ATRIAS stands for “Assume The Robot Is A Sphere,” describing the key design goal: having the robot behave like a spring-loaded, inverted pendulum (SLIP). This concept is what makes ATRIAS relatively agile compared to other walking robots, such as Honda’s ASIMO.

The SLIP Model

The spring-loaded, inverted pendulum (SLIP) is a biologically-inspired template model which can accurately describe walking and running in humans. SLIP has many valuable features, so ATRIAS reaps the same benefits:

• Self-stable under disturbances (like changing ground height or composition) without requiring a complicated feedback and control system.
• Naturally energy-conservative, having a spring to cycle gait energy, and zero impact losses.

A foot is necessary to stabilize ATRIAS when it is ultimately taken outside the laboratory. It will need to carefully preserve the existing favorable dynamics of ATRIAS while removing the spin instability.

Soft foot pads prevent harmful “chattering” of the foot on impact, where ground contact is repeatedly broken and re-established.

Foot Design Requirements

• Lightweight
• Senses ground contact
• Compliant to reduce chatter
• Removes yaw degree of freedom
• Return mechanism resets after each cycle

Need for a Foot

When taken off the support boom, ATRIAS has a yaw instability which leads it to spin like a top around a single contact point.

A Stabilizing Foot

An ankle and a linear footprint remove the yaw instability without affecting the behavior of ATRIAS. A spring return is used to reset the foot after each step.

Impulse and step responses of the return mechanism characterize the oscillation of the foot. A simulation of the foot’s behavior under a real ATRIAS gait shows the mechanism to be very effective at preventing ground contact during swing phase.

Friction testing is performed using a force plate and a jig which restricts the foot to translation and rotation in the vertical direction only. The prototype has a measured peak friction torque of 29 N.m, more than enough to stabilize ATRIAS.

[2] suggests that the foot stiffness should be no more than five times the leg stiffness to prevent chatter:

ATRIAS leg stiffness: 15 N/mm
Max foot stiffness: 75 N/mm

Foot stiffness: 250 N/mm
- Needs more compliance!

The revised foot design includes non-laminated layers of fiberglass composite to increase compliance. This allows a high degree of modularity in the number of layers and what materials are used. Friction between the sliding layers has a damping effect, further reducing chatter.

Additionally, a magnetic return mechanism is designed to be fully enclosed in the foot, preventing damage and ensuring operation in uncontrolled environments.

References