**4视觉系统**

This section describes our vision system. In Section 4.1, we model an eye coordinate frame and eye behaviors such as saccades and pursuits. In Section 4.2, we describe how to determine the point of sight at which the character is looking. In Section 4.3, we discuss how to estimate the state of a moving object with our vision system.

本节介绍我们的视觉系统。在第4.1节中，我们建立了眼睛坐标系和眼睛行为的模型，如眼跳和追踪。在第4.2节中，我们描述了如何确定角色正在寻找的视点。在第4.3节中，我们讨论了如何用我们的视觉系统来估计运动物体的状态。

**4.1 眼部模型**

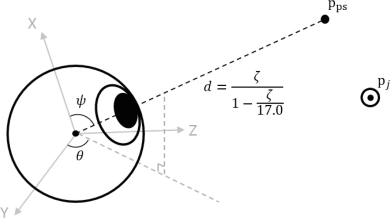
As shown in Figure [2](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=122.205.5.129&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574280850_ed68f5ad2990d4cd532b3ea91481679e#fig2), we adopt a spherical coordinate system to define the eye frame. In this frame, we use three parameters to specify an eye pose  ，Here θ and ψ are respectively the azimuthal and polar angles, which together represent a gaze direction, and ζ is the focal length. We bound each parameter with a normal range of eye movement that can be obtained from medical research [Serway et al. [2018](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=122.205.5.129&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574280850_ed68f5ad2990d4cd532b3ea91481679e#Bib0046); Shin et al. [2016](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=122.205.5.129&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574280850_ed68f5ad2990d4cd532b3ea91481679e#Bib0048)]: That is, −44.2∘≤θ≤44.2∘ for adduction and abduction, −47.1∘≤ψ≤27.7∘ for depression and elevation, and 0.0≤ζ≤17.0 (mm) for focal length. The focal length approaches 17.0mm when human looks at a point at infinity.

如图[2](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=115.156.140.169&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574148925_581c80d73e5154b164c4bbb251ae28a4#fig2)所示，我们采用球坐标系来定义眼框。在此框架中，我们使用三个参数定义眼睛姿势，这里θ我和ψ分别是方位角和极角，它们共同代表凝视的方向，ζ 是焦距长度。我们用正常眼睛的移动范围（可以在医学研究上获取到）去界定每一个参数。其中：

内收和外展

凸显和隆起

其中17.0mm代表人看向无限远处的点时的焦距



**Fig. 2. Eye coordinate frame.**

We also bound eye movement to generate realistic gaze behaviors, saccades and pursuits, which are important characteristics of human eyes. Saccades and pursuits refer to rapid movements of eyeballs to find new objects and slow eyeball movements to track objects, respectively. As in Yeo et al. [[2012](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=122.205.5.129&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574280850_ed68f5ad2990d4cd532b3ea91481679e#Bib0063)], we adopt a simplified profile of saccades and pursuits and impose velocity constraints on these behaviors based on the results from Robinson et al. [[1965](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=122.205.5.129&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574280850_ed68f5ad2990d4cd532b3ea91481679e#Bib0042)], Meyer et al. [[1985](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=122.205.5.129&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574280850_ed68f5ad2990d4cd532b3ea91481679e#Bib0030)], Leigh and Zee [[2015](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=122.205.5.129&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574280850_ed68f5ad2990d4cd532b3ea91481679e#Bib0064)], and Itti et al. [[2006](http://delivery.acm.org/10.1145/3370000/3360905/a3-eom.html?ip=122.205.5.129&id=3360905&acc=ACTIVE%20SERVICE&key=BF85BBA5741FDC6E%2ECC932049E1B2BA72%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1574280850_ed68f5ad2990d4cd532b3ea91481679e#Bib0018)]. Note that our system only uses velocity constraints for a natural gaze behavior and does not enforce explicit saccades or pursuits in relation to the object motion.

我们还通过眼睛的运动来产生真实的注视行为、扫视和追踪，这些都是人眼的重要特征。扫视和追踪分别是指眼球快速转动寻找新的物体以及眼球缓慢转动来追踪物体。借鉴Yeo等人所说的，[2012]，我们采用了一个对扫视和追逐的简化描述，并根据Robinson等人的研究结果对这些行为施加速度限制。注意，我们的系统只对自然凝视行为使用速度约束，不对于物体运动相关的明确的扫视或追踪行为进行（速度）限制。

In particular, we set the maximum saccade speed to 800∘/s and the maximum pursuit speed to 100∘/s considering only azimuthal and polar eyeball movements. Saccades repeat in every 200ms interval, each followed by a 200ms pause for recharge. Pursuits occur simultaneously even during the recharge times for saccades. We incorporate all of these in our vision system as follows:

where is the eyeball speed for azimuthal and polar movements and B is the upper bound of its magnitude.

特别地，只考虑方位角和极性眼球运动情况下，我们将最大扫视速度设定为800。/ s，最大跟踪速度为100。/s。每间隔200毫秒重复一次扫视，然后每间隔200毫秒暂停一次（进行休息）。即使在扫视的休息时间内，追逐也会同时发生。我们将所有这些都纳入我们的视觉系统，如下所示：

这里是眼球方位角和极角的移动速度，B是其大小的上限。