Dex-Net as a Service: A Cloud-Based, Generic Parallel-Jaw Grasp Planning System

Albert Author[1] and Bernard D. Researcher[2]

***Abstract*— The ability for machines to accurately compute and successfully execute candidate grasps on adversarial target objects is paramount to the future success of robotic automation in industry and in our homes. To reach acceptable levels of performance, robots must rely on either expert domain knowledge, which can be expensive to acquire, or complex machine learning algorithms, which require large amounts of data to train and may be specific to a single robot's geometry.**

Cloud Robotics helps offload these costs from end-robotics-users to Platform as as Service (PaaS) and Software as a Service (SaaS) offerings. These services accelerate the development velocity of robotic systems and avoid complex software installation and maintenance costs. The availability of myriad specialized robotic software implementations, however, creates its own problem of vendor lock-in, increasing the switching cost associated with using new robotic hardware and software.

We present Dex-Net as a service (DNaaS), a cloud-based grasp planning system for parallel-jaw grippers built on top of Dexterity Network 2.0 (Dex-Net). Unlike other cloud-based grasp planners, DNaaS can be parameterized to compute grasps using arbitrarily specified parallel-jaw grippers. DNaaS accepts generic 3D object meshes over HTTP and returns a set of candidate stable-pose grasps ranked by their Ferrari-Canny probability of force closure under sampled uncertainty in object and gripper pose and friction. To try the system live, visit `http://automation.berkeley.edu/dex-net`.

I. INTRODUCTION

The development of Cloud Robotics highlights the utility of a shared knowledge base of common interfaces to robotic control policies. Data repositories such as ROS and RoboEarth enable internet connected robots to draw from, and ultimately contribute their sensing data back to, a unified robotic knowledge graph [1]. Already we are seeing the fruits of democratized and commoditized robotics in automated manufacturing services used for rapid hardware design [5] and web-based science laboratories aimed at streamlining controlled experiments [6].

Such repositories of information can present their own complications, as each module in the system may come coupled to a specific robot, operating on a narrow set of environments and objects [2]. As a result, end users of such systems may become locked-in [7] and unable to upgrade their grasping hardware due to an incompatible software dependency. Likewise, roboticists may be unable to upgrade their grasping software due to the constraints of their current hardware.

A similar phenomenon of vendor lock-in occurs in the software industry, where it can prevent consumers from using optimal software tooling due to the prohibitively high switching-costs of migrating between software providers. Data, application, and infrastructure lock-in are serious concerns for consumers leveraging cloud services [3], [4]. The robotics industry is no different, as the installation of new gripper hardware on robotic fleets due to a forced software upgrade may require serious capital expenditure.

We present Dex-Net as a Service (DNaaS), an HTTP API for computing and ranking grasps on generic 3D object meshes using arbitrary parallel jaw grippers. DNaaS leverages GQ-CNNs [8] to enable the computation of optimal stable pose grasps. We present six experiments over which we vary the parallel-jaw grippers of the robot, as well as the RGB-D camera used for object perception to access the performance of DNaaS in real-life situations across multiple hardware configurations.

To visualize our grasping algorithm, we also developed a web UI from which you can adjust your hardware settings and upload object meshes to experiment with DNaaS using your own data. Our contributions are thus three-fold:

- We present DNaaS, a public HTTP API which computes and ranks grasps on arbitrary 3D object meshes (in `.obj` format with triangular faces) using arbitrarily specified parallel jaw grippers and RGB-D sensors,
- We develop a web UI from which users can upload candidate objects and evaluate the robustness of stable pose grasps, and
- We evaluate the real-time performance of DNaaS across varied hardware configurations and adversarial object grasps.

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[1]Albert Author is with Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, 7500 AE Enschede, The Netherlands `albert.author@papercept.net`

[2]Bernard D. Researcheris with the Department of Electrical Engineering, Wright State University, Dayton, OH 45435, USA `b.d.researcher@ieee.org`

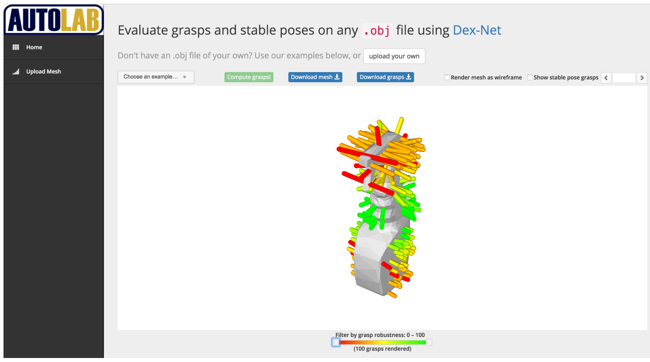

Fig. 1. Web UI for interacting with DNaaS. Users may choose an example object mesh to use, or they may upload their own `.obj` file to compute grasps on using DexNet. Each candidate grasp is represented by a line-segment whose color corresponds to the grasp's robustness (red being the least robust, green the most robust).

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Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as 3.5-inch disk drive.
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$$\alpha + \beta = \chi \tag{1}$$

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TABLE I

AN EXAMPLE OF A TABLE

One	Two
Three	Four

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Fig. 2. Inductance of oscillation winding on amorphous magnetic core versus DC bias magnetic field

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity Magnetization, or Magnetization, M, not just M. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write Magnetization (A/m) or Magnetization A[m(1)], not just A/m. Do not label axes with a ratio of quantities and units. For example, write Temperature (K), not Temperature/K.

V. CONCLUSIONS

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

APPENDIX

Appendixes should appear before the acknowledgment.

ACKNOWLEDGMENT

The preferred spelling of the word acknowledgment in America is without an e after the g. Avoid the stilted expression, One of us (R. B. G.) thanks . . . Instead, try R. B. G. thanks. Put sponsor acknowledgments in the unnumbered footnote on the first page.

References are important to the reader; therefore, each citation must be complete and correct. If at all possible, references should be commonly available publications.

REFERENCES

[1] http://roboearth.ethz.ch/wp-content/uploads/2011/06/Waibel2011RoboEarth.pdf
[2] from the RoboEarth article, ”World Robotics 2010,? Int. Federation Robot. Statist. Dept., 2010z
[3] https://www.capgemini.com/blog/capping-it-off/2016/12/how-to-minimize-the-3-main-cloud-vendor-lock-in-risks
[4] www.capgemini.com/resource-file-access/resource/pdf/minimizing_cloud_vendor_lock-in.pdf
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