Virtual Reality Engineering
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Lecture - 88
Introduction to Extended Kalman Filter

In the last video, we looked at Kalman filter, which is which can be useful for SLAM techniques. There is an extended Kalman filter which is used in most of the SLAM algorithms. In this next few minutes, we are going to see, what is the difference between the Kalman filter and the extended Kalman filter, and then see how we can use the extended Kalman filter in a simple visual SLAM.

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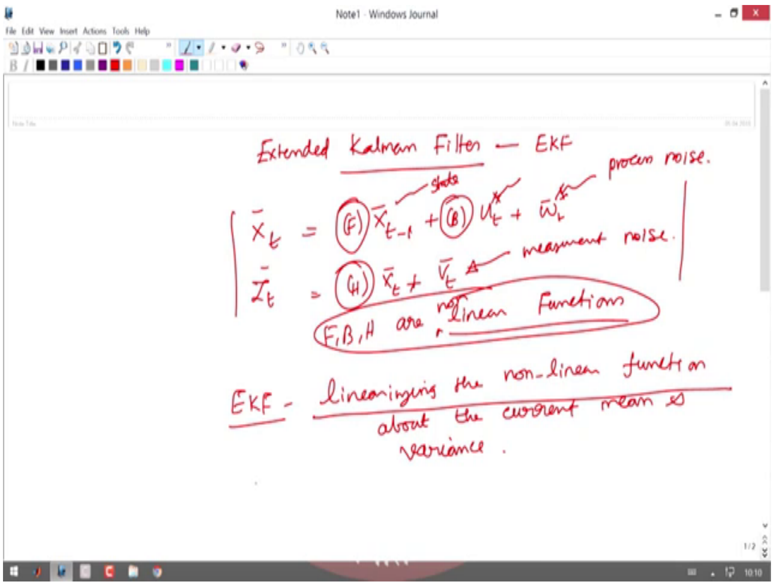

We are talking about a extended Kalman filter, usually it is called EKF in the reading material or and the textbooks. So, the Kalman filter what we looked at is if you just for recollecting, we have this state vector t plus 1, we wanted to you know predict this state vector from the earlier state, it should be yes or earlier state vector some function. And another function into you know u of t it is a control this is the you know position or yeah state vector, the earlier time stamp, this is the control vector earlier at the current state and also some noise right, this is the process noise we said process noise.

And similarly, we have this is a measurement as a some function of t you know x of t, and there is a there is a measurement noise measurement noise. These are the two equations we saw in the last class about the Kalman filter.

So, these functions we mentioned that this is a F function, this is a B function, this is a H function. These functions it is assumed to be linear functions; F, B, and H are linear functions. If it is a linear function, this algorithm works fine, but usually in most of the real cases they are all non-linear functions, it is not linear a linear function. If it is not non-linear, then and we need to we cannot at use the Kalman filter as it is, we need to linearize the non-linear equations and before we use it for the VSLAM techniques.

So, EKF is nothing but linear version of linear version of linearizing the non-linear functions about the current mean and you know variance. So, it is an approximation of the non-linear functions which is most of the cases in a in a real situations so that is what the EKF of Kalman filter is extended Kalman filter is.

Again I am not going to go into the details of the mathematical equations, I am going to give a tutorial in the website; I am going to ask you to go through the tutorial and then do a very simple assignment as required in the in the course that will help you to you know pick up the real basic concepts of the Kalman extended Kalman filter which is necessary for the visual SLAM ok.

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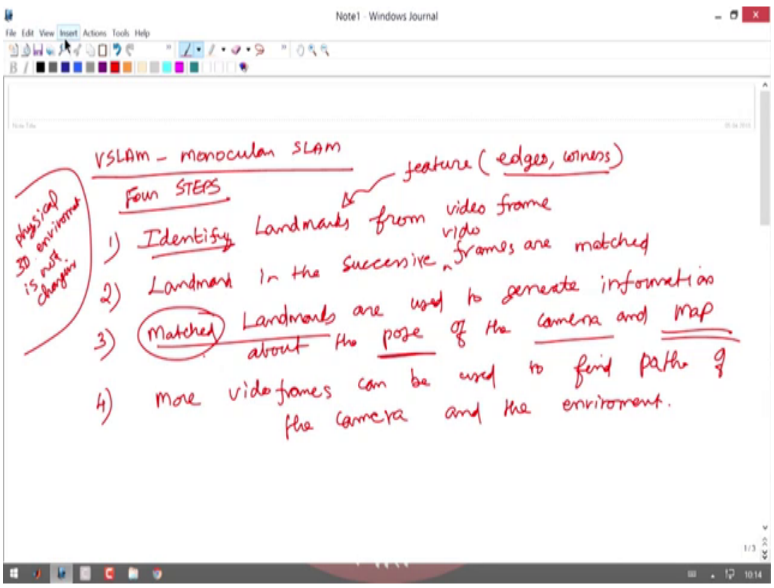

Now, with EKF how can we do these visual SLAM. In the visual SLAM essentially VSLAM, specifically we are going to look at the monocular monocular slam, monocular SLAM involves really four steps; the first step is the identification of the landmarks from the images, identify landmarks from images, from video frame. So, this is the landmarks are also called the features.

The features are examples of these features are the edges or corners so many edges and corners in a typical image is can be used as a no landmark. Identifying the landmark is the first step in an image for the monocular slam, and then landmarks in these successive frames are matched in these successive frames, we are talking about the video frames; video frames are matched.

So, the next take the next frame from the video and identify this same landmarks, and make there may be a different set of features in the second frame. And match the feature set from first frame and the second frame, once you have the match then the matched landmarks are used to generate information generate information, about the pose of the camera pose of the camera and the map of the environment.

The matched through landmarks can then be used to estimate the pose, and the map of the environment. Then you know more video frames, frames can be used can be used to find the path of the camera, camera and the environment right, these are the four steps.

Only one assumption major assumption in all these four steps is that the environment is not changing, the 3D you know or physical environment. Physical environment is not changing; if it is changing then the features may be different. So, we may not be able to match the landmarks if we cannot match the landmarks, then the pose and the mapping cannot be you know estimated. This estimation again will be you know using these EKF algorithms, which we just talked about. So, visual SLAM or monocular SLAM involves mostly these four steps.

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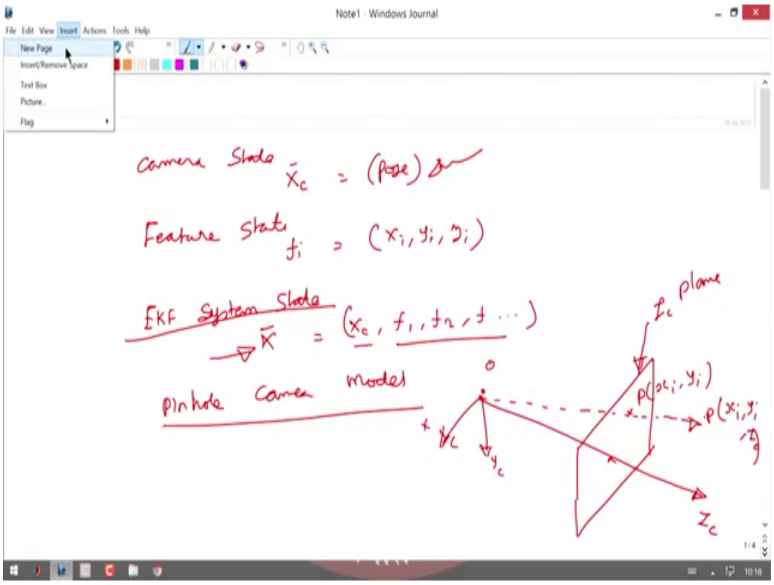

So, in a visual SLAM the camera state can be written as, let us say camera state is nothing but the pose. The pose can be either in a quaternion or vector notation, or anything you can use. And then we have this feature state, let us say feature state i, each feature state let us say x i, y i, z i. And then we can say EKF system state we can write that is nothing but x is nothing but the camera, comma x 1, f 1, f 2, feature two and such like this.

So, this is a system state and for each of this state it is we can also come up with the variance matrix, and the estimation or the measurement from the camera also will have a variance. And the prediction stage as well as the update stage can be you know used to a accurately estimate the pose as well as a map of it. Again in a in all of this algorithms, the pinhole camera model is used. In the pinhole camera model, we have one image and we have the origin over here; and in this origin we are talking about the x, and then we are talking about the y, and then we can talking about the z which is going through this one, so this is going to be the z of the camera, let us say these are all camera.

And any point on the image then can have a ray let us say this point p is x of i, y of i, then this ray can be of p of x of i, y of i comma z of c, z of c this is the depth of the this particular plane right z c plane. So, all the points on the plane will have the depth z of c, there is a pinhole camera so with this simple camera model I will we can and the EKF algorithm. We can recursively estimate the pose as well as the map of this map of the environment that is a monocular SLAM.

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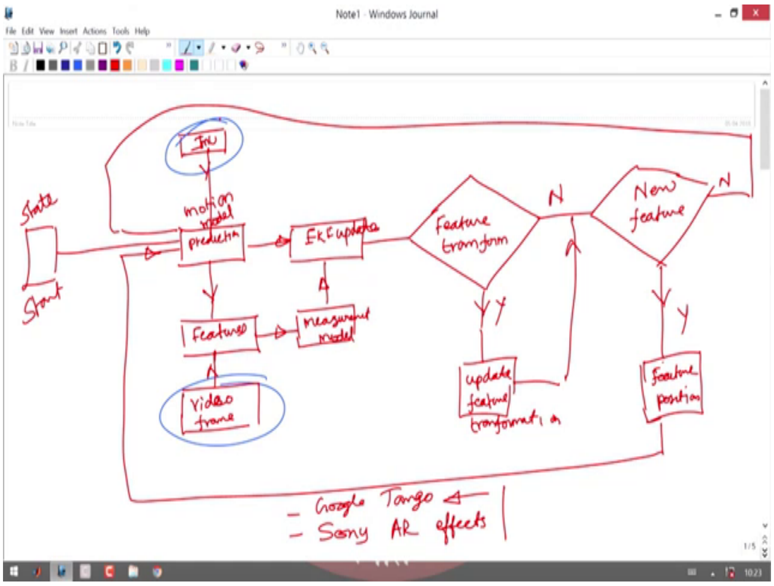

So, again to make it a little more clear. Let us start with yeah video frame, from the video frame let us estimate features, and from the features let us do the measurement model, from the measurement model we have this EKF update, from the EKF update the EKF update also needs prediction right; model prediction, motion model prediction so motion model prediction right. And the from the motion model prediction, again the features it can be a input to the feature. And this motion model prediction can be you know can have input from IMU also, these are the inputs.

So, let me put this as an input, there is an input right. And then so you are we are talking about the after the update, we are talking about the we were checking whether the features are feature transform, or there any change in the feature each of the feature; if there is yes then and up update the feature transformation, if there is no it is again going over here, if it is no let us say this is no..

Then we are talking about the are there any new features predictor new features; if there are new features yes then we give this to the prediction state, if there are no new feature again we give this back to prediction. So, basically if there is yes then, we are talking about the feature position or matching, or yeah position we are talking about, estimative feature position, which can be given back to this. Initially it we might need to start with some you know initial variables start starting states, this is a typical virtual SLAM or monocular SLAM works.

So, in this case we have taken IMU also has an input, in most of the cases you know IMU may not be necessary, or some cases is IMU with the help of IMU, it might give you much more better results. I am sure you are all aware of the Google Tango projects, Google Tango projects. And unfortunately this project is you know stopped recently. If you are not aware of it, you can download this Google Tango app into your mobile phone and then play with this. And recently there is also Sony AR effects Sony AR effects.

So, if you are not aware of it, at I am going to request you to pause this video for a minute, and then play with this Sony AR of effects in your mobile phone, and then continue this tutorial. So, we are also you know giving you a link for the you know extended Kalman filter tutorial. I will in this website as. So, please practice this tutorial very well, which is going to be you know useful for many of the AR projects in the coming years. We will stop here.

Thank you.