# Image Formation

**Discussion #2**

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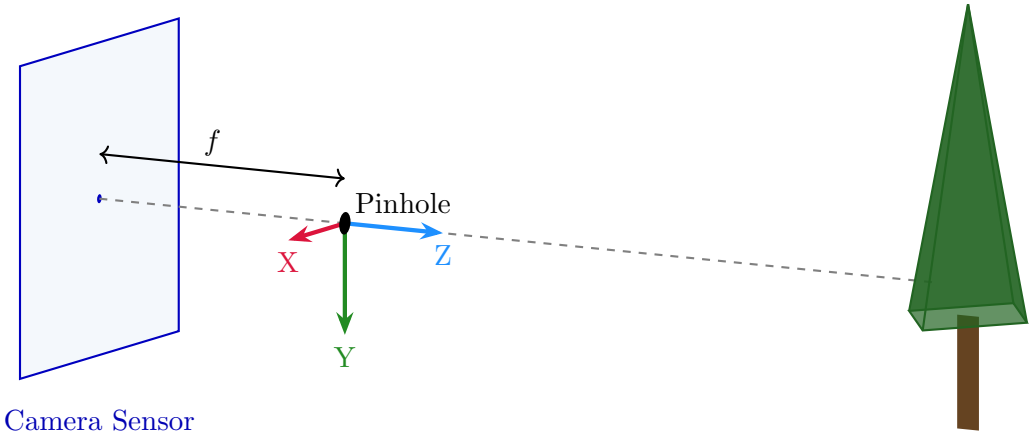
## Topics

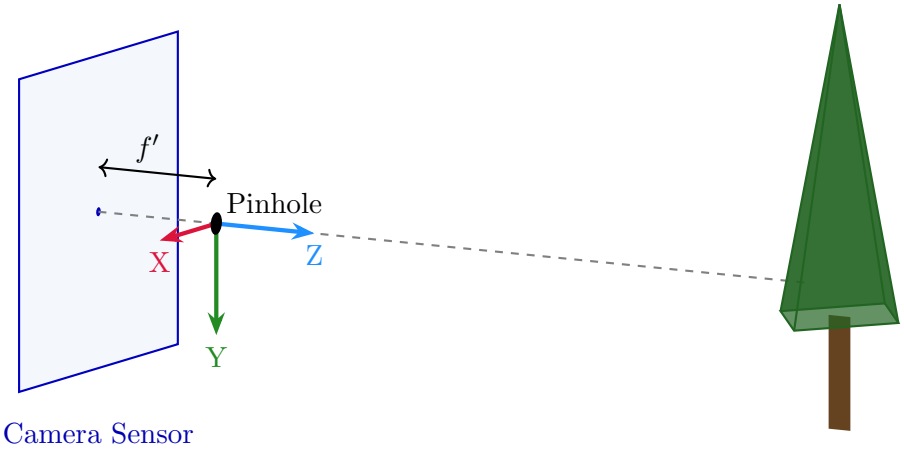
This section covers the pinhole camera model.

## 1 Warmup

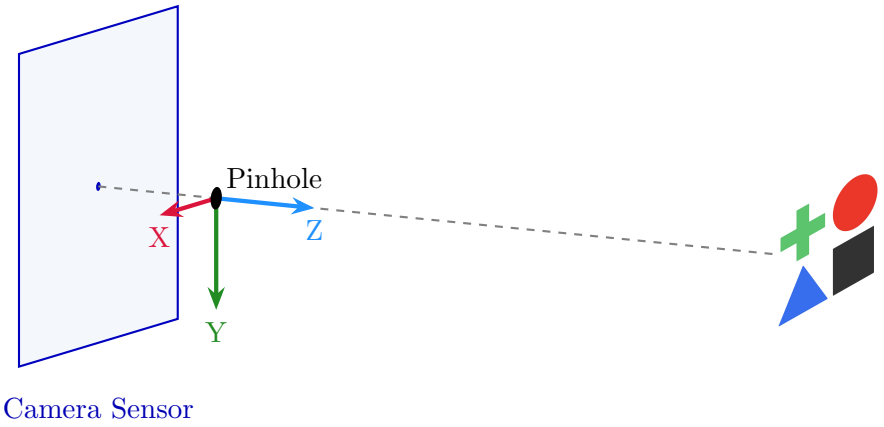
**Problem 1.1:** Chung Min points a pinhole camera with focal length $f$ directly at a beautiful ponderosa pine tree. How is this object projected onto the image? Draw on the sensor below.




**Problem 1.2:** Unhappy with the original composition, Chung Min shortens the focal length of the camera. How does the image change? Draw on the sensor below.



**Problem 1.3:** Let's try on a harder object. Draw the image as it appears on the sensor below.




**Problem 1.4:** Assume the object has a height of $H$, and is located distance $d$ away from the camera. Given focal length $f$, how tall is the projected object on the image plane?

## 2 Dolly Zoom

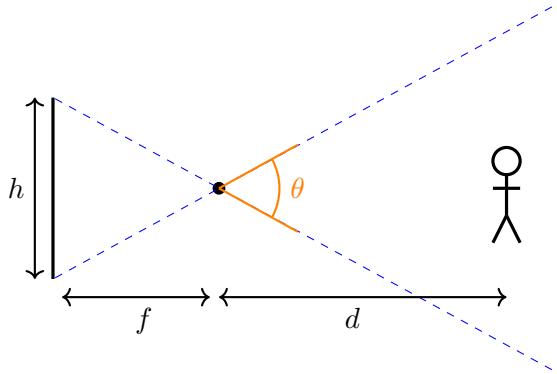
In Project 0, we saw the dolly zoom effect, where multiple camera parameters are adjusted to keep a subject the same size in the image.

**Problem 2.1:** ***Project 0 recap.*** Between Problem 1.1 and 1.2, Chung Min decided to shorten the camera's focal length. In words, what else needs to be done to achieve a dolly zoom effect?

**Problem 2.2:** ***How to zoom?*** A camera has initial focal length $f$, and is placed a distance $d$ from a subject. If the camera is moved to distance $d'$, what focal length $f'$ would maintain the subject's size in the image?

**Problem 2.3:** ***Zoom vs crop.*** Can you achieve the dolly zoom effect without changing the physical focal length of the camera system? Assume $d' > d$.

**Problem 2.4:** ***Angles.*** Real-world computer vision systems often have to grapple with multiple conventions for camera geometry. One that we saw in lecture was field-of-view, which can be expressed in radians as $\theta$:




Given initial field-of-view $\theta$, initial subject distance $d$, updated subject distance $d'$, how can we compute updated FOV $\theta'$ to achieve the dolly zoom effect?

*Hint: you can start from the answer to 2.2, but your final answer should not depend on $f$ or $h$.*