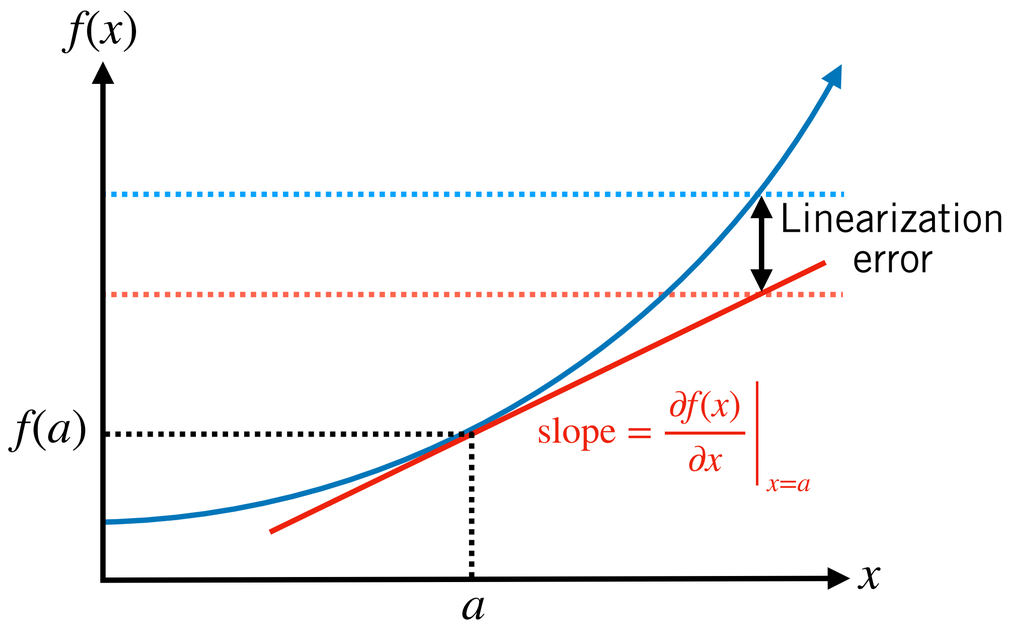
MODULE 2 LESSON 5

# LIMITATIONS OF THE EXTENDED KALMAN FILTER

# **Limitations of the EKF** | Linearization error

The EKF works by *linearizing* the nonlinear motion and measurement models to update the mean and covariance of the state

The difference between the linear approximation and the nonlinear function is called *linearization error*



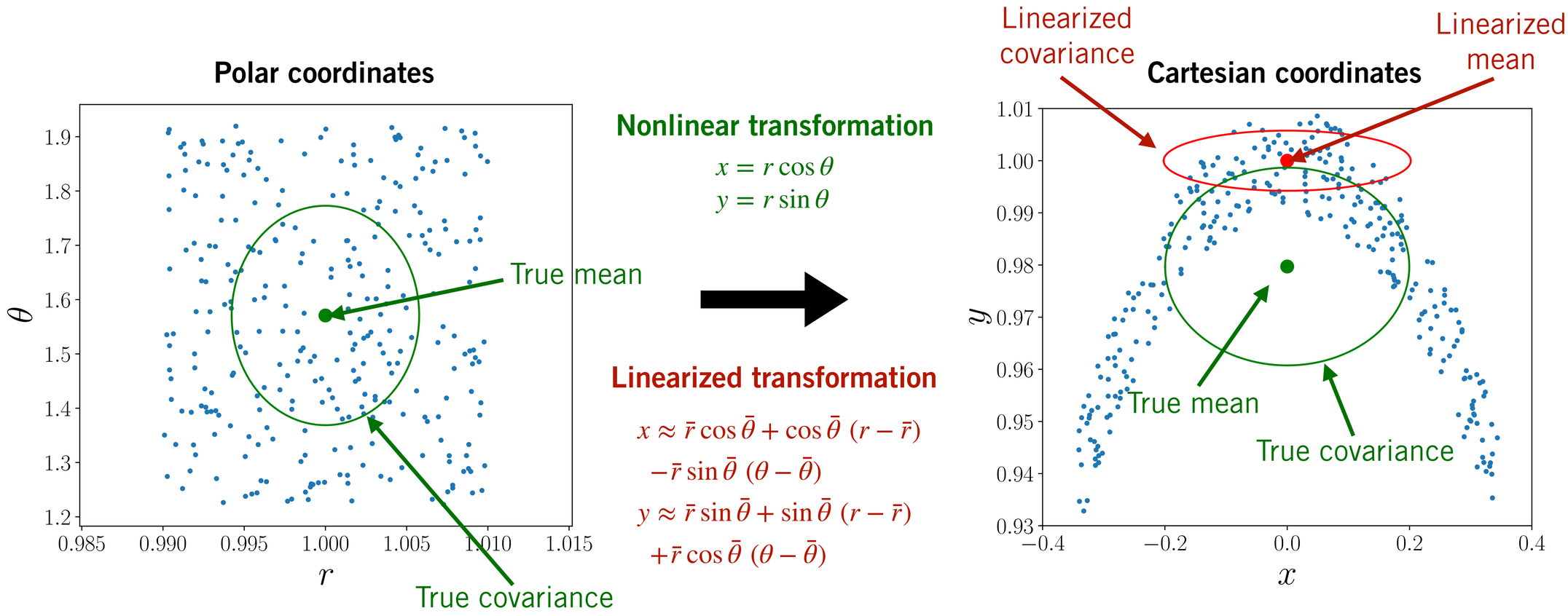

In general, linearization error depends on

1. How nonlinear the function is
2. How far away from the operating point the linear approximation is being used

$$f(x) \approx f(a) + \left.\frac{\partial f(x)}{\partial x}\right|_{x=a} (x - a)$$

# **Linearization Error** | Example

Let's look at an example of how linearization error affects the mean and covariance of a random variable transformed by a nonlinear function:



# **Limitations of the EKF** | Linearization Error

The EKF is prone to linearization error when

1. The system dynamics are highly nonlinear
2. The sensor sampling time is slow relative how fast the system is evolving

How far away from the operating point

This has two important consequences:

1. The estimated mean state can become very different from the true state
2. The estimated state covariance can fail to capture the true uncertainty in the state

**Linearization error can cause the estimator to be overconfident in a wrong answer!**

# **Limitations of the EKF** | Computing Jacobians

Computing Jacobian matrices for complicated nonlinear functions is also a common source of error in EKF implementations!

- Analytical differentiation is prone to human error
- Numerical differentiation can be slow and unstable
- Automatic differentiation (e.g., at compile time) can also behave unpredictably

What if one or more of our models is non-differentiable?

Do we really need linearization for nonlinear Kalman filtering?

# **Summary** | Limitations of the EKF

- The EKF uses analytical local linearization and, as a result, is sensitive to linearization errors
- For highly nonlinear systems, the EKF estimate can *diverge* and become unreliable
- Computing complex Jacobian matrices is an error-prone process and must be done with substantial care