QUESTION A and apply K-means on the PCA transformed data that you obtained in SUB-QUESTION B.
  - Follow the guidelines and use the material found in the provided archive.

	Correct	Wrong
The optimal K is: 3	○	✔
The optimal K is: 4	○	✔
The optimal K is: 5	✔	○
The optimal K is: 6	✔	○
For 95%, the number of needed components is: 3	○	✔
For 95%, the number of needed components is: 4	○	✔
For 95%, the number of needed components is: 5	○	✔
For 95%, the number of needed components is: 6	✔	○
Inertia has a value between: 3000 and 3500	○	✔
Inertia has a value between: 4000 and 5000	○	✔
Inertia has a value between: 5000 and 5500	○	✔

Question 24 (6.0% of the test grade):

Apply Linear Regression to the provided data to obtain a model of the form *y=ax+b*. Follow the provided guidelines for the implementation.
What are the values of the parameters "a" and "b" in that model (APPROXIMATELY)?
Required material and guidelines are provided in this archive: [link] *(alternative link to the same archive [link]).*

	Correct	Wrong
a = 0.55	✔	○
a = 0.23	○	✔
a = 0.82	○	✔
b = 12.37	○	✔
b = 19.86	✔	○
b = 25.60	○	✔

Question 25 (1.0% of the test grade):

The clustering algorithm DBSCAN needs to assign some points as "noise points".
Is this statement correct or wrong?

- [x] Correct
- [ ] Wrong

Question 26 (2.5% of the test grade):

With regards to **State Estimation**, select TRUE or False for each one of the following statements?

	TRUE	FALSE
Histogram Filter Concerns Discrete States	☑	○
Kalman Filter Concerns Discrete States	○	☑
Histogram Filter Concerns Unimodal Uncertainty Distributions	○	☑
Kalman Filter Concerns Unimodal Uncertainty Distributions	☑	○
In the Histogram filter, measurement involves Bayes rule and movement involves convolution	☑	○
In Kalman filter, the variance of the estimation is higher after measurement	○	☑
In Kalman filter, the variance of the estimation is higher after movemtn	☑	○

Question 27 (5.0% of the test grade) - Numerical - Kalman Filter, State Prediction, Covariance Prediction

You are tracking an object with a Kalman filter. At the current time the state is:

x	3
x'	0.5
y	2
y'	0.33

and the current covariance is:

5	1	0	0
1	2	0	0
0	0	5	1
0	0	1	2

With x and y being the position in the x and y direction and x_dot, y_dot being the velocities in the x and y direction.
We assume the object follows a constant velocity model and that there are no external forces (u=0) and no process noise.

If we have a timestep of dt=1, What is:
The next predicted state and the next predicted covariance?

○

x	4
x'	0.5
y	2
y'	0.33

5	4	0	0
4	2	0	0
0	0	5	4
0	0	4	5

○

x	3
x'	1
y	2
y'	0.33

1	2	0	0
2	1	0	0
0	0	1	4
0	0	4	1

✔

x	3.5
x'	0.5
y	2.33
y'	0.33

9	3	0	0
3	2	0	0
0	0	9	3
0	0	3	2

○

x	3
x'	0.5
y	2.33
y'	0.33

7	1	0	0
1	2	0	0
0	0	7	1
0	0	1	2

Question 28 (2.5% of the test grade) - Numerical - Kalman Tracking

You are now tracking a different object using a Kalman filter and a constant velocity model. You have just predicted the state and covariance:

x	5
x'	0.5
y	7
y'	0.8

0.2	0	0	0
0.2	0.1	0	0
0	0	0.2	0
0	0	0.2	0.1

Furthermore, we have just measured the position of the object to be:

4.8
7.1

Finally, we have the observation noise R:

0.2	0.2
0.2	0.2

What is the state after having updated it with the current measurement (do not run the predict step, only the update step)?

- [x]

x	4.833333
x'	0.333333
y	7.133333
y'	0.933333

- [ ]

x	5.133333
x'	0.633333
y	6.933333
y'	1.133333

- [ ]

x	4.933333
x'	0.533333
y	7.033333
y'	0.833333

- [ ]

x	4.733333
x'	0.533333
y	6.833333
y'	0.833333

Question 29 (6.0% of the test grade):

You will train and test a Support Vector Machine (SVM).
Required material and guidelines are provided in this archive: [link] *(alternative link to the same archive [link]).*

SUB-QUESTION A
- Examine the provided code. What proportion of the original dataset is used for **training**?

SUB-QUESTION B
- Apply a SVM as instructed in the provided code. What is the reported accuracy of your SVM (APPROXIMATELY)?

	Correct	Wrong
Proportion used for training: 30%	○	✔
Proportion used for training: 70%	✔	○
Proportion used for training: 75%	○	✔
Accuracy: 0.83	○	✔
Accuracy: 0.92	✔	○
Accuracy: 0.96	○	✔

Question 30 (1.0% of the test grade):

he classification algorithm k-NN requires approximately similar time for training and testing (inference).
Is this statement correct or wrong?

- ○ Correct
- ✔ Wrong

Question 31 (2.0% of the test grade) - Visual Odometry

Concerning **Visual Odometry**, select TRUE or False for each one of the following statements?

	TRUE	FALSE
The 3D to 3D methods are less accurate than the 3D to 2D ones	☑	○
The axis angle representation suffers from the "gimbal lock" problem	○	☑
Visual Odometry can only be performed on a frame to frame manner	☑	○
3D to 3D approaches use the image coordinates of the current frame and the 3D position of the previous frame to estimate the motion	☑	○
2D to 2D methods are "accurate up to scale"	☑	○
3D to 2D methods use the PnP solutions	☑	○
2D to 2D methods are equivallent to calculating the essential matrix	☑	○

Question 32 (10.0% of the test grade) - Numerical - Visual Odometry

As an alternative to GPS, a car is driving while recording images with a stereo camera setup with the goal of tracking the relative position of the car.

The two directories left and right contain timestamped images from the drive. [link to zip of the folders]() ([Alternative link to zip of the folders]())

The steps to tracking the car is as follows:

- Do only once:
  1.1. Capture two frames I_{k-2}, I_{k-1}
  1.2. Extract and match features between them
  1.3. Triangulate features from I_{k-2}, I_{k-1}
- Do at each iteration:
  2.1. Capture new frame I_k
  2.2. Extract features and match with previous frame I_{k-1}
  2.3. Compute camera pose (PnP) from 3-D-to-2-D matches
  2.4. Triangulate all new feature matches between I_k and I_{k-1}
  2.5. Iterate from 2.1

Compute the final Pose (Position: [X,Y,Z] Orientation: [axis angles x, axis angles y, axis angles z]) of the car.

- ○ Position = [-11.908 [0.984] [1.727]
  Rotation = [0.000] [1.296] [0.002]
- ○ Position = [-16.908] [0.684] [11.727]
  Rotation = [0.0102] [1.596] [0.072]
- ○ Position = [-6.908] [0.384] [4.727]
  Rotation = [0.040] [1.396] [0.271]
- ○ Position = [-7.908] [0.184] [7.727]
  Rotation = [0.040] [1.996] [0.471]

Question 33 (2.0% of the test grade):

With regards to **non-linear least squares optimization** for SLAM select TRUE or False for each one of the following statements?

	TRUE	FALSE
Gauss-Newton suffers from overshooting	✔	○
Gradient-Descent suffers from slow covergence	✔	○
Levenberg Marquadt is a combination of Gauss-Newton and Gradient Descent	✔	○
Levenberg Marquadt suffers from all the above	○	✔

Question 34 (2.0% of the test grade):

With regards to SLAM select TRUE or False for each one of the following statements?

	True	False
SLAM is concerned solely with the identification of the position of a camera	○	✓
SLAM is defined as a graph where nodes are the poses/landmarks and edges are the observations/odometry	✓	○
The goal of SLAM is to satisfy all the constrains in the pose graph	✓	○