

Computational Modeling of Ardipithecus Ramidus: A Revolution in Evolution

Shawn McGuan

Founder/CEO/CTO LifeModeler, Inc.

email: smcugan@lifemodeler.com, web: <http://lifemodeler.com>

INTRODUCTION

The discovery of the 4.4 million year old Ardipithecus Ramidus (Ardi) was termed the “Most Significant Scientific Breakthrough” by the Journal of Science in 2009. The scientific effort involved 15 years of research, 47 scientists and 9 nations and represented one of the largest collaborative efforts of its kind. LifeModeler is proud to be one of these scientific organizations, providing significant evidence to the mobility and social behavior of this fascinating creature.

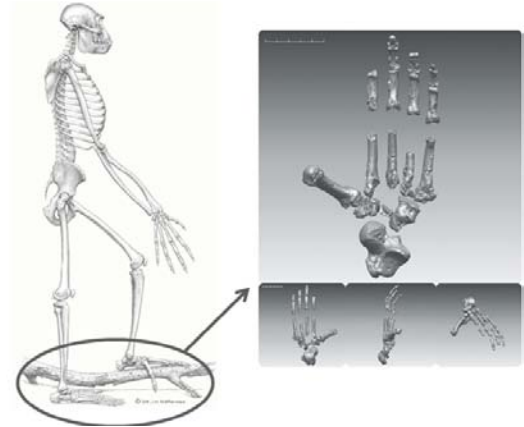


Figure 1: Ardipithecus Ramidus foot bones

This work describes the odyssey of discovery in how the scientific team used computational biomechanics tools to reconstruct locomotion and other patterns of behaviors from the fossil record. It presents the succession of computational models which incorporate the various theories of joint articulations, muscle attachments and segment positions to provide additional evidence to the question which has been troubling Ardi scientists for years: “How can a foot that can grasp a branch, also walk efficiently?”

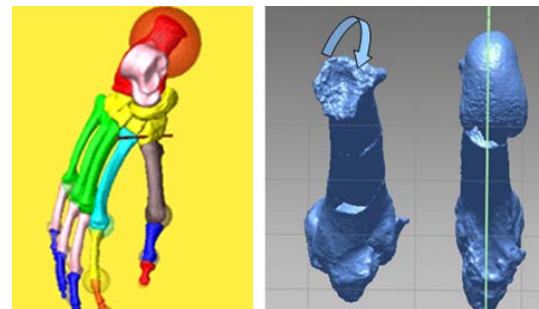


Figure 2: Segment axes and ROM were established by examining the articular surfaces of the bones.

It concludes will detail the methodology of mapping the motion of Ardi from the computational models derived from the fossil record into the motion of a human subject which led up to the animation sequences seen in the Discovery Channel special “Discovering Ardi” in December 2009.

METHODS

The bones gathered from the fossil record were used build (Fig.1) the computational biomechanics model of the lower limb in LifeMOD[®]. Kinematic axes and range of motion between each bone segment were established by examining the articular surfaces (Fig.2).

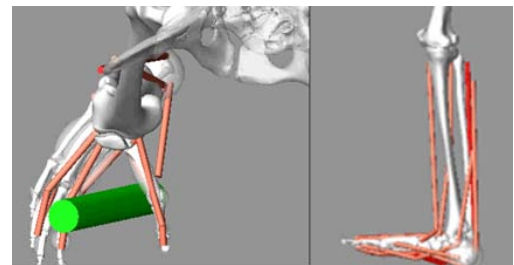


Figure 3: Dual purposed lower limb model; grasping and walking.

Muscles were then laced through the lower limb model using a variety of wrapping and scaffolding techniques. The lower limb model was then used to model two distinct activities of the limb; grasping and walking. The combination of segment geometry, joint axes, muscular attachment and

activations produced very specific motions at the hip and knee.

The hip/knee/ankle motion patterns were then morphed into full body model derived from a motion capture experiment with a test subject.

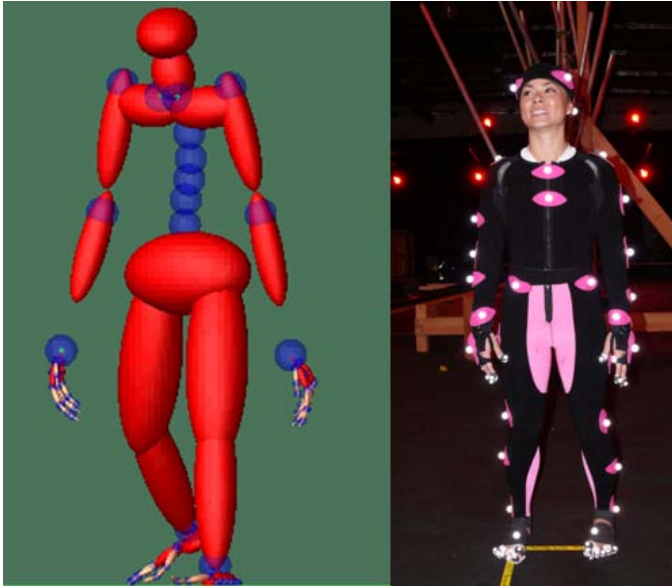


Figure 4. Mapping the motion derived from the lower limb model onto a full body model

RESULTS AND DISCUSSION

The modeling of functional behaviors of *Ardipithecus Ramidus* amounted to a forensic study of a creature that existed 4.5 million years ago. The biomechanical model was created from the partial set of bones from the fossil record, guidance from the team of evolutionary biologists and knowledge of human and chimpanzee anatomy [1,2].

The model was used to support various theories regarding physical behaviors of the creature postulated by the evolutionary biologists of the scientific group. The key to the discovery was the dual purpose foot; a foot that can grasp a branch yet effectively fulcrumate during locomotion.

One of the key components in the model was the attachment location of the peroneus longus (PL) muscle. From the fossil record, scientists determined that the PL muscle in *Ardi* was quite large. In addition the distal attachment of the muscle was on the medial aspect at the base of the

first metatarsal, instead of the medial cuneiform as it is in modern humans. This attachment location had a very distinct effect of adducting and internally rotating the great toe. This motion coupling facilitated the grasping action as well as to provide a stable platform for locomotion. It was also determined from the fossil record, that *Ardi* fulcrumated of the second ray instead of the first ray as in modern humans. These kinematic couplings and action along with the location of the talocrural and subtalar joint axes in *Ardi*, provided information on tibial axial motion during walking and climbing. The lordosis of the lumbar spine in *Ardi*, provided information on the necessary muscular activity of the hip flexors and extensors during locomotion.

This knowledge provided a “dynamic template” which was used to adapt the motion from a modern human (of similar stature to *Ardi*). In reproducing the motion and activity patterns of *Ardi*, all muscular activity was guided by the physical limitations of each active muscle.

CONCLUSIONS

The computational biomechanics model lead to new insights of walking and grasping behaviors of *Ardi*. It functioned as a platform for the evolutionary biologists to test theories about motion while being restricted to the physical limitations of the creature as dictated by the fossil record.

The model will be extended to explore more complex activity patterns of *Ardi*.

REFERENCES

1. Lovejoy, C.O., et al. Combining Prehension and Propulsion: The Foot of *Ardipithecus Ramidus*, October 2009, *Science* 326, 72
2. Keith, A., The history of the human foot and its bearing on orthopedic practice, *J Bone Joint Surg Am.* 1929;11:10-32.

ACKNOWLEDGEMENTS

Professor Owen Lovejoy, Kent State University.