**Biomechanical eye model**

It has already been stated that the approach we have followed, is to create a complete simulation framework which takes into consideration all the parts that contribute to the generation of motion, from the brain down to the muscles. Therefore, in order to close the physiological/virtual neural loop, a biomechanical model of the human eye is required. The biomechanical model’s input is the activation signal vector originating in the superior colliculus. Its output is the motion of the eyeball, namely the orientation of the eye at every time instance. The activation signal is treated as vector, because it is consisted of the individual activations of each one of the six extraocular muscles (EOMs).

**Eye model anatomy**

The eyeball is anatomically represented with a sphere of uniform mass distribution. The diameter of the eye is 24 mm for adults, with small variation between individuals. The mass of the eye is 7.5 grams. Both aforementioned parameters can be personalized. Responsible for the actuation of the eyeball are the six extraocular muscles. They are arranged in three pairs and form a cone inside the orbit with the apex being located inside the cranium in a tendonous ring called the annulus of Zinn. The eye has three rotational degrees of freedom, and each muscle pair is in charge of actuating the eye in one of them. A pair is required instead of a single muscle for each DOF since muscles are only able to apply tractive forces and not repulsive. The six EOMs with their DOFs are: Medial/lateral rectus for horizontal movements, superior/inferior rectus for vertical movements and superior/inferior oblique for torsional movements. An important aspect of the oculomotor system that greatly affects the overall behavior is the existence of the EOM pulleys. They are structures composed of collagen, elastin and smooth muscle fibers which influence the path of the muscles. More specifically, their role is to keep the moment arm of the muscle force unchanged regardless of the eye orientation. In a way, this simplifies the work of the neural system when it comes to rotating the eye. In our model, the pulleys have been modeled by a point on the orbit whose exact location depends on the current eye orientation. Every EOM has its own pulley point, and its path is enforced to pass through that point. The coordinates of the pulley points and the way they move with the eye have been well studied in the literature. All the above features, as well as the dynamics, which are explained below, have been modeled using the OpenSim biomechanics framework.

**EOM dynamics**

Muscles are actuators that produce force by contracting. The nervous system can control the force they produce by adjusting the excitation signal that is supplied to them through motoneurons. The dynamics of muscular force production are complicated, but can be split into some basic components: 1) The elasticity due to the elastic nature of the muscles. 2) The delay between the onset of the excitation signal and the actual muscle contraction, caused by the transmission of the action potentials time and by the necessary calcium release on the muscle fibers. All these have been captured by the custom extraocular muscle model that has been developed.

**Orbital fat force**

Apart from the muscle forces, the oculomotor behaviour depends heavily on the passive forces coming from the fat tissues inside the eye orbit. Their role is critical in the optical stabilization required to eliminate the influence of head movements and other perturbation caused by body movement. We modelled the fat tissue passive force developing a custom torque with elastic and viscous properties governed by the following equation: where ; . Each element of vector is the time derivative of the respective element of vector . This custom torque acts like a rotational spring-damper apparatus that resists to any eyeball movements and tends to bring it back to the primary orientation.