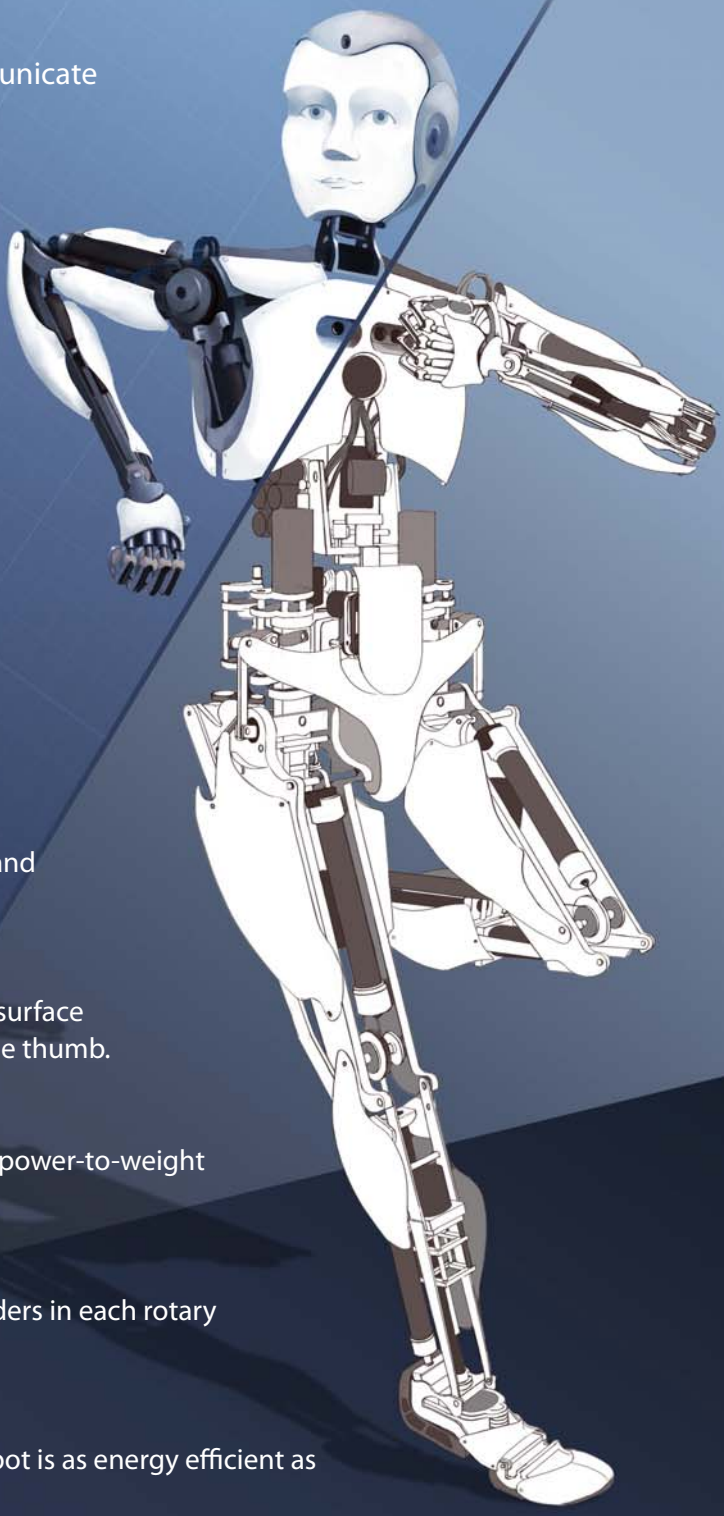
At Engineered Arts, our robots are not utility machines or household servants. They were conceived as a communication tool - a way for a machine to deliver a human message, with gesture, expression, and voice. Now, we are creating a new full-sized dynamic humanoid, able to walk, run, jump and hop.
We present a design preview of Byrun.

why a walking robot?

The ability to move like a human adds to our ability to communicate with humans. With his vastly increased degrees of freedom, numerous touch sensors, and high range of movement, Byrun will be our most interactive and relatable robot yet.

But mainly because:
It's interesting.
It's entertaining.
And because you want to see it.



Byrun concept sketch

Parallel electro-pneumatic actuation
Parallel actuators ensure compliance and allow the robot to move with both speed and precision

Expressive head
Projective technology gives an infinite array of possible facial features and expressions

Bi-articulated limbs
Inspired by a biomimetic mechanical linkage system, both upper and lower limbs are bi-articulated.

Tactile pneumatic hands
Fingers are pneumatically driven, with pressure, temperature and surface detecting sensors. Byrun has a fully articulated wrist and opposable thumb.

Custom-built BLDC motors
Bespoke motor technology gives our actuators an extremely high power-to-weight ratio.

Precision encoders
Precise position control is enabled by sensitive and accurate encoders in each rotary joint.

Energy storage via muscles
By using pneumatic muscles as variable springs, we ensure the robot is as energy efficient as possible, with a wide range of possible gaits.

Ground contact sensing
Multiple pressure sensors embedded in the feet provide ground contact and force information.

Series-elastic actuators
Series-elastic actuators in the legs simplify precision force control.

byrun

biarticulate. compliant.dynamic.

concept

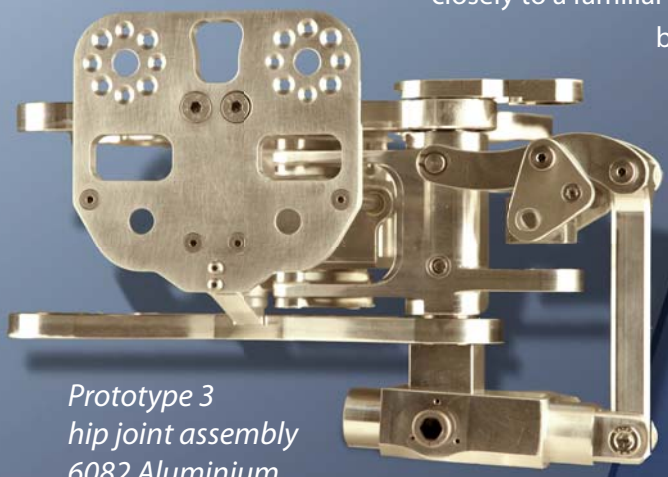
Byrun is conceived as a dynamic humanoid robot for human interaction and communication, and a development platform for research and experimentation. Able to walk, run, hop and jump, with facial expression, voice and gestures, Byrun is a machine able to imitate many forms of human communication and expression.

design principles

Byrun has a biomimetically driven design rationale. Namely, to emulate human movement and dynamics. Unashamedly a robot - it has no rubber face mask or fabric clothes. Neither is it a faceless white appliance, it's a machine built to imitate life (without entering the uncanny valley!).

This philosophy is echoed in all our mechanical and aesthetic design choices. Byrun's proportions, joint locations and actuation ranges are as closely matched to a human model as possible - this is not because we believe that dressing like a bird will make us fly, but because people are acutely sensitive to minor deviations in the human form. We recognise the mood, gender and intention of others from their movement. For a communication robot to do the same, it should adhere closely to a familiar body model. The goal is to be a fluid as possible, to reproduce the biological motion of people.

In practical terms this means placing actuators, linkages and ancillaries in biologically analogous positions, finding a compromise between optimum mechanical efficiency and aesthetic acceptability.



Prototype 3
hip joint assembly
6082 Aluminium

kinematics

Bi-articulate actuation: motors and pneumatic muscles that affect two degrees of freedom simultaneously. These links feature in the upper and lower limbs. In the legs the actuator linkage mimics the action of human muscle pair rectus femoris and biceps femoris. It maintains an angular relationship between knee pitch and hip pitch, creates a simple and effective way to keep the robots COM, (centre of mass) over the support during the stance phase, and maintains a straight line vector for the end effector as the leg extends or contracts. And we haven't sacrificed any DOF's to do it. Hip pitch can still be independently controlled.

Series and Parallel Elastic Elements: are used to sense force and store energy, they also counter gravity loads which can drastically reduce motor power consumption and required maximum output power, motors can be smaller and lighter and the duration of autonomy can increased. Traditional steel springs are heavy, we use them where necessity dictates, and substitute pneumatic muscles where possible.

Multiple Actuation Types: the human body has at least four muscle types, with skeletal muscle dividing broadly into two variants, fast and slow twitch. There is no single actuation type that works well for all the speed, force, endurance and efficiency requirements of a truly dynamic robot, so we use the most appropriate actuator for the task, or combine multiple actuators to utilise two sets of desirable characteristics.

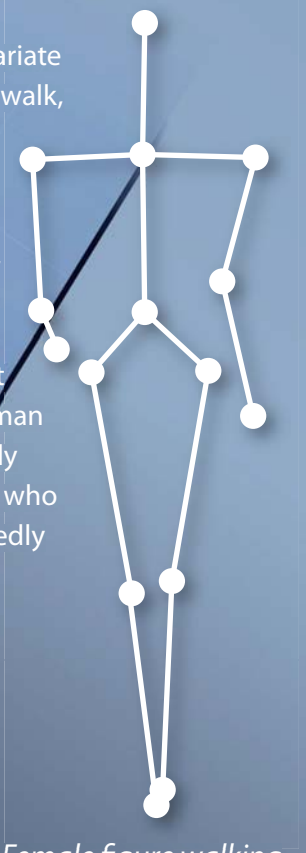
motion

Walking is not merely a means of locomotion. It can also act as a multivariate signalling device, particularly between humans. From nothing but their walk, we can make judgements about a person's age, gender, weight, health and mood.

Walking robots have been commercially available for some time, however none with true human-like biomechanics and bipedal abilities. A cautious, shuffling robot may get to where it needs to go (eventually, and if there are no obstacles in the way). But it will not inspire confidence in onlookers. It will not inhabit a human space naturally and gracefully, nor will it be able to seamlessly integrate into a human-robot interaction scenario. We envision a robot who can spring optimistically into action, run across a room, or walk dejectedly back to a corner. A truly dynamic bipedal robot

Male figure walking

Figure data courtesy
Bio Motion Lab
Ontario CA



Female figure walking

expression

Byrun is not just a mobile set of limbs. We have brought years of engineering expertise to tackle the problem of a truly interactive robot. This means a robot that can shake your hand and can pick up an object; a robot who can hold a conversation and respond to your commands; a robot who can read your facial expressions and body language, and modify their own.

Precision manipulation: With biarticulate, pneumatically-powered upper limbs, Byrun's movements are fluid and naturalistic. But even with a compliant robot, when it comes to interaction, precision is of paramount importance. That's why we have extended our use of custom BLDC motors to parallel elbow actuation, for accurate end-effector positioning. 3DoF wrist actuation means Byrun's hands are fully poseable, allowing a multiplicity of grasping positions and approach angles.

Fully actuated hands: Our new hand design includes variable pneumatic curl actuation on all five fingers, a fully opposable thumb, and individual control of abduction and adduction to allow for hand spread and precise finger positioning. Each finger has pressure sensors for force feedback, contact sensors which can also give information about surface roughness and temperature.

Projective head technology: Byrun's head shape has been carefully designed to be androgynous - combined with our advanced projective head technology, this means Byrun can take on the appearance of anyone.

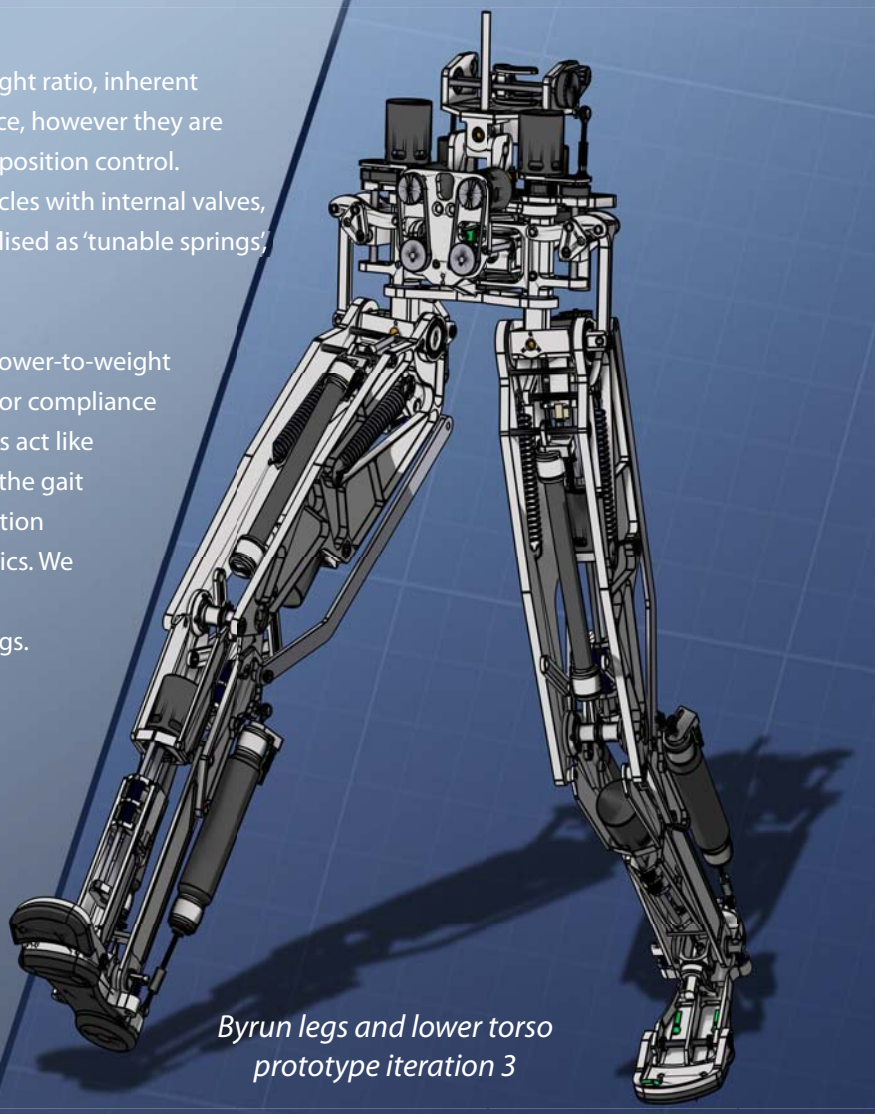
actuators

Pneumatic muscles have the benefit of high power-to-weight ratio, inherent compliance and the ability to act as an energy storage device, however they are inefficient in high cyclical use and difficult to utilise for fine position control. Engineered Arts Ltd have developed highly integrated muscles with internal valves, sensors and control which are unique to Byrun. They are utilised as 'tunable springs', working in parallel with force controlled motors.

Brushless DC (BLDC) motors can offer moderate to high power-to-weight ratio, however additional springs and sensors are required for compliance (programmed compliance is possible but inefficient. Springs act like human tendons, which can store and return energy during the gait cycle.) BLDC motors need to be finely matched to the actuation requirements and highly integrated with the robot mechanics. We specified custom rotors and stators that outperform any commercially available BLDC and machined custom housings.

Brushed DC motors work well for fine control on lightly loaded axis. We use motors with graphite brushes which outlast precious metal types in servo applications. Rare earth magnets provide best power to weight ratio.

Ball Screws are an efficient, and lightweight alternative to harmonic or planetary gears, up to 95% efficient and with load capacities over 2kN they are readily configured as force controlled drives.



Byrun legs and lower torso prototype iteration 3

to follow...

Byrun's first functional demonstrator is scheduled for completion in Febuary 2015. Detailed technical, software specification and preview videos will be released as they become available through 2014

DOF Name	Actuation	Range	DOF Name	Actuation	Range
Head Roll	Brushed DC	(-15 +15)	Torso Roll	BLDC	(-13 +13)
Head Pitch	Brushed DC	(-30 +45)	Torso Pitch	BLDC	(-13 +8)
Head Yaw	Brushed DC	(-60 +60)	Torso Yaw	BLDC	(-30 +30)
Shoulder Roll	BLDC / Pneumatic	(-20 +90)	Hip Pitch	BLDC / Pneumatic	(-30 +90)
Shoulder Pitch	BLDC / Pneumatic	(-30 +170)	Hip Roll	BLDC	(-15 +30)
Shoulder Yaw	BLDC	(-45 +60)	Hip Yaw	BLDC	(-30 +60)
Elbow Pitch / Shoulder Pitch	BLDC / Pneumatic/ Bi Articulate	(0 +150)	Knee Pitch / Hip Pitch	BLDC / Pneumatic Bi Articulate	(0 +90)
Wrist Roll	Brushed DC	(0 +180)	Ankle Pitch	BLDC / Pneumatic Bi Articulate	(-35 +45)
Wrist Pitch	Brushed DC	(-70 +70)			
Wrist Yaw	Brushed DC	(-30 +30)	Ankle Roll	Passive	(-10 +10)
Digit 1 - 5 Pitch	Pneumatic	(0 +90) + (0 +60)	Toe Pitch	Passive	(0 +45)
			Digit 1 - 5 Yaw	Pneumatic	-