

AMENDMENTS TO THE CLAIMS

Please amend the claims as indicated below.

1. (Currently Amended) An underactuated end effector for a humanoid robot, the underactuated end effector comprising:
 - an end effector frame;
 - a plurality of finger assemblies removably connected to the end effector frame, wherein each finger assembly of the plurality of finger assemblies includes a finger motor assembly; and
 - a thumb assembly removably connected to the end effector frame, the thumb assembly comprising:
 - a first thumb motor with a first motor shaft, wherein the first motor shaft is rotatable about a first motor shaft axis;
 - a first motor gear connected to the first motor shaft and being rotatable about: the first motor shaft, and a first motor gear axis that is coaxial the first motor shaft;
 - a second thumb motor with a second motor shaft, wherein the second motor shaft is rotatable about a second motor shaft axis;
 - a second motor gear connected to the second motor shaft and configured for rotation about: the second motor shaft, and a second motor gear axis that is coaxial with the second motor shaft; and
 - wherein (i) the first motor shaft axis is oriented substantially parallel to the second motor shaft axis, and (ii) the first motor gear axis is oriented substantially parallel to the second motor gear axis.
2. (Original) The underactuated end effector of claim 1, wherein the thumb assembly further comprises:
 - a worm wheel that is configured to facilitate movement of the thumb assembly between an uncurled position and a curled position, and
 - a thumb drive assembly that is in geared engagement with the first motor gear and the worm wheel.
3. (Currently Amended) The underactuated end effector of claim [[2]]1, wherein the second thumb motor facilitate movement of the thumb assembly between an

- uncurled position and a curled position~~the thumb drive assembly includes: (i) a~~
~~flexion gear in geared engagement with the first motor gear, (ii) a worm drive~~
~~gear in geared engagement with the worm wheel, and (iii) a drive shaft coupled to~~
~~both the flexion gear and the worm drive gear.~~
4. (Currently Amended) The underactuated end effector of claim ~~[[2]]~~1, wherein the
first thumb motor facilitates movement of the thumb assembly between an
unrotated position and a rotated position~~flexion gear is rotatable about a flexion~~
~~axis, wherein the flexion axis is oriented perpendicular to both the first motor gear~~
~~axis and the first motor shaft axis.~~
 5. (Currently Amended) The underactuated end effector of claim 2, wherein the
thumb assembly includes:
 - a thumb frame with an upper frame member that is removably connected
to the thumb drive assembly and ~~the frame~~the end effector frame, and
 - a lower frame member that is rotatable in response to rotation of the
second motor shaft.
 6. (Currently Amended) The underactuated end effector of claim 5, wherein the
thumb drive assembly further includes an interposition ~~anterposition~~-gear that is
both: coupled to the lower frame member and in geared engagement with the
second motor gear.
 7. (Original) The underactuated end effector of claim 1, wherein each finger
assembly of the plurality of finger assemblies further includes:
 - a metacarpophalangeal joint;
 - a proximal finger interphalangeal joint; and
 - a distal finger interphalangeal joint.
 8. (Currently Amended) The underactuated end effector of claim 1, wherein ~~the~~
~~frame~~the end effector frame includes a palm region, and wherein the first thumb
motor and the second thumb motor are at least partially ~~received~~positioned within
the palm region of ~~the frame~~the end effector frame.
 9. (Currently Amended) The underactuated end effector of claim 1, wherein the
thumb assembly further comprises:
 - a main proximal link ~~that is pivotally connected to the thumb frame;~~

a main medial link that is pivotally connected to the main proximal link;
a ~~main-medial~~ drive link that is pivotally connected to the main medial link; and

wherein the first thumb motor is configured to rotatably actuate the main proximal and medial links about a worm wheel axis.

10. (Original) The underactuated end effector of claim 1, wherein the thumb assembly lacks a mechanical cable configured to actuate any component of the thumb assembly.
11. (Currently Amended) The underactuated end effector of claim 1, the thumb assembly further comprising:
 - a carpometacarpal joint housing assembly having a base joint receiver;
 - a proximal housing assembly including a rear extent that is positioned within the base joint receiver when the thumb assembly is in an uncurled position, and wherein less than a minor portion of said rear extent of the proximal housing assembly is ~~not positioned~~ within the base joint receiver when the thumb assembly is in a curled position.
12. (Original) The underactuated end effector of claim 1, wherein the thumb assembly lacks both a pressure sensor and a force sensor, and wherein the thumb assembly is configured to covered within a textile covering.
13. (Currently Amended) The underactuated end effector of claim 1, wherein the thumb assembly further comprises a biasing member ~~having a first extent connected to the proximal link and a second extent connected to the medial drive link, and wherein the biasing member is configured to bias the medial drive link toward an uncurled position.~~
14. (Original) The underactuated end effector of claim 1, wherein the end effector further comprises:
 - a palm housing that overlies an extent of the first and second thumb motors, and
 - a carpometacarpal joint housing assembly configured to rotate in response to rotation of the first motor shaft, wherein the carpometacarpal joint housing

assembly includes an upper edge that is positioned proximate to a lower extent of the palm housing.

15. (Currently Amended) An underactuated end effector for a humanoid robot, the end effector comprising:

~~a frame~~ an end effector frame;

a plurality of finger assemblies connected to ~~the frame~~ the end effector frame, each finger assembly of the plurality of finger assemblies comprising:

a metacarpophalangeal joint;

a proximal finger interphalangeal joint;

a distal finger interphalangeal joint; and

a thumb assembly removably connected to ~~the frame~~ the end effector

frame, the thumb assembly comprising:

a first carpometacarpal joint;

a second carpometacarpal joint;

a metacarpophalangeal joint;

an interphalangeal joint;

a carpometacarpal encoder positioned proximate the first carpometacarpal joint and configured to collect data related to rotation of the first carpometacarpal joint;

a first thumb encoder positioned proximate the metacarpophalangeal joint and configured to collect data related to rotation of the metacarpophalangeal joint; and

a second thumb encoder positioned proximate the interphalangeal joint and configured to collect data related to rotation of the interphalangeal joint, and wherein the first thumb encoder and second thumb encoder are positioned adjacent to a main medial link of the thumb assembly.

16. (Original) The underactuated end effector of claim 15, wherein the thumb assembly further comprises: (i) a first motor gear, (ii) a worm wheel configured to

- facilitate movement of the thumb assembly between an uncurled position and a curled position, and (iii) a thumb drive assembly in geared engagement with the first motor gear and the worm wheel.
17. (Original) The underactuated end effector of claim 16, wherein the thumb drive assembly further includes: (i) a flexion gear in geared engagement with the first motor gear, (ii) a worm drive gear in geared engagement with the worm wheel, and (iii) a drive shaft coupled to both the flexion gear and the worm drive gear.
 18. (Currently Amended) The underactuated end effector of claim 15, wherein ~~the frame~~the end effector frame includes a palm region, and wherein a first thumb motor and a second thumb motor are at least partially ~~received~~positioned within the palm region of ~~the frame~~the end effector frame.
 19. (Original) The underactuated end effector of claim 15, the thumb assembly further comprising:
 - a carpometacarpal joint housing assembly having a base joint receiver; and
 - a proximal housing assembly including a rear extent that is positioned within the base joint receiver when the thumb assembly is in an uncurled position, wherein said rear extent of the proximal housing assembly is positioned external to the base joint receiver when the thumb assembly is in a curled position.
 20. (Original) The underactuated end effector of claim 15, wherein the thumb assembly is configured to covered by a textile covering, and wherein the thumb assembly lacks a mechanical cable that actuates a component of the thumb assembly.
 21. (Original) The underactuated end effector of claim 15, wherein the thumb assembly further comprises:
 - a first thumb motor with a first thumb motor shaft, wherein the first thumb motor shaft is configured to rotate about a first motor shaft axis;
 - a first motor gear connected to the first thumb motor shaft and configured for rotation about both: the first motor shaft and a first motor gear axis that is coaxial with the first motor shaft;
 - a second thumb motor with a second thumb motor shaft, and wherein the second thumb motor shaft is configured to rotate about a second motor shaft axis;

a second motor gear connected to the second thumb motor shaft and configured for rotation about both: the second motor shaft, and a second motor gear axis that is coaxial with the second motor shaft; and

wherein the first motor shaft axis is oriented substantially parallel to the second motor shaft axis, and the first motor gear axis is oriented substantially parallel to the second motor gear axis.

22. (Currently Amended) A humanoid robot with an underactuated end effector, the end effector comprising:

an end effector frame;

a palm housing coupled to the end effector frame and having a sagittal plane;

a plurality of finger assemblies removably connected to a first side of the end effector frame, wherein the sagittal plane of the palm housing is aligned with a longitudinal plane of a finger assembly of the plurality of finger assemblies;

a thumb assembly removably connected to a second side of the end effector frame, the thumb assembly comprising:

a thumb motor assembly, the thumb motor assembly comprising:

a first thumb motor with a first thumb motor shaft, wherein the first thumb motor shaft is configured to rotate about a first motor shaft axis;

a second thumb motor with a second thumb motor shaft, wherein the second thumb motor shaft is configured to rotate about a second motor shaft axis;

wherein at least an extent of the first thumb motor and the second thumb motor are positioned between ~~the frame~~ the end effector frame and the palm housing; and

wherein both the first motor shaft axis and the second motor shaft axis are not arranged parallel to the sagittal plane.

23. (Original) The humanoid robot with the underactuated end effector of claim 22, wherein the end effector further comprises a carpometacarpal joint housing

- assembly configured to rotate in response to rotation of the first thumb motor shaft, wherein the carpometacarpal joint housing assembly includes an upper edge that is positioned proximate to a lower extent of the palm housing.
24. (Original) The humanoid robot with the underactuated end effector of claim 22, wherein the thumb assembly further comprises:
- a worm wheel configured to facilitate the movement of the thumb assembly between an uncurled position and a curled position, and
 - a thumb drive assembly in geared engagement with a first motor gear and the worm wheel.
25. (Original) The humanoid robot with the underactuated end effector of claim 24, wherein the thumb drive assembly further includes: (i) a flexion gear configured to be in geared engagement with the first motor gear, (ii) a worm drive gear configured to be in geared engagement with the worm wheel, and (iii) a drive shaft coupled to both the flexion gear and the worm drive gear.
26. (Currently Amended) The humanoid robot with the underactuated end effector of claim 24, wherein the thumb assembly includes:
- a thumb frame with an upper frame member configured to be removably connected to both the thumb drive assembly and ~~the frame~~ the end effector frame, and
 - a lower frame member that is rotatable in response to the rotation of the second thumb motor shaft.
27. (Currently Amended) The humanoid robot with the underactuated end effector of claim 26, wherein the thumb drive assembly further includes an interposition ~~anterposition~~ gear that is coupled to the lower frame member, and is in geared engagement with a second motor gear.