Carnegie Mellon University

Visual and Design Engineering Lab

Functionally-Based Conceptual Design through Data-driven Shape Analysis

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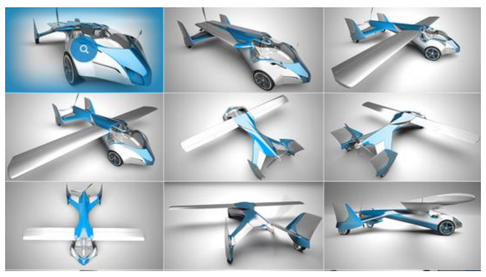
Motivation



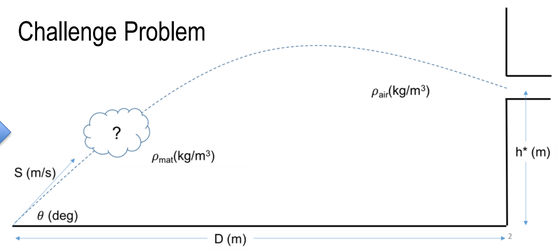
Generating promising design candidates that satisfy certain functional requirements is a challenge that has confused CAD researchers for decades. To explore this challenge problem, we need a synthesis method that is able to take advantage of a diverse database and generate innovative patterns which are not existed in the given database. A design system established based on this method could be a fast design support system bringing many benefits to researchers and designers.

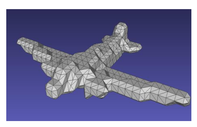
Challenge Problem

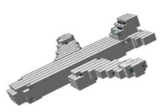
Geometry-based performance metric

- wing loading
- Lift power
- Take-off/landing distance
- Turn performance

Challenge Problem





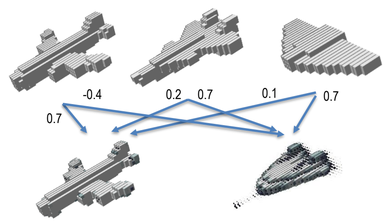


Hit the target accurately for arbitrary launch configurations.
Input: S, θ. Fixed: D, ρmat, ρair
Objective: Go through gap at height h* (target height)
Constraints: Projectile fits in a 1mX1mX1m box, no propulsion
Task: Design the shape of the projectile

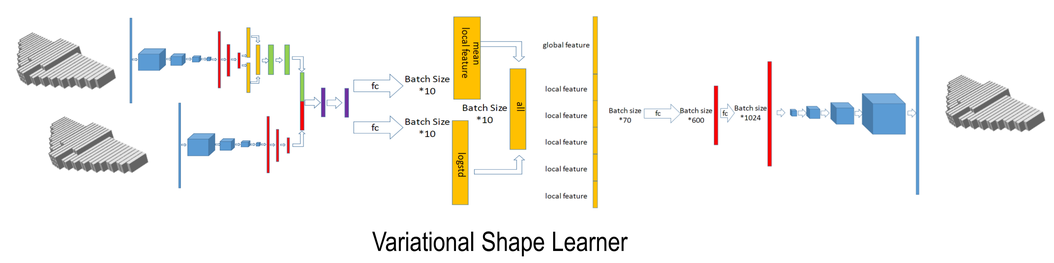
Design System

Genetic Algorithm

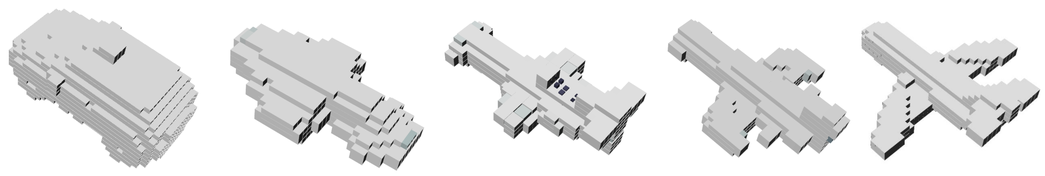
Population size:
100 | Genome: 70X1
Initial population:
Random selection from 4500 designs
Fitness: $(h\text{-}h^*)^2$
Probability of selection $\propto$ Fitness
Crossover (interpolation) between parents



Deep-Learned Design DNA

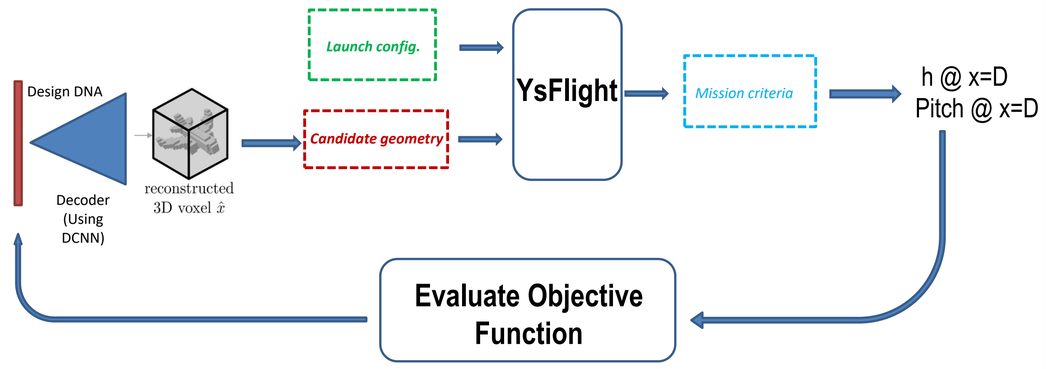


Variational Shape Learner



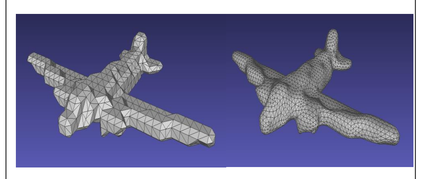
cross categories transfer learning using DNA

Pipeline of Conceptual Design

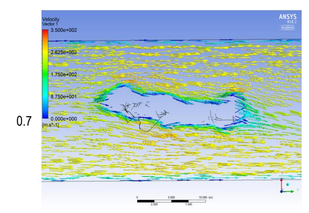


To optimize the shape pf the projectile, we employ the structure shown above. To achieve the requirement users assign, we combine the power of Autoencoder, Genetic Algorithm and our team's design simulator.

Meshes and Sims



Voxel2Mesh

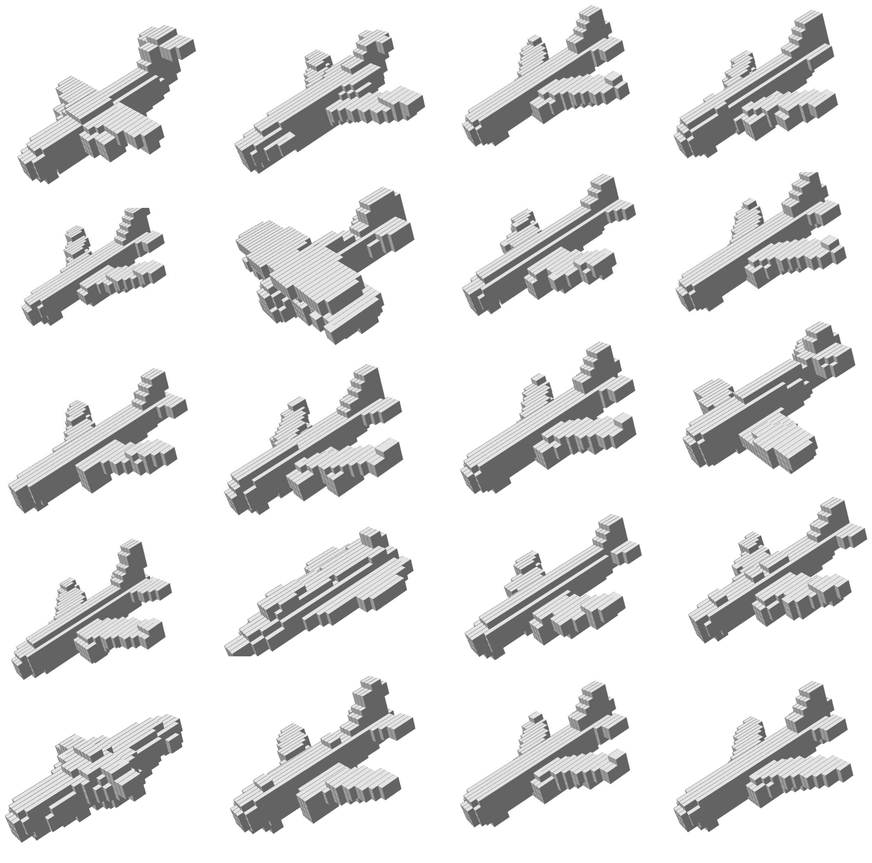


CFD simulation

Results

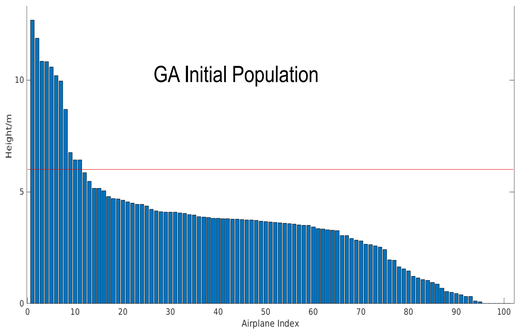
Conditions and Design Results

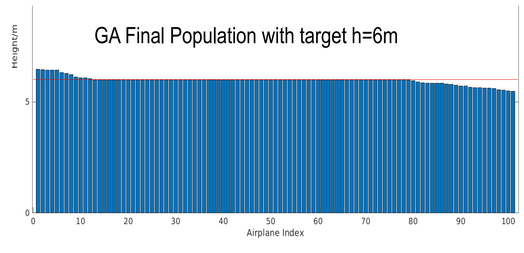
Conditions: S=45.7, θ = 10, ρ_{mat}=1000, D=100. Dataset: h varies: -0.2m - 12.67m, Landing pitch varies: 4.24°-8.27°

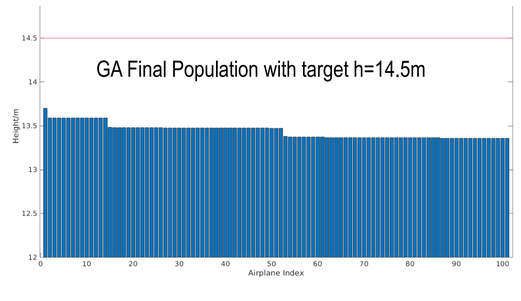


10 Random samples from the initial population

10 Random samples from the final population







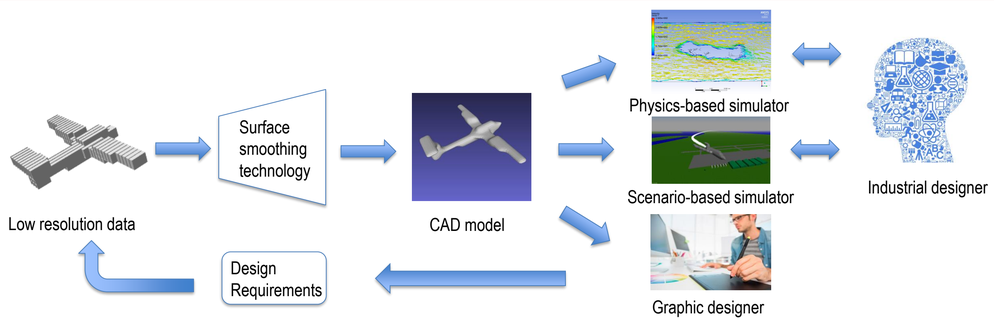
Figures above are showing the airplanes in the database before we run the system and the airplanes the system generates. Also, the distributions of the results of different target heights are shown.

Conclusions and Future Work

Conclusions

- We developed a data-driven method which is capable of extracting conceptual design blocks from a database of solutions.
- We studied the properties of the identified conceptual blocks for automatic, function-driven design synthesis.
- We demonstrated the utility of the approach on a challenge problem allowing design realization, physics simulations, and design optimization

Future Work



In the future, by tapping into more smooth data type like point cloud data or even mesh files, we hope our work could generate more promising designs. Also, we hope to improve the method by exploring more categories of objects and geometry-based performance requirements.

References

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2. Leon Gatys, Alexander Ecker, Image Style Transfer Using Convolutional Neural Networks, 2016
3. Panos Achlioptas, Olga Diamanti, Ioanis Mitliagkas, Leonidas Guibas, Learning Representations and Generative Models for 3D Point Clouds, 2018