ASME 2012 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference
DETC-CIE
August 12-15 2012, Chicago, Illinois, USA

DETC2012-70244

DESIGN OF A ROBOTIC GRIPPER BASED ON A PSITTACUS ERITHACU BEAK

Alex W. Grammar, ag153810@ohio.edu
Electrical Engineering, Ohio University
Athens, Ohio, USA

Robert L. Williams II, Ph.D., williar4@ohio.edu
Mechanical Engineering, Ohio University
Athens, Ohio, USA

ABSTRACT

A high versatility, low degrees-of-freedom (DOF) gripper was designed based on avian morphology. Grasping mechanisms for robotic manipulators are often developed for application-specific tasks, such as manipulating a single part or performing a repetitive action. In contrast, more dexterous grippers are complex, multiple-DOF mechanisms. A simple, minimal-DOF, versatile gripper has been developed based on the morphology of the Psittacus Erithacu (African Grey Parrot) beak shape. This species is highly intelligent and uses its beak for digging, gripping, climbing, and foraging. Giving a robot a similar capability would allow the platform to pick up targets such as single, small seeds, liquids, large irregular rocks and soft Robocup style balls. By using the beak as a model for a grasping mechanism the design maintains its versatility without the need for a complex system and allows a large range of targets to be gripped. This gripper is intended for use in the new open-source humanoid robot DARwIn-OP.

1. INTRODUCTION

The Psittacus Erithacu, or African Grey parrot, is considered to be one of the most intelligent species of parrots. These birds are not only able to mimic human speech; they are able to intelligently interact with people on the mental level of a toddler. In the wild these birds live near rivers and feed on the tough palm nuts foraged in mud [1]. Their beaks are used for the majority of day-to-day tasks in the life of these birds. The first author of this paper observed hundreds of hours of captive specimens and can attest not only to the frequency of beak usage, but as to its wide functional range as well. Beaks are specialized through evolutionary processes to perform specific tasks. These beaks can dig out nesting burrows, pick nuts from the mud, move twigs, assist in climbing, shred through dense material, and act as a defensive weapon. Most parrots engage in similar activities and their jaw anatomy does not differ, but due to the high intelligence level and tool use the authors have singled this species out. This wide range of activities suggest there is some underlying principle the parrot beak capitalizes on that is being overlooked in current manipulator gripper design. It is the intent of this design to create a functional analog for a robotic platform to investigate this biological mechanism as a gripper.

Figure 1: An African Grey Parrot yawning, showing extension of both articulating beak parts.
farm1.static.flickr.com/113/262149114_ea9787245b.jpg

The specific robotic platform this gripper is being designed for is the DARwIn-OP humanoid robot. The DARwIn-OP is a humanoid robotics platform developed by Virginia Tech, the University of Pennsylvania, and Robotis Inc. It is a 20-DOF robot that is designed to be open-source and anthropomorphic in nature. Currently each arm only accounts for three degrees of freedom and lacks a gripping mechanism. An upgrade exists but it only extends this to five degrees (including hand actuation) with a simple claw-like grasper [2]. The DARwIn platform has just recently been opened to the public and there has not been much development in the area of custom gripper technology. The open-source nature of the platform makes it ideal for developing a new type of gripper. All technical specifications and hardware schematics are available for incorporating a new gripper design. The DARwIn-OP robot is shown in Figure 2 (455 mm tall, mass of 2.8 kg).

Figure 2: The DARwIn-OP 20-DOF humanoid robot. The shoulder has two rotational joints and the arm terminates with an elbow flexion joint. This model does not contain a robotic gripper.
www.engadget.com/media/2010/11/darwin-op-1.jpg

The parrot beak and skull anatomy is more complex than most animal jaws. In parrots, the beak is composed of a hard bone body covered in a constantly-regenerating layer of keratin. Small channels are present on the tip allowing sensory information to be transmitted from the beak edge. This growing edge is constantly worn down through use. The sharpened, rough edge allows the beak edge to bite into whatever material it is grasping to prevent slippage [3].

The lower jaw articulates in a traditional fashion and the muscle attached from jaw to skull articulates about a hinge. What makes the parrot jaw unique is the secondary articulating mechanism that enables the upper jaw to move independently of the lower jaw. Muscles articulate the Quadrate bone, which in turn forces the Jugal and Pterygoid bones to apply pressure on the upper beak. The beak is attached to the cranium via flexible connective tissue creating a hinge joint at the peak. This hinged joint also allows independent yawing motion as each quadrate muscle can act slightly independently. This extra motion of the upper beak allows grasping of large, irregular objects. This structure is illustrated in Figure 3 [3].

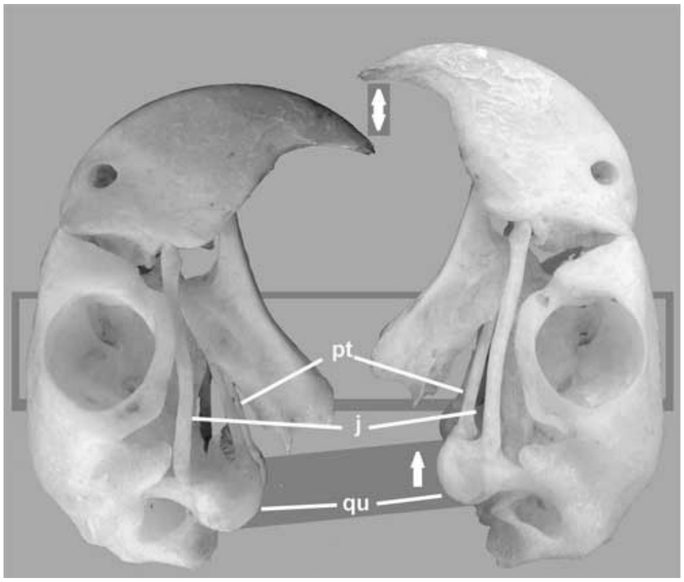

Figure 3: Upper jaw articulation mechanism. The Quadrate (qu) is shifted by muscles. The motion of the Quadrate applies pressure to the Jugal and Pterygoid (j and pt) bones which then push the upper beak forwards. Soft connective tissue creates the hinge where the top of the beak meets the cranium
innerbird.com/other_special_features/head/billmove1_fullsize

Another feature of the beak is the concave shape of each mandible piece. This allows for the scooping of soft material, liquids, and small granular pieces. It is suspected that this shape allows the beak to apply gripping force to large, irregularly shaped objects by clamping around deformities and curvatures on the surface of the target. Both beak segments capture the target but the upper beak applies compressional force. This can pierce, for example, a hard nut's shell on the rigid tip of the lower beak. The lower beak's curvature comes into play again, allowing softer material to be scooped out of the shell.

2. GRIPPER DESIGN

Based on the observations of African Grey Parrot beak anatomy, the prototype gripper will consist of the following elements. Two independently articulating rigid, concave, beak parts will make up the majority of the gripper. The upper mandible will be moved via dual linear actuators. Mimicking the anatomy of an African Grey Parrot beak, the lower beak will be actuated by a cable attached to either side of the beak. This cable is counter-tensioned by a torsional spring placed inside the mandible about the axle. These beak parts will be similar in shape to the African Grey Parrot's beak.

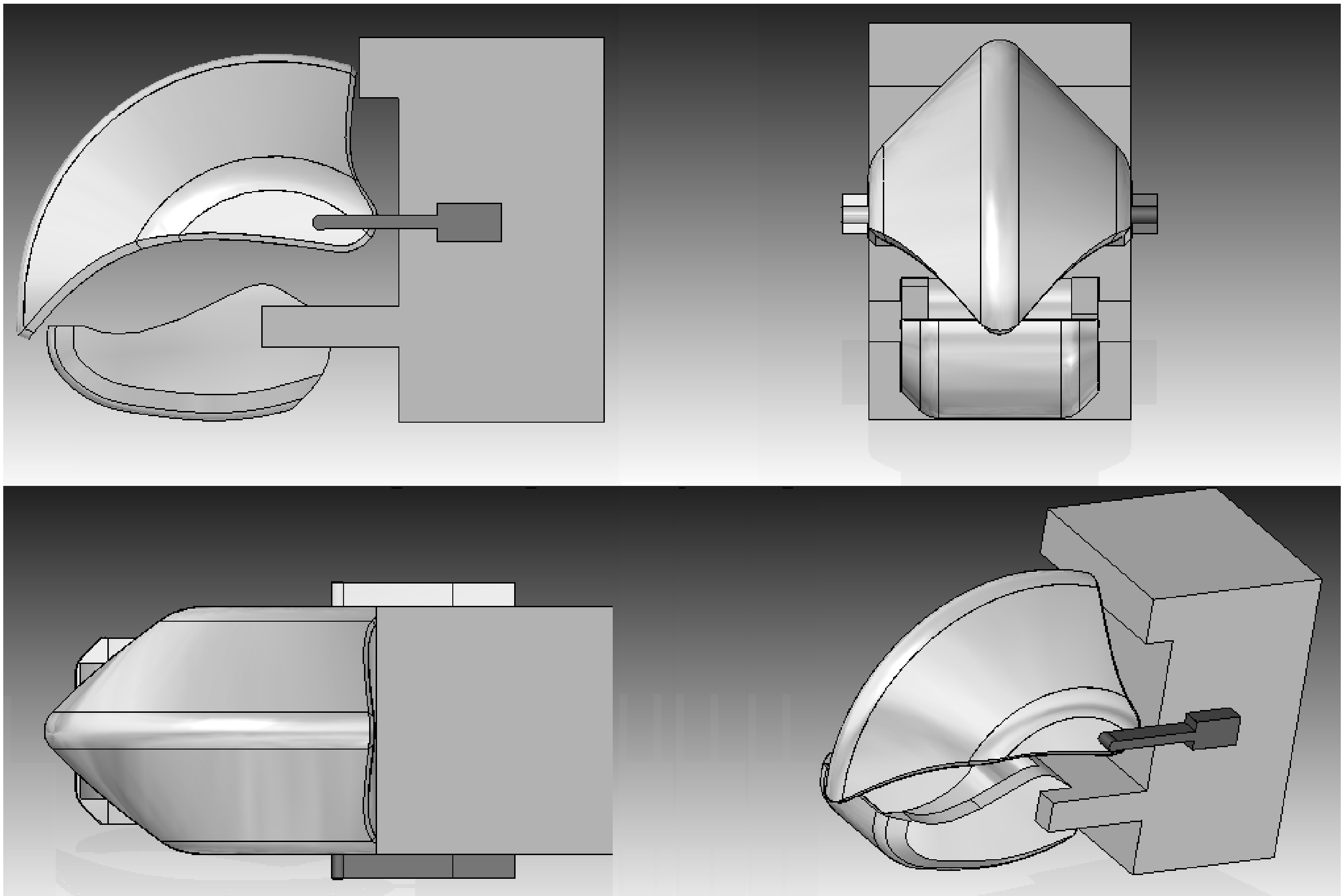

Figure 4: Prototype Gripping Mechanism based on Psittacus Erithacu Beak. The black elements are pivoting linear actuators. The light grey base houses the lower jaw driving cable (not shown) and serves as a frame for the axle and hinge of each beak part. The silver sections are the grasper and in future designs will incorporate a high-friction surface along the beak edge.

An initial CAD design has been developed (Figure 4). The independent articulation of the beak parts allows for large diameter targets to be grasped. The upper beak is allowed to rotate up to 45 degrees forward in addition to the lower beak rotating 90 degrees downward. No studies were found to indicate the range of motion an African Grey exhibits, however, cursory visual examination of Grey behavior suggests these limits are satisfactory for biomimicry. The actual gripper mechnaisim will be made to replace the current DARwIn-OP robot's forearm and will be of roughly the same width and length dimensions. The gripper articulation can be seen in Figure 5.

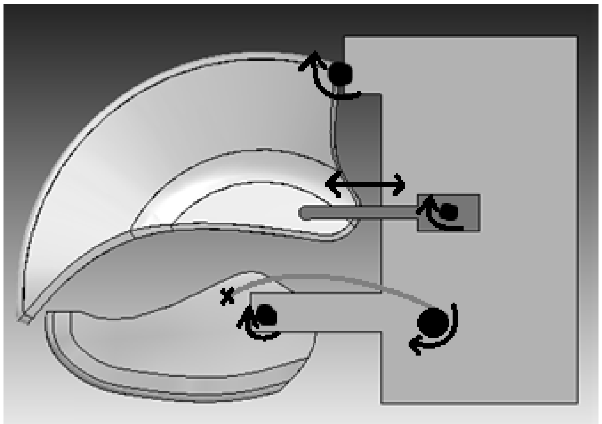

Figure 5: Gripper articulation showing lower jaw cable and linear actuator rotation

Parrot beaks are highly attuned sensory organs. They provide the bird with temperature and pressure information. To replicate this, a proprioceptive sensor grid will be integrated into the beak. Pressure transducers will be placed at regular intervals along the rim of the lower beak, similar to teeth along the jaw. These sensors will be embedded in a flexible material to allow the beak to grip and retain the target, transmit pressure, and protect the sensors. An example circuit for converting pressure to voltage is shown in Figure 6.

.

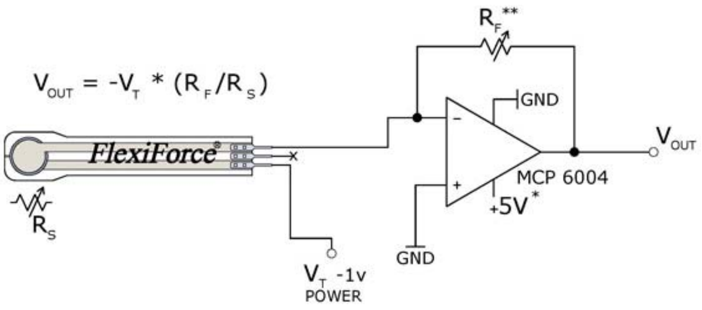

Figure 6: Example pressure-to-voltage sensing circuit. This circuit is used in conjunction with the low-cost FlexiForce pressure transducers.

www.tekscan.com/flexiforce-sample-circuit

As a target is gripped it will press into the soft material and create a specific pattern. This pattern can be used to determine not only the shape and orientation of the gripped object; it will also allow the controller to monitor applied pressure to the target. This sense will work in conjunction with the camera built into the DARwIn-OP architecture. Two examples of grip profiles are shown below for symmetrical positioning of a regular cylinder and a rectangular prism. Specific pressure position units and values are arbitrary, but reflect a theoretical response to grasping the aforementioned objects. The position is centered along the beak midline and increases from jaw joint to beak tip. It is also assumed that the grip force is normal to the surface of the targets. The pressure-position profiles are shown in Figure 7 and Figure 8.

The robotic gripper will be appended to the current 3-DOF DARwIn arm. The right arm is shown in Figure 9. To incorporate the gripper into the robot, we will need to be able to mathematically describe the manipulator kinematics. This procedure, including Denavit-Hartenberg parameters, forward pose kinematics, and partial inverse pose kinematics solution, in presented in detail in [4].

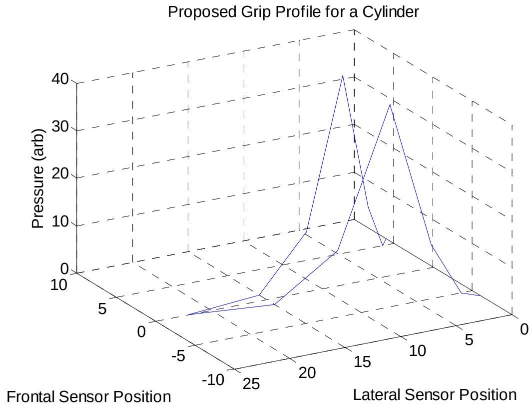

Figure 7: Pressure-Position Grip Profile. The Cylinder is positioned perpendicular to the beak edge, creating a concentration of pressure over one sensor.

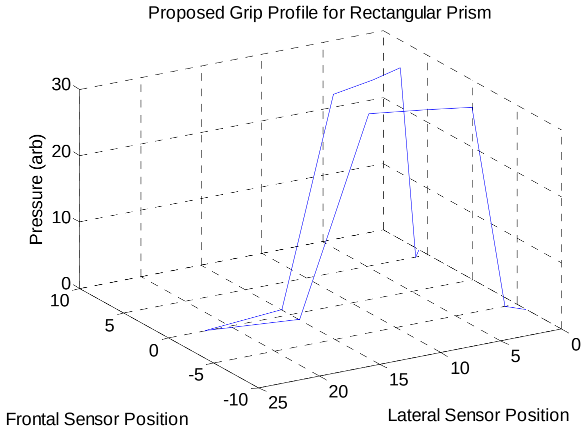

Figure 8: Pressure-Position Grip Profile for a Rectangular Prism. The flat edge distributes pressure evenly along the sensors underneath the target.

This parallel gripper design will have several advantages over standard grippers. Firstly the shape of the gripper allows for several closure modes for a simple, non-specialized mechanism; pure enclosing, partial form fit, and pure force depending on the shape of the target and the gripping strategy. [5] Another benefit is the weight conscious nature of the design behind the beak. In flight, birds must be as light as possible, and with the beak serving little or no aerodynamic function [6], the beak should be as light as possible while retaining functionality. This parallels our design goals in avoiding gripper weight interfering with robot locomotion. In addition to being a versatile parallel gripper, the beak has an additional degree of freedom (upper beak yaw) without additionally complicating the mechanism.

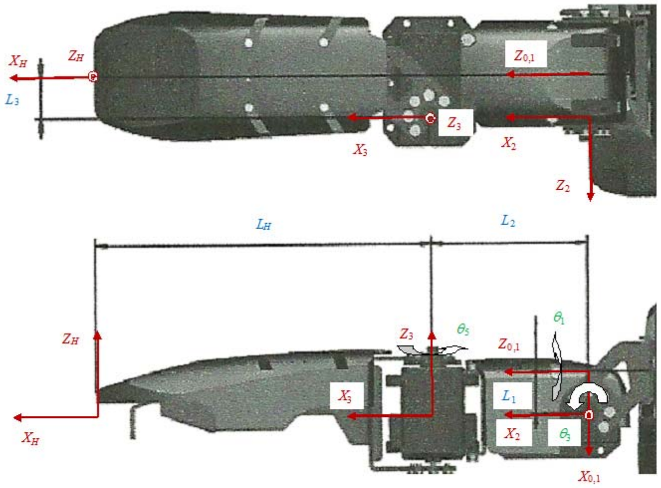

Figure 9: 3-DOF DARwIn Right Arm with Cartesian Coordinate Frames.

3. FUTURE WORK

As this design is in the preliminary stages, some further design work is needed. The DARwIn-OP robot is fortunately open source and hardware schematics are available. First, a prototype gripper must be constructed and attached to the robotic platform. Secondly, laboratory observations of African Grey Parrots interacting with various gripping targets needs to be recorded to develop biomimetic grasping strategies. Lastly, the need to append an additional 3-DOF wrist prior to the gripper should be evaluated. However, it is hoped that the beak-like gripper will eliminate the need for high-DOF and high-precision gripper positioning.

4. CONCLUSION

This paper outlines the beginning of a biologically inspired gripper based on the physical shape and mechanisms of the African Grey Parrot. This research intends to develop a novel mechanical gripping device for the new DARwIn-OP platform that is mechanically simple and versatile.

REFERENCES

[1] M. Wright, “Learning From the Wild Nature of Greys” www.africangreys.com/articles/overview/learning, Feb 2012.

[2] Robotis Inc., 2012, “Open Platform Humanoid Project”, Feb 2012, www.robotis.com/xe/darwin_en.

[3] G. Kaiser, 2007, “The Inner Bird: Anatomy and Evolution”, University of British Columbia Press.

[4] R.L. Williams II, 2012, “DARwIn-OP Humanoid Robot Kinematics”, Proceedings of the ASME IDETC/CIE, Chicago IL, August 12-15, 2012, DETC2012-70265

[5] G. Monkman, S. Hesse, R. Steinman, H. Schunk, “Introduction to Prehension Technology”, Wiley-VCH 2012, media.wiley.com/product_data/excerpt/90/35274061/3527406190.pdf

[6] J.Videler,2006, “Avian Flight”, Oxford University Press, pg.45