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Alberto Parmiggiani

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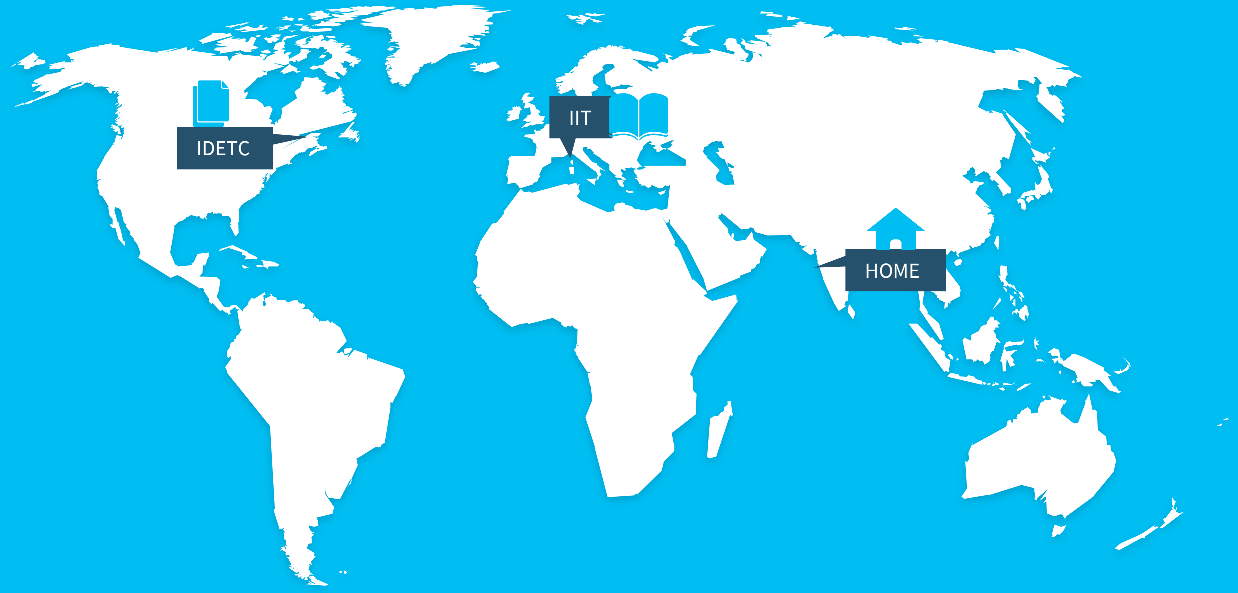
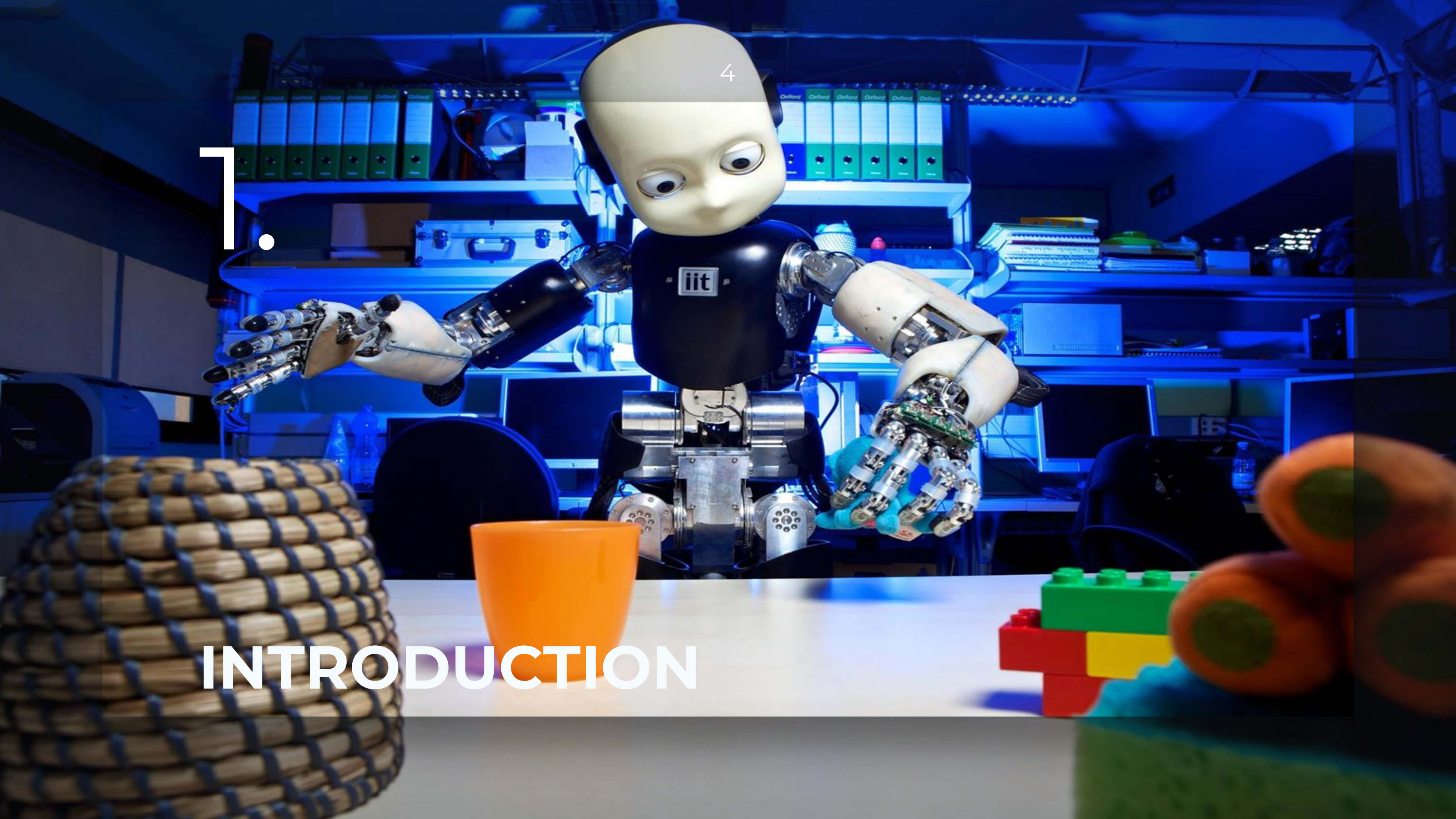
ISTITUTO ITALIANO
DI TECNOLOGIA

BACKGROUND



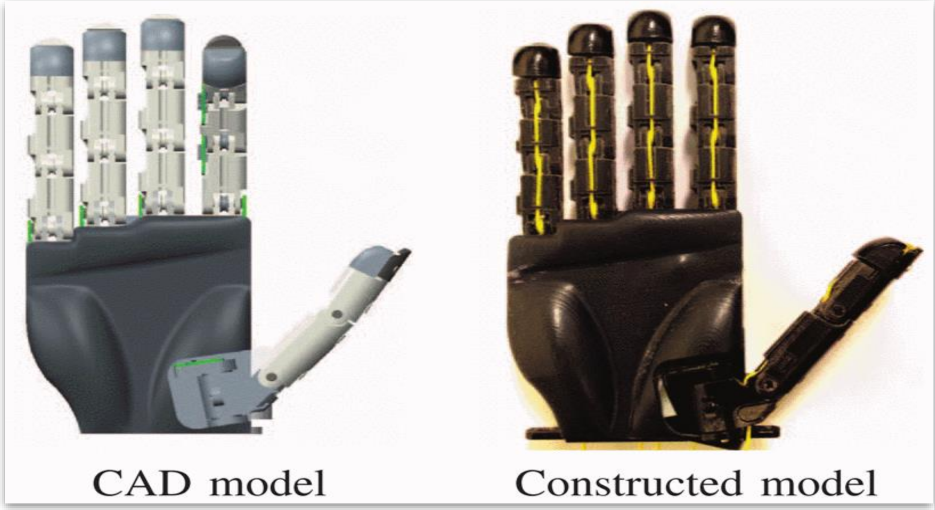
WORKSPACE ANALYSIS AND THE EFFECT OF GEOMETRIC PARAMETERS FOR PARALLEL MECHANISMS OF THE N-UU CLASS

DETC2018-85258
27.08.2018



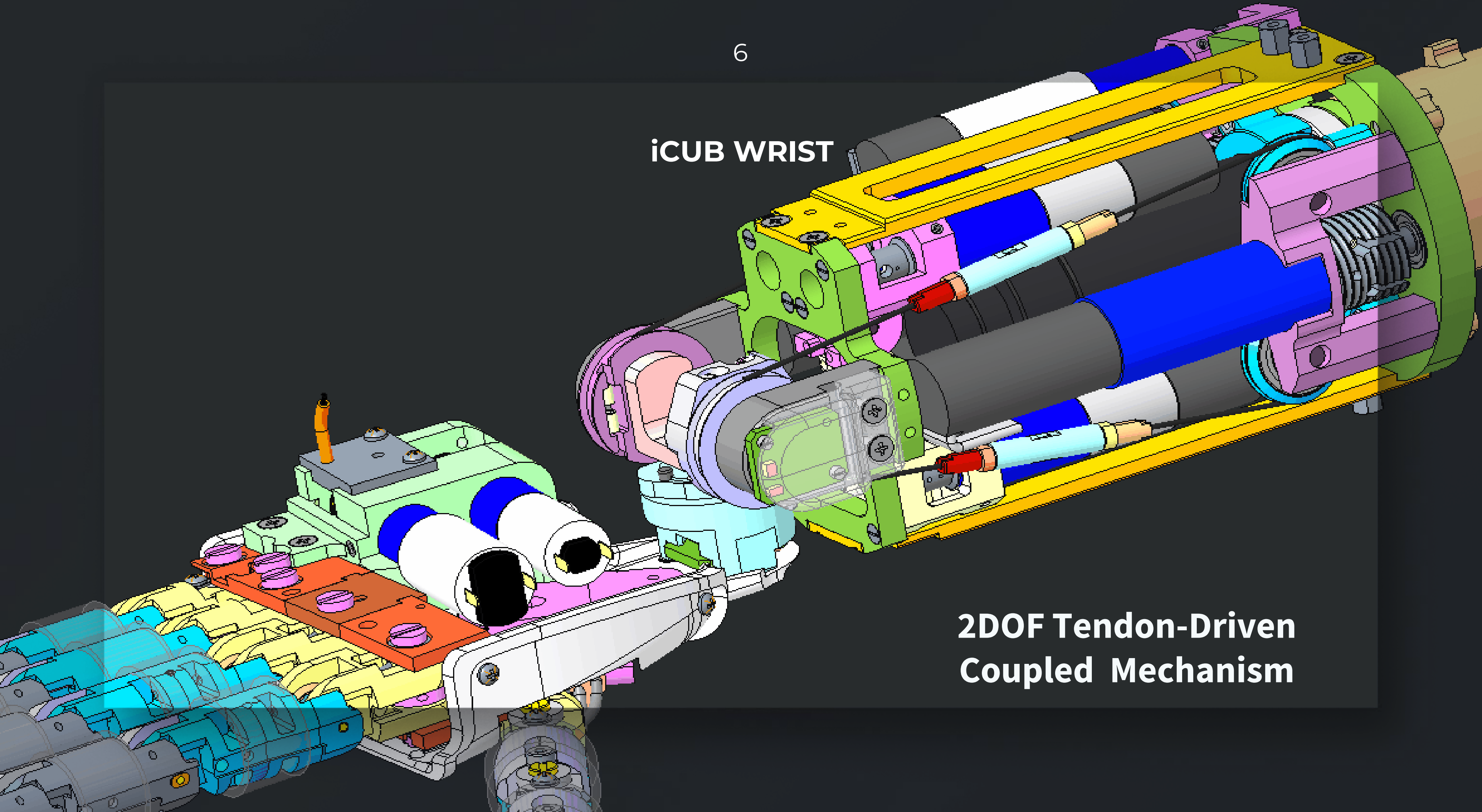
1. INTRODUCTION

- Hand-Forearm Assembly
  - 12 DOF
  - 290mm x 70mm x 40mm
  - 0.95 kg



Sureshbabu, Metta and Parmiggiani; IEEE HUMANOIDS; 2015

iCUB WRIST



2DOF Tendon-Driven Coupled Mechanism

DESIRED CHARACTERISTICS

2 Fully Decoupled DOF

Independent Yaw and Pitch Motions.

Large Range of Motion

Over +/- 45 degrees.

Simpler Kinematics

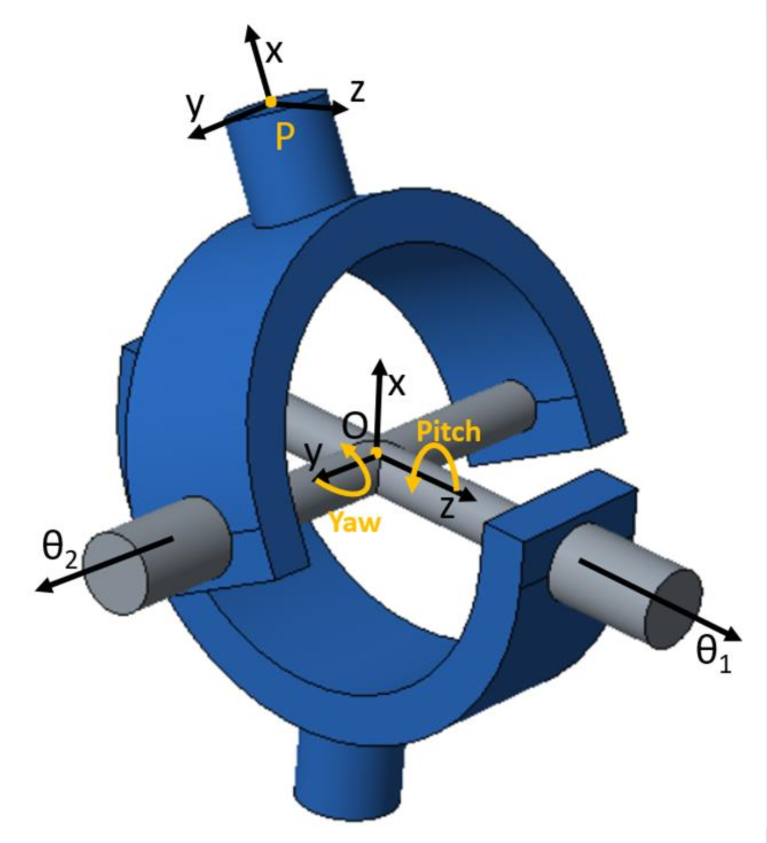
Easy to model and control.

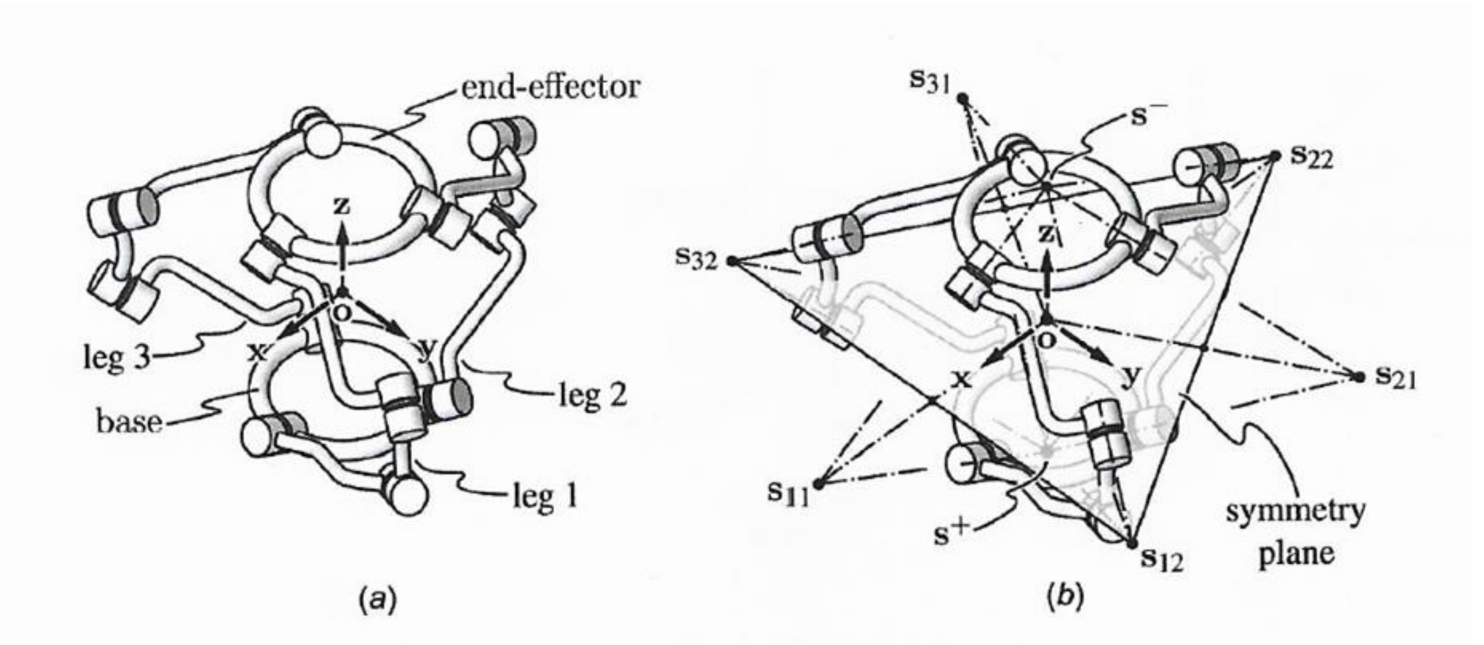
Compact Design

Space Constraints on the forearm.

Higher Payload-to-Weight Ratio

Higher payload-to-weight ratio.





N-UU MECHANISMS

Wu and Carricato; ASME J. Mechanisms and Robotics; 2017

OMNI - WRIST III

Mirror-symmetric architecture, large hemispherical workspace, slender form factor

2.

MODELLING & SIMULATION

OUR APPROACH

CAD Model

Create conceptual design of the mechanism using CAD tools.

Mechanism Simulation

Run kinematic simulations spanning the entire actuator range.

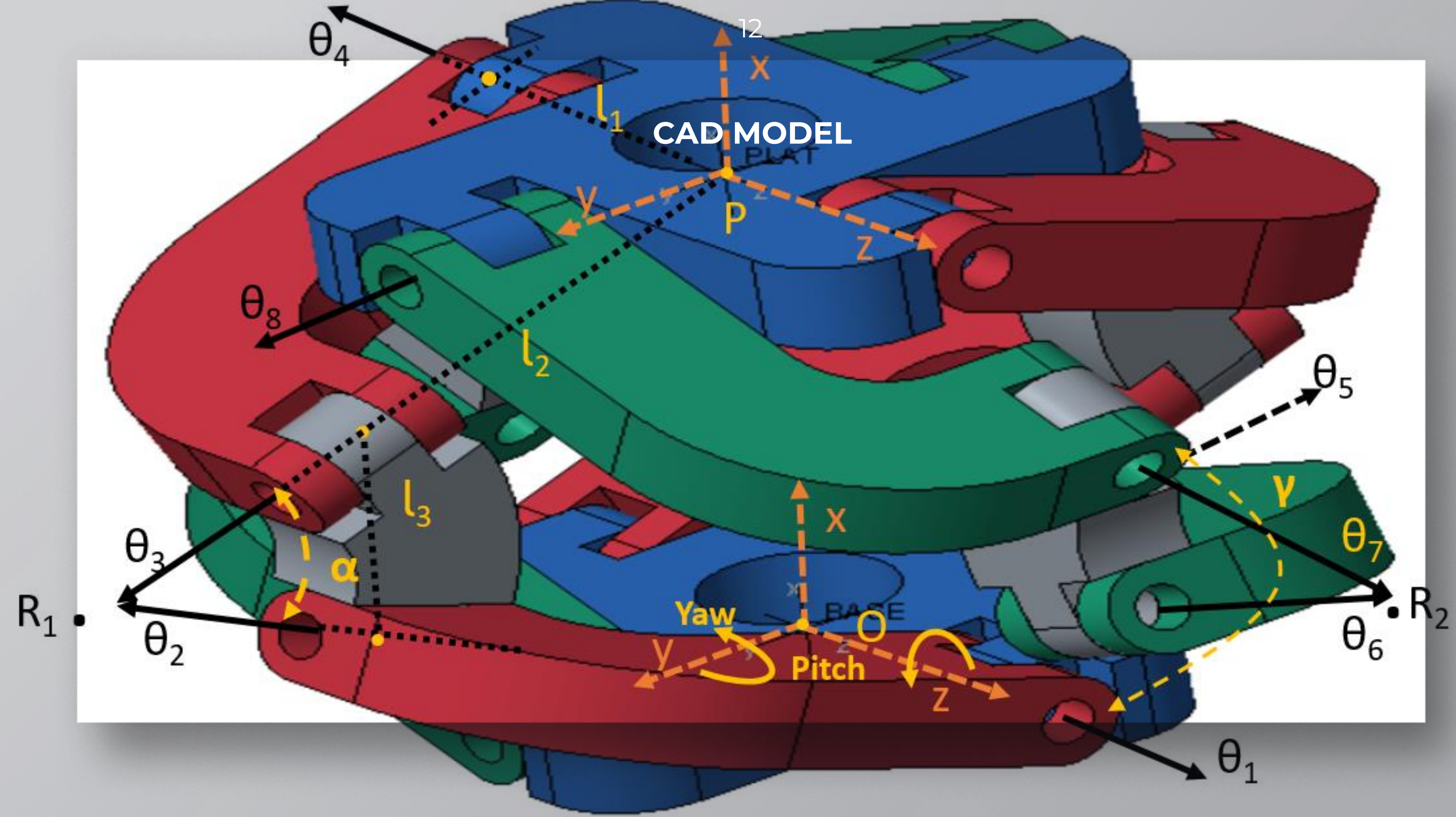
Extract Measures

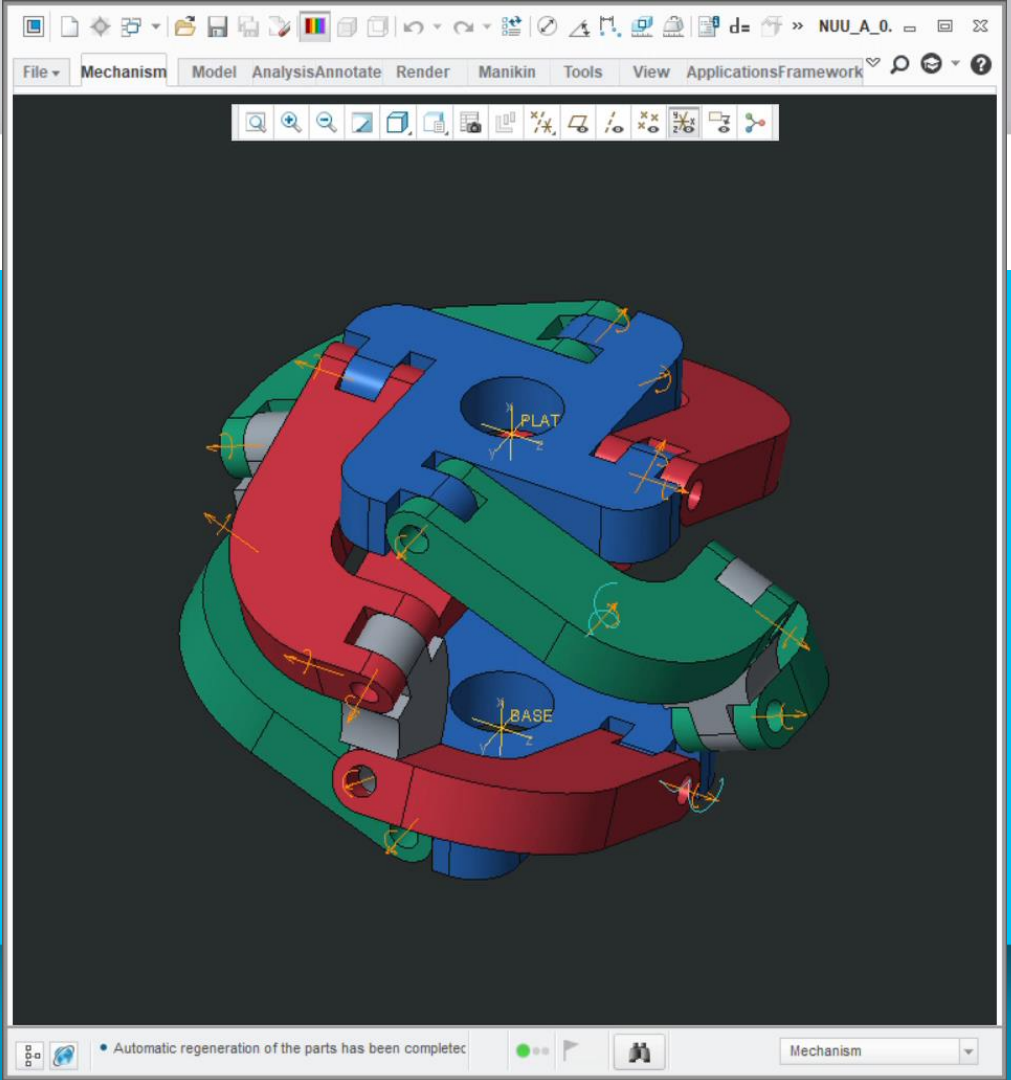
Record and extract platform coordinates and orientation angles throughout the simulation.

Contour Plots

Generate workspace and isotropy contours against the input actuators.

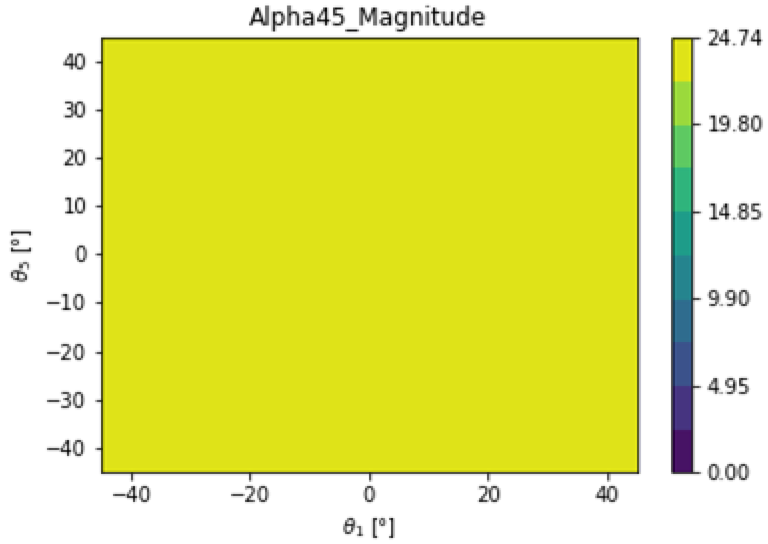
CAD MODEL


θ4
l1
x
PLAT
y
P
z
θ8
l2
θ5
γ
θ7
θ3
α
l3
x
R1
θ2
Yaw
BASE
O
y
Pitch
z
θ6
R2
θ1

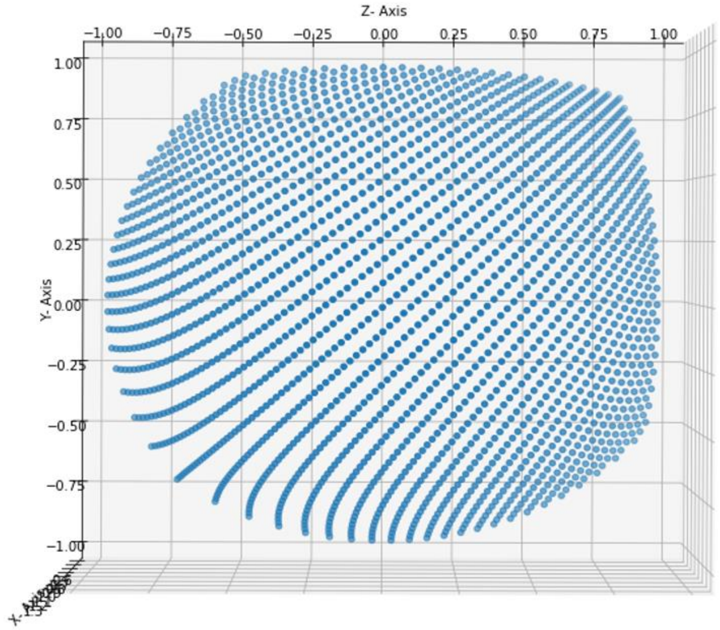


MECHANISM SIMULATION

Full workspace scan of the mechanism.



CONSTANT MAGNITUDE



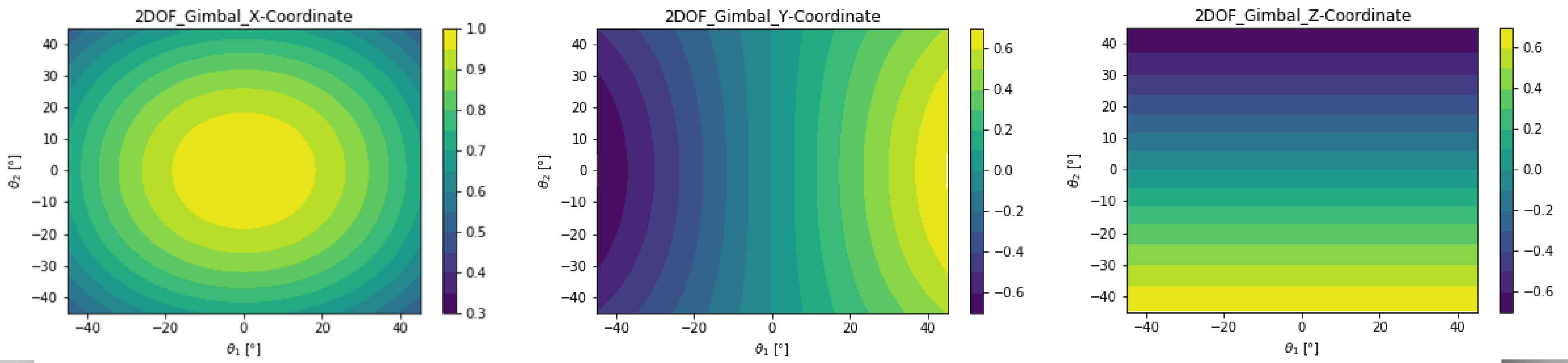
NORMALIZED CARTESIAN WORKSPACE

3.

ANALYSES

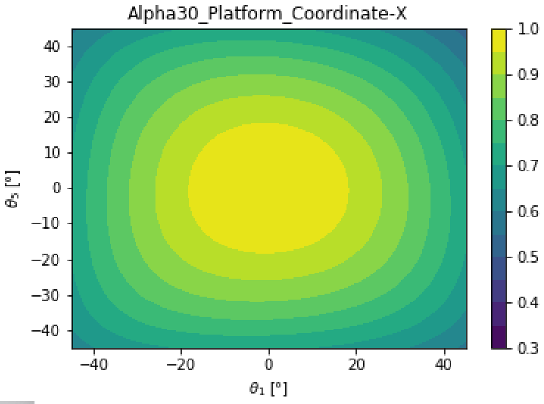
WORKSPACE ANALYSES - PLATFORM COORDINATES - GIMBAL

X Y Z

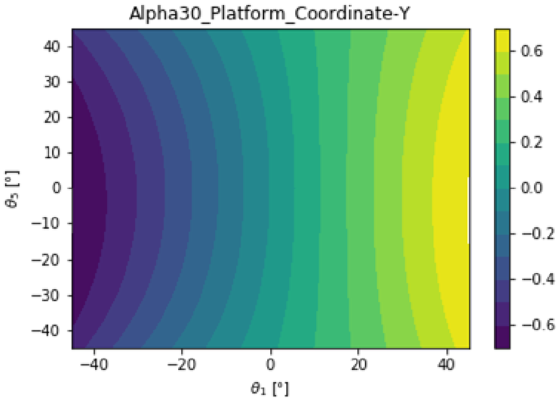


WORKSPACE ANALYSES - PLATFORM COORDINATES - α = 30°

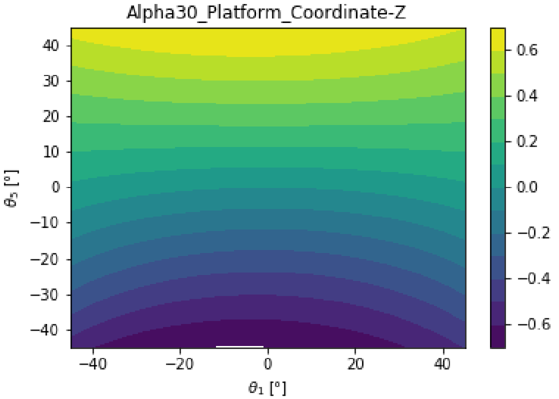
X



Y

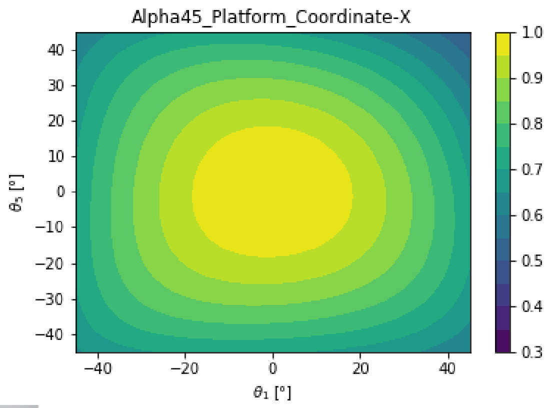


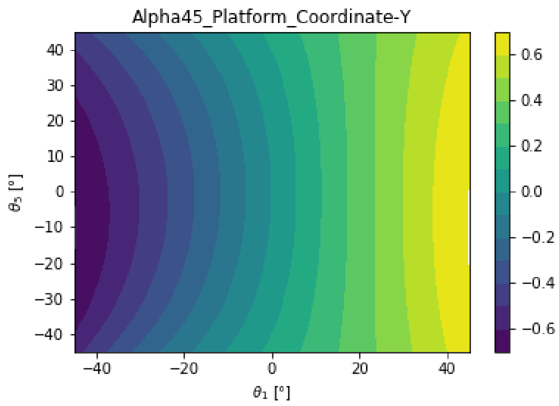
Z

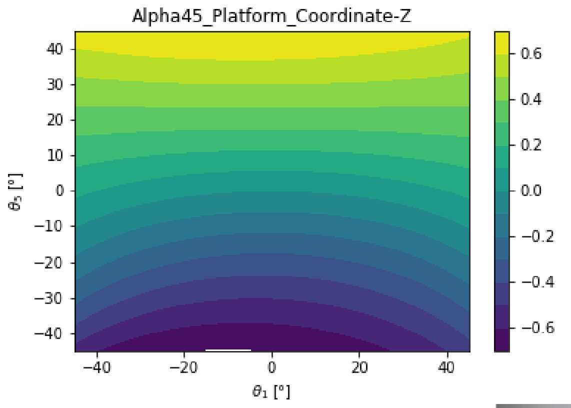


WORKSPACE ANALYSES - PLATFORM COORDINATES - α = 45°

X **Y** **Z**





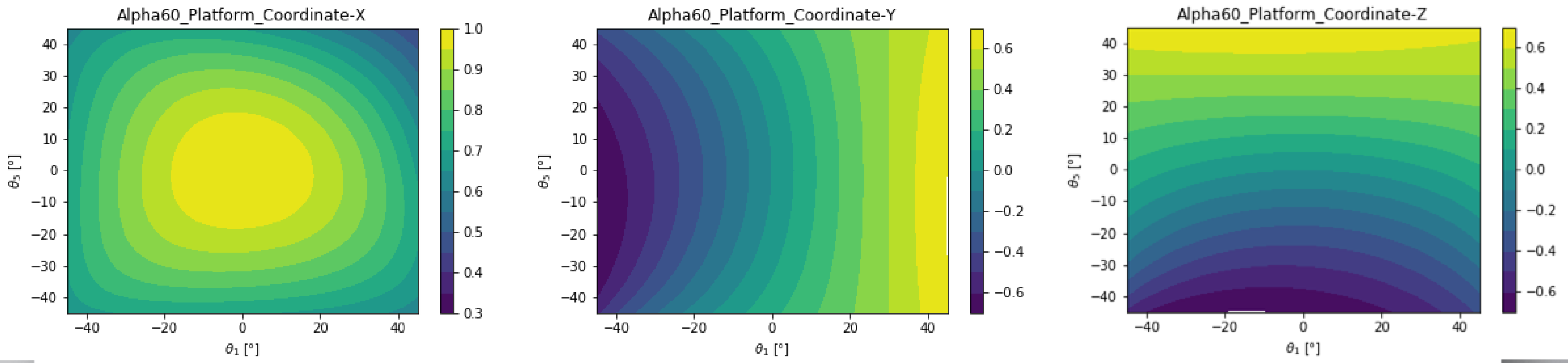


WORKSPACE ANALYSES - PLATFORM COORDINATES - α = 60°

X

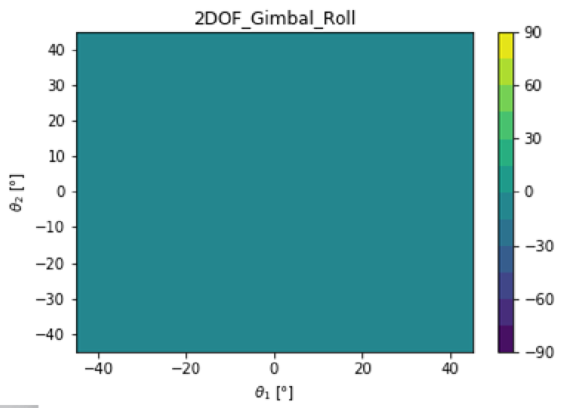
Y

Z

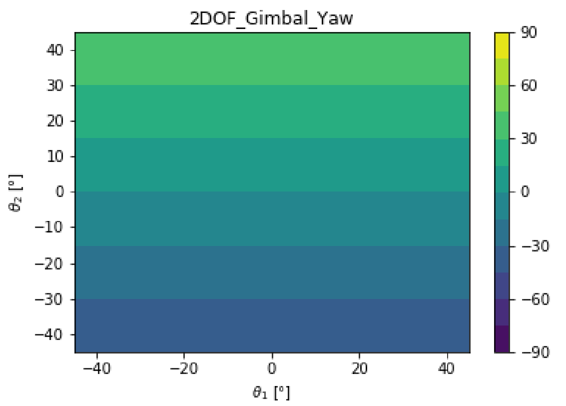


WORKSPACE ANALYSES - EULER ANGLES - GIMBAL

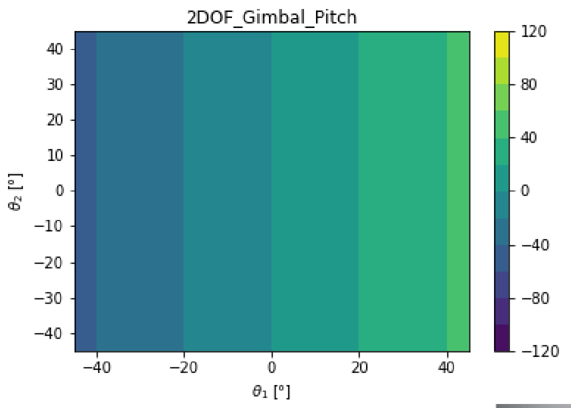
Roll



Yaw

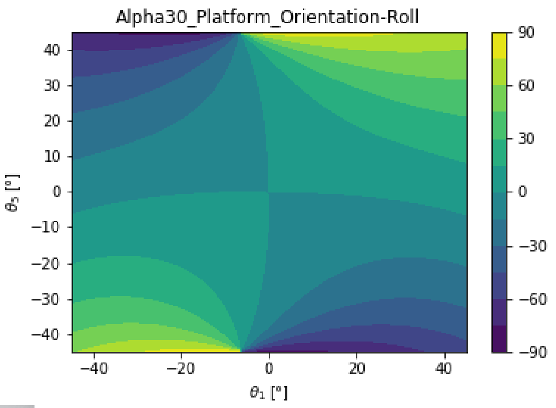


Pitch

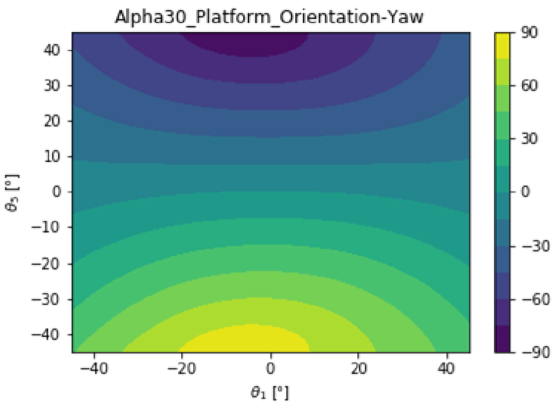


WORKSPACE ANALYSES - EULER ANGLES - α = 30°

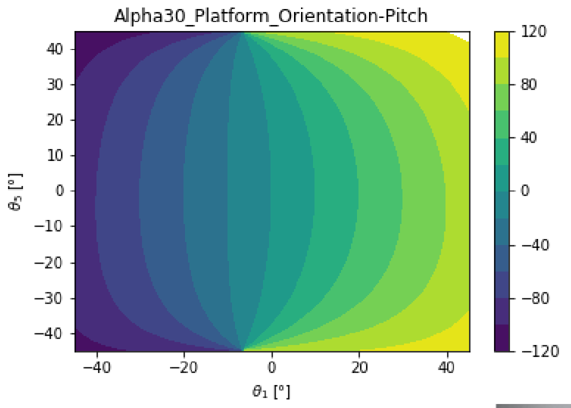
Roll



Yaw

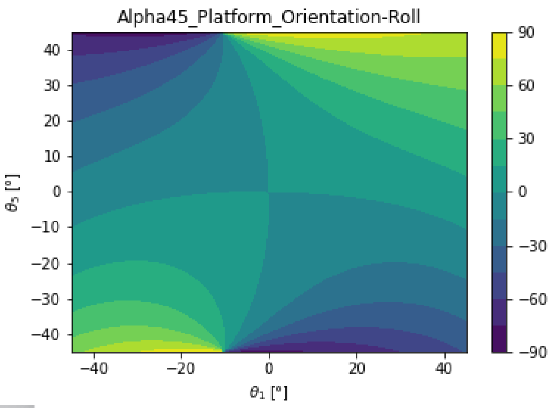


Pitch

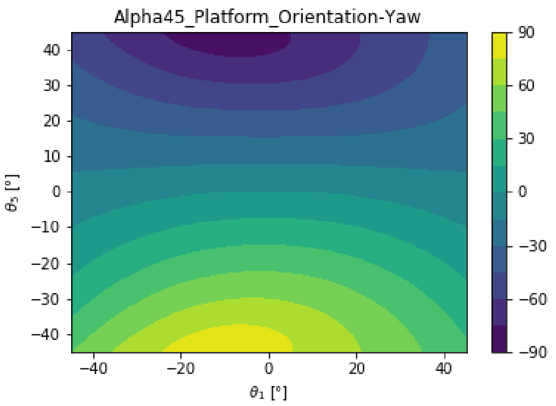


WORKSPACE ANALYSES - EULER ANGLES - α = 45°

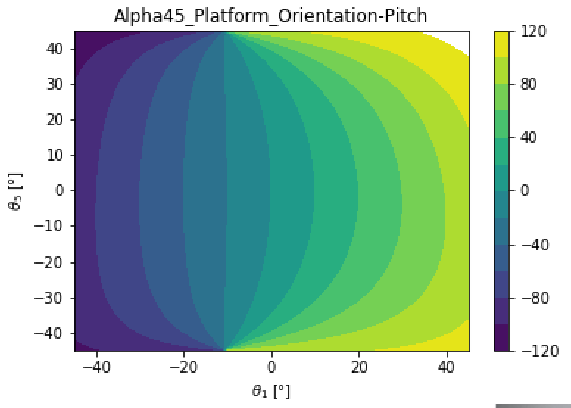
Roll



Yaw

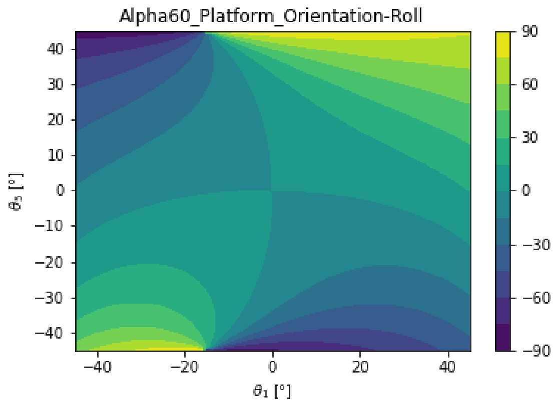


Pitch

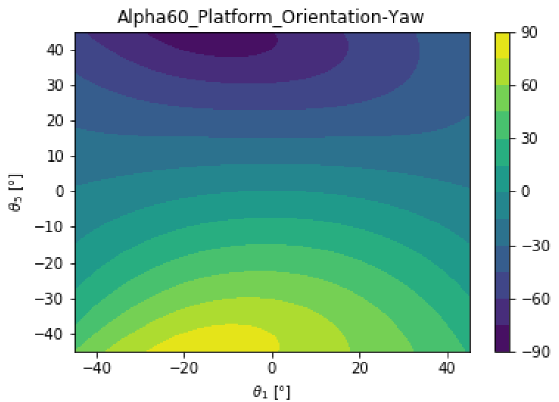


WORKSPACE ANALYSES - EULER ANGLES - α = 60°

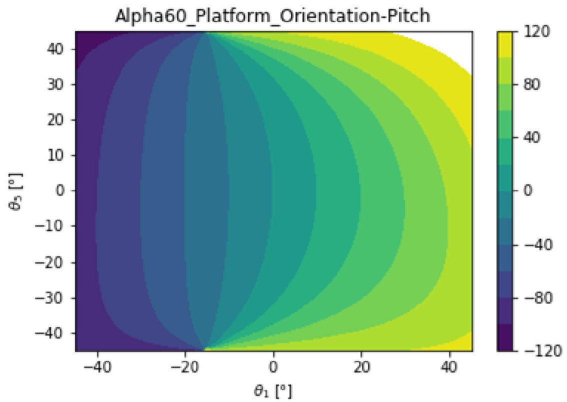
Roll



Yaw



Pitch

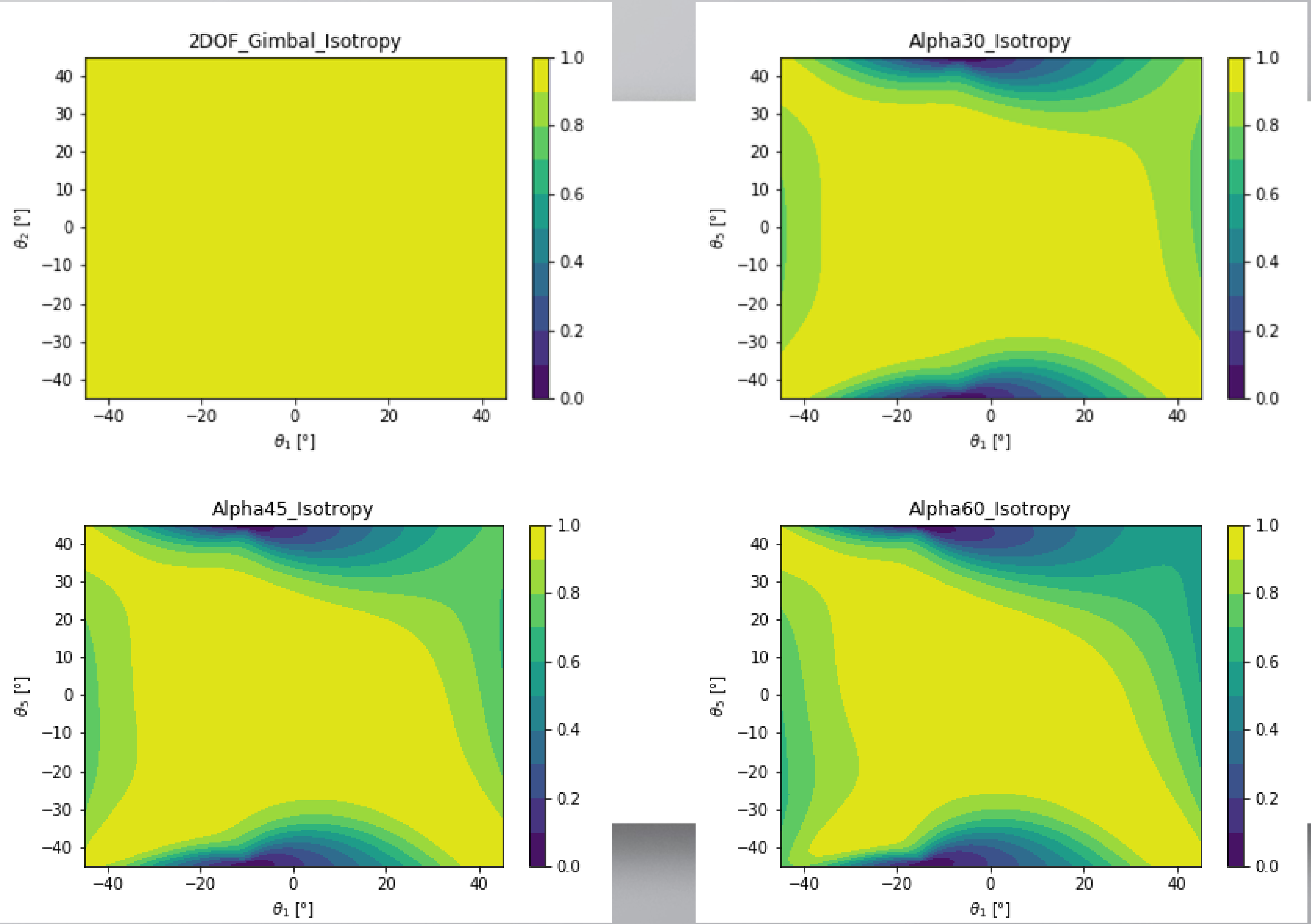


ISOTROPY ANALYSIS

$$\mathbf{J} = \begin{bmatrix} \dfrac{\partial \theta_p}{\partial q_1} & \dfrac{\partial \theta_p}{\partial q_2} \\ \dfrac{\partial \theta_y}{\partial q_1} & \dfrac{\partial \theta_y}{\partial q_2} \end{bmatrix}$$

$$\Delta = \frac{M}{\Psi} = \frac{\sqrt[m]{det(\mathbf{J}\mathbf{J}^{\mathbf{T}})}}{trace(\mathbf{J}\mathbf{J}^{\mathbf{T}})/m}$$

Kim and Khosla; IEEE IROS; 1991


2DOF_Gimbal_Isotropy
θ_2 [°]
θ_1 [°]
Alpha30_Isotropy
θ_5 [°]
θ_1 [°]
Alpha45_Isotropy
θ_5 [°]
θ_1 [°]
Alpha60_Isotropy
θ_5 [°]
θ_1 [°]

CONCLUSIONS

Spherical

The magnitude of the platform center w.r.t the base is always constant.

Asymmetry

Mechanism behaviour is not symmetric, i.e., the plots are not centered with zero.

Warping

Workspace diverges towards the extremes. This effect increases with **α**.

Parasitic motion

Platform posses undesired **Roll** motion.

Coupling

Pitch and yaw motions of the platform are dependent of each other.

Anisotropy

Mechanism is not fully isotropic throughout the workspace. Anisotropy increases with **α**.

OPENING

ISTITUTO ITALIANO
DI TECNOLOGIA
iCub FACILITY

Post-Doc on “The design of better iCub Hands”

alberto.parmiggiani@iit.it

THANK YOU FOR YOUR ATTENTION!

Any questions?

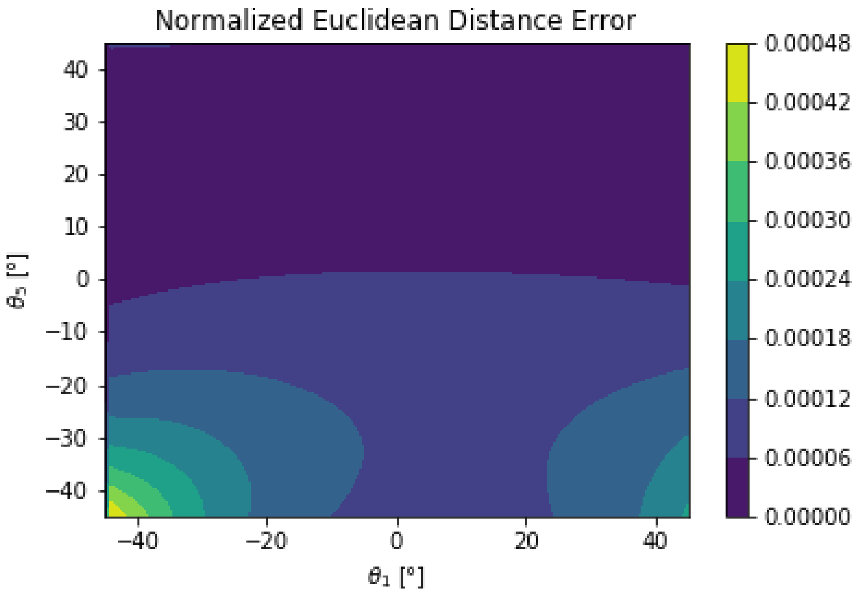
divya.shah@iit.it
iit.it/people/divya-shah

“

FIN.

ANALYTICAL MODEL

- Limb A $\mathbf{A} = \mathbf{A_1}(\theta_1)\mathbf{A_2}(\theta_2)\mathbf{A_3}(\theta_3)\mathbf{A_4}(\theta_4)$
- Limb B $\mathbf{B} = \mathbf{B_5}(\theta_5)\mathbf{B_6}(\theta_6)\mathbf{B_7}(\theta_7)\mathbf{B_8}(\theta_8)$
- Platform C $\mathbf{C} = \mathbf{T_{XYZ}}(x, y, z)\mathbf{R_Z}(a)\mathbf{R_Y}(o)\mathbf{R_X}(n)$
- Closed-Form $\mathbf{A} = \mathbf{B} = \mathbf{C}$



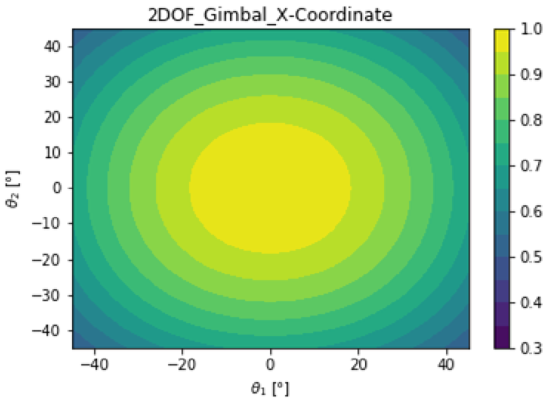
ERROR COMPARISON BETWEEN CAD SIMULATION AND ANALYTICAL COMPUTATIONS

4.

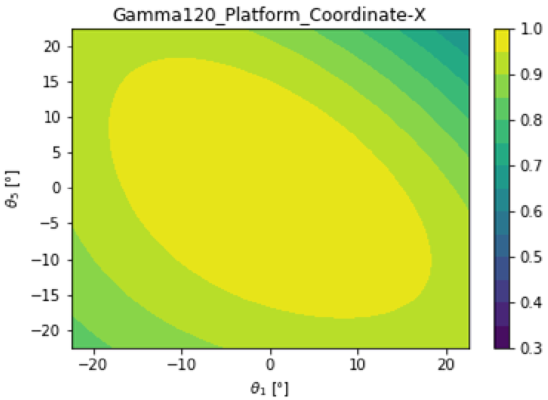
GAMMA CASE PLOTS

WORKSPACE ANALYSES - X COORDINATE [GAMMA CASE]

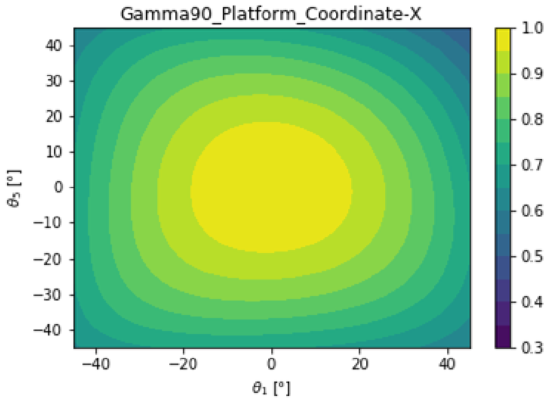
Gimbal



$\gamma = 120°$

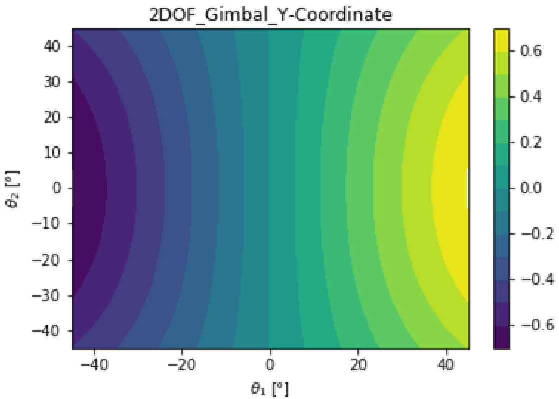


$\gamma = 90°$

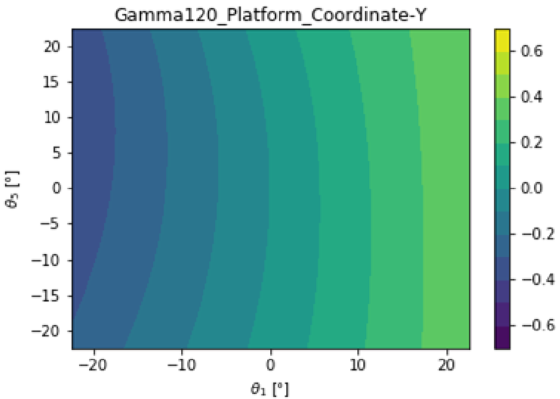


WORKSPACE ANALYSES - Y COORDINATE [GAMMA CASE]

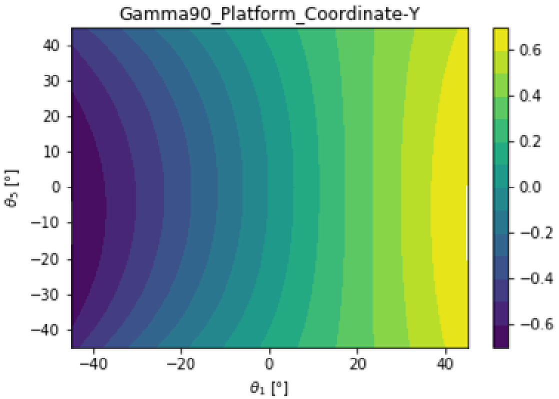
Gimbal



$\gamma = 120°$

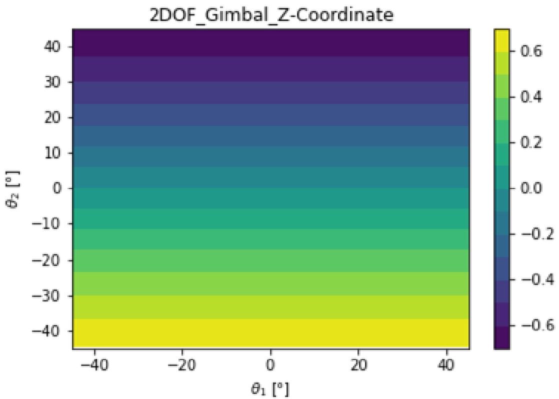


$\gamma = 90°$

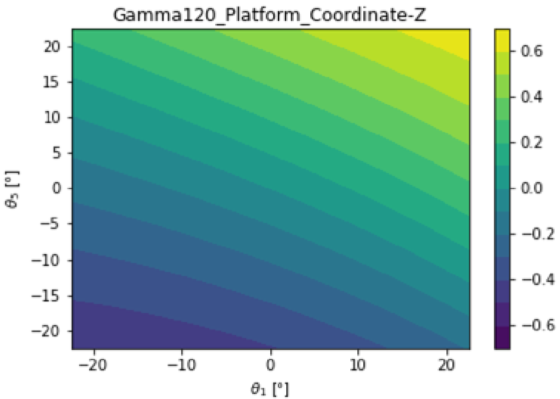


WORKSPACE ANALYSES - Z COORDINATE [GAMMA CASE]

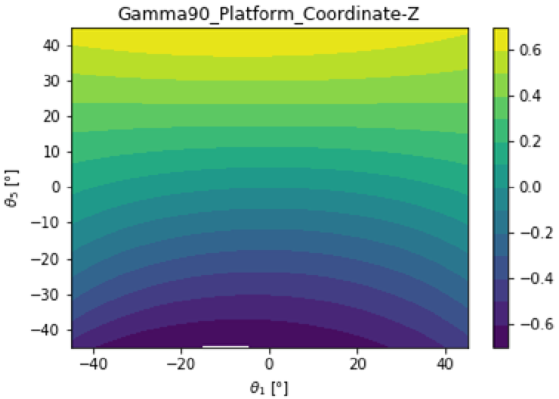
Gimbal



$\gamma = 120°$

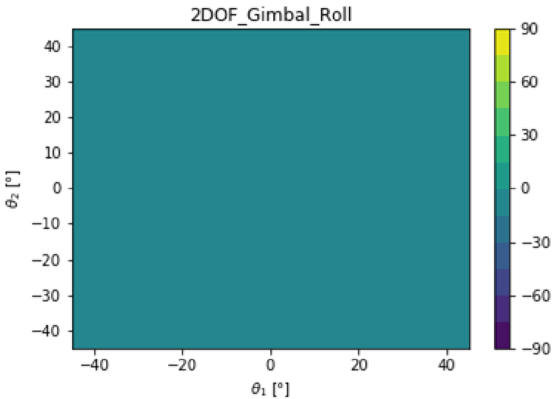


$\gamma = 90°$

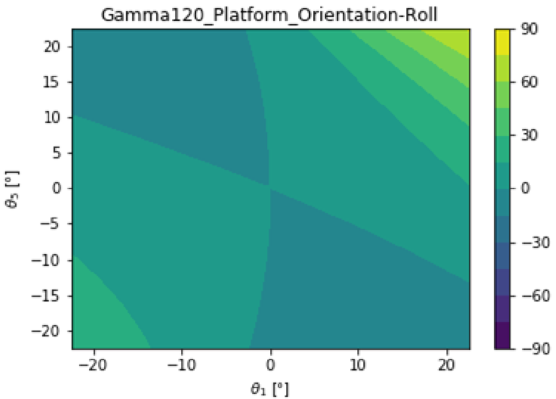


WORKSPACE ANALYSES - ROLL [GAMMA CASE]

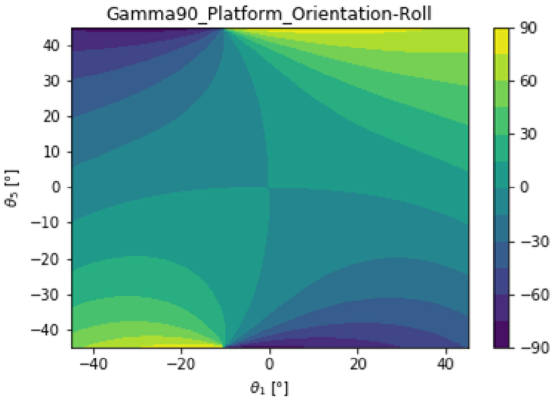
Gimbal



$\gamma = 120°$

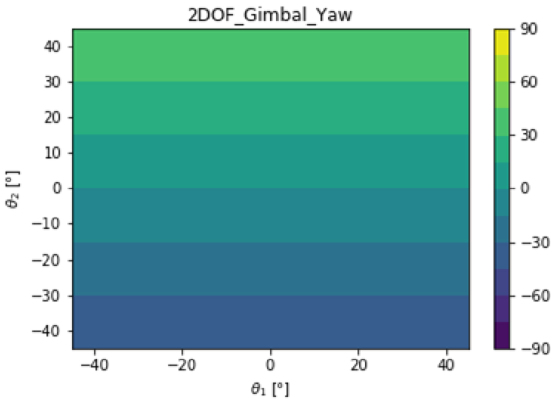


$\gamma = 90°$



WORKSPACE ANALYSES - YAW [GAMMA CASE]

Gimbal



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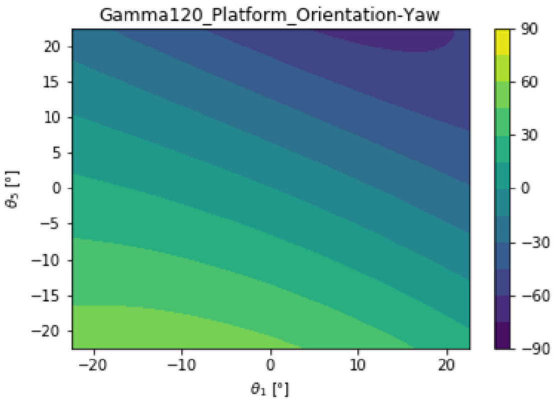

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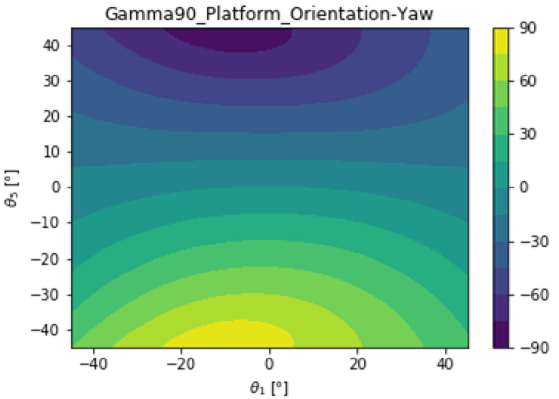
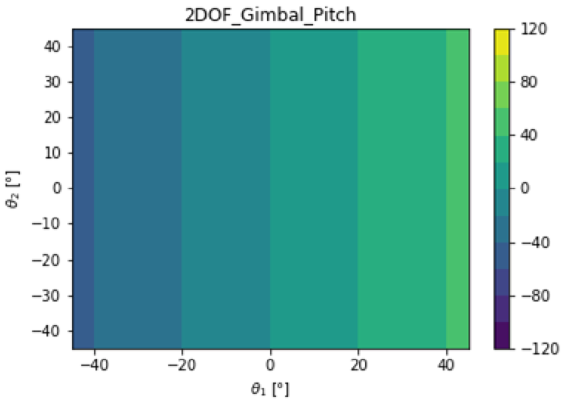
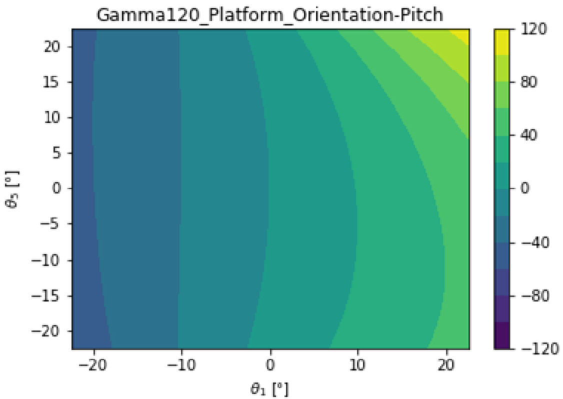


WORKSPACE ANALYSES - PITCH [GAMMA CASE]

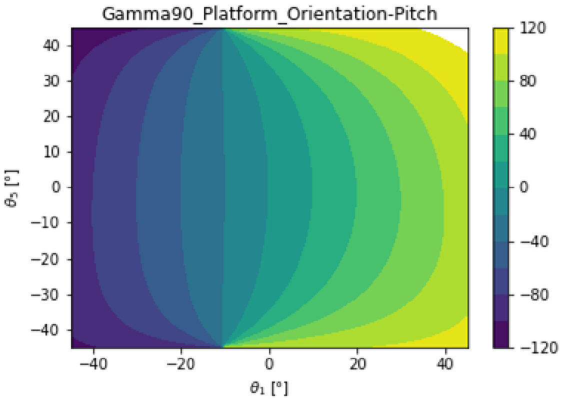
Gimbal



$\gamma = 120°$

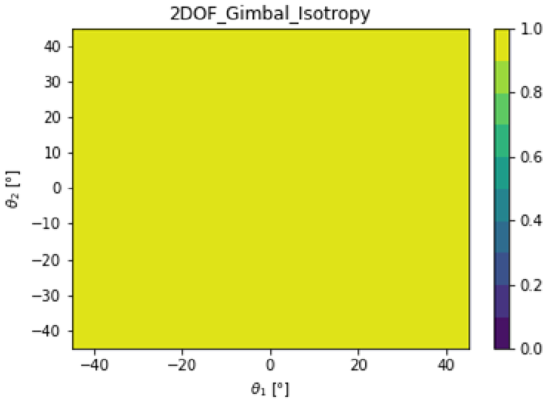


$\gamma = 90°$

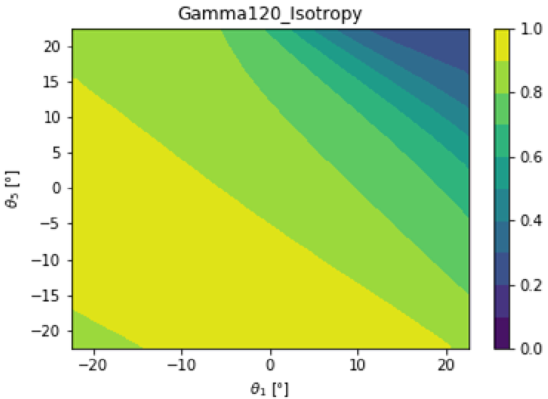


ISOTROPY ANALYSIS [GAMMA CASE]

Gimbal



$\gamma = 120°$



$\gamma = 90°$