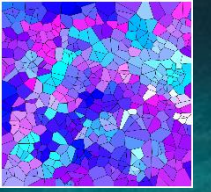


Encuentro Nacional de Computación 2021, SMCC
Taller de Geometría Discreta y Computacional



Thermal Pack

A packing engine tailored to drive HP MJF production yield up

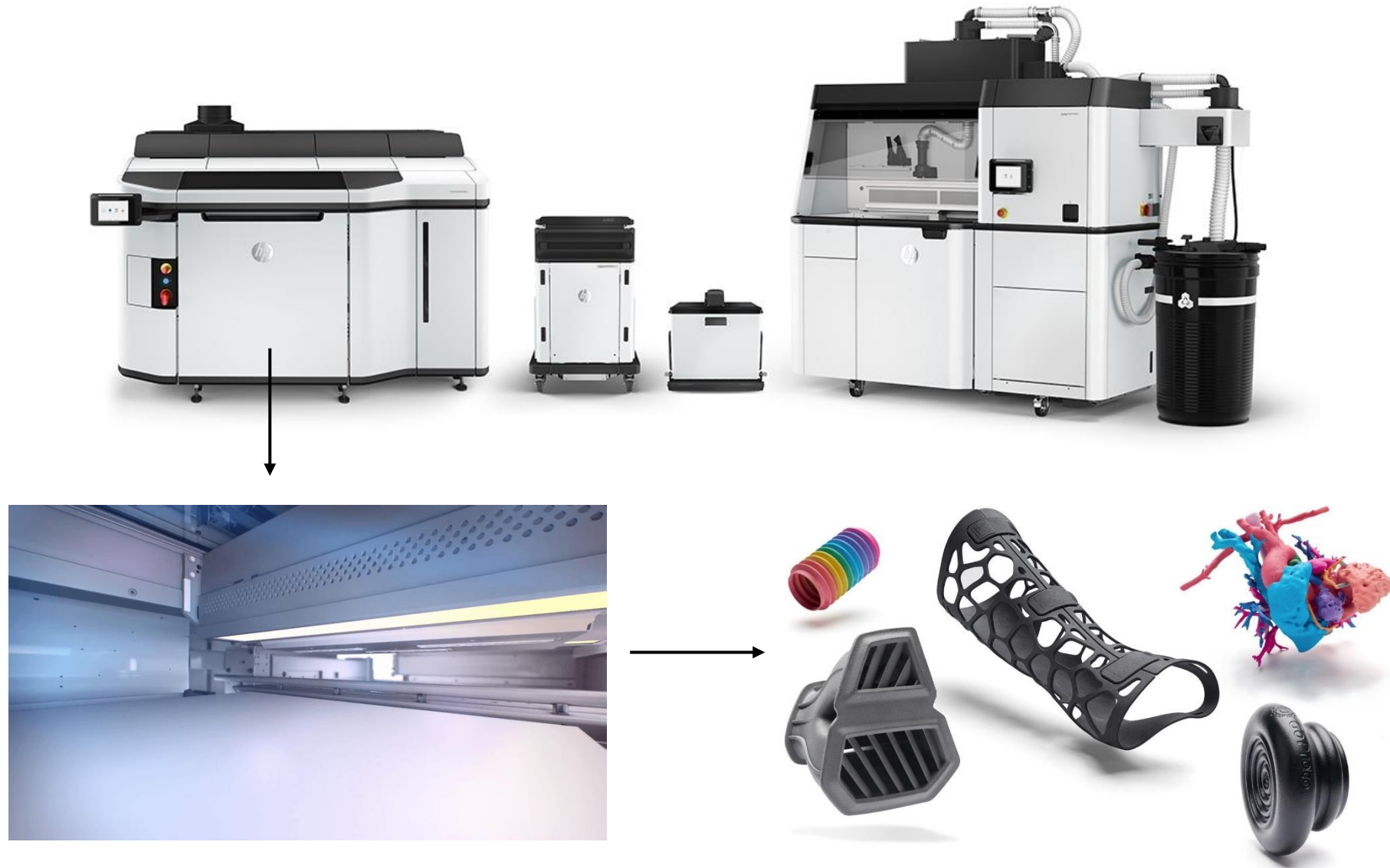
Presenter:

Juan Carlos Catana, 3D Lab, HP Labs

10/08/2021



What exactly is a 3D printer?

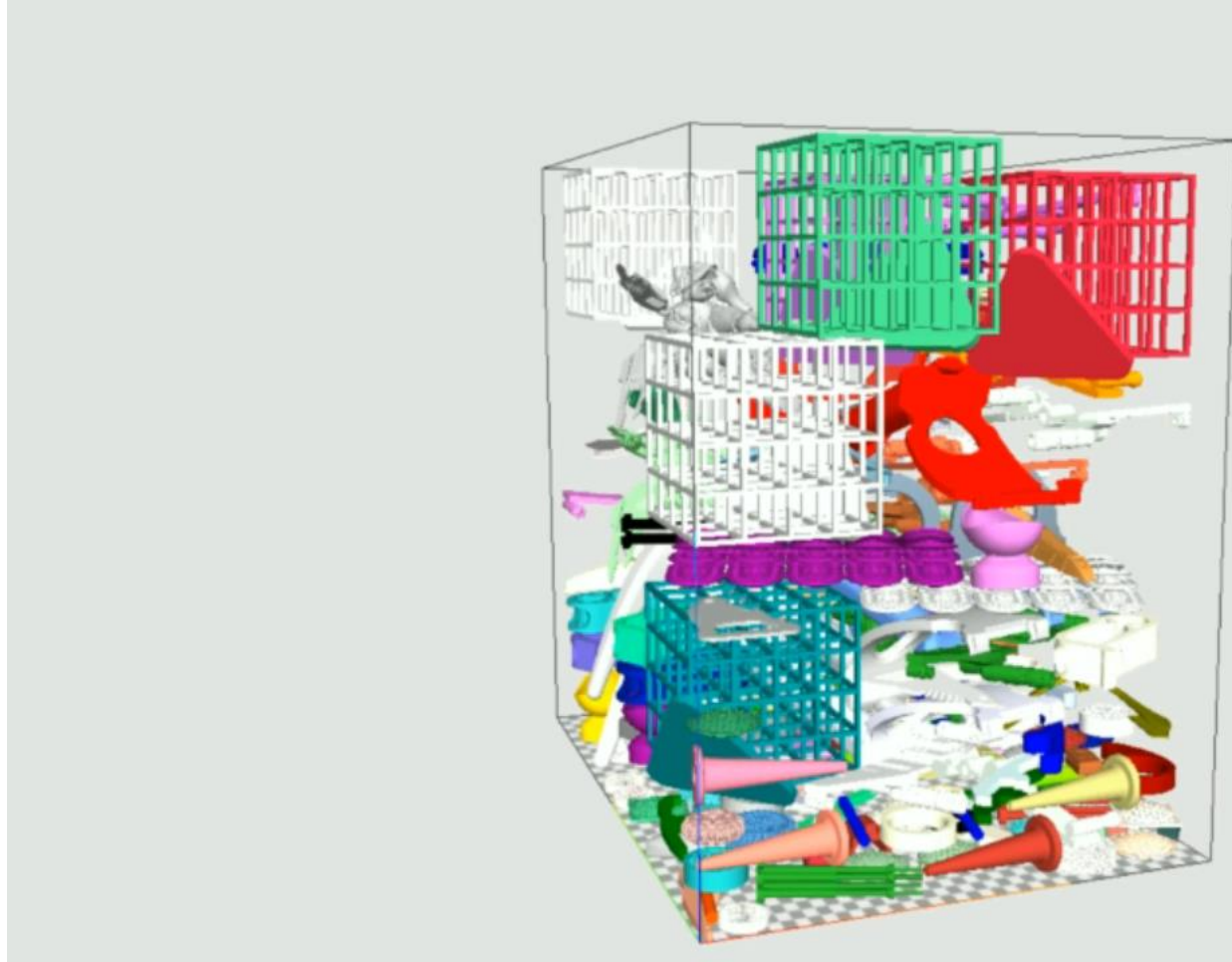


Thermal Pack: An Introduction

Also known as *3D Nestor*, *HP Labs' Nestor*. Part-shape-based multi-objective packing engine that takes a set of 3D model files and creates build buckets.

Based on Genetic Algorithm, optimize build bed usage by aiming predefined multiple objectives (Fitness).

The geometrical optimization component of *Thermal-aware Autopack* project.

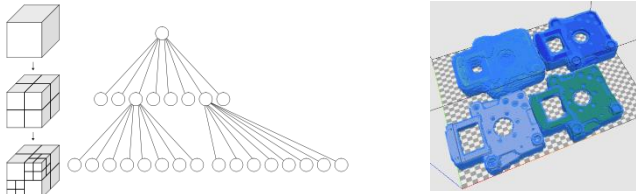


Thermal Pack Building Blocks



Voxelized Profile

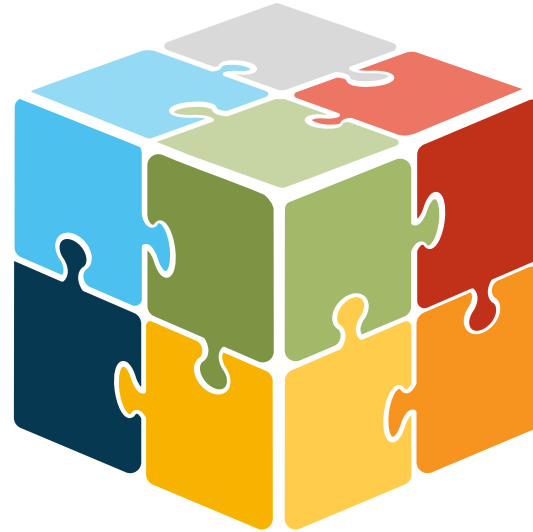
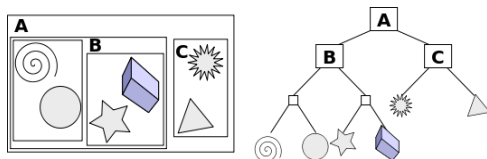
Voxelized profiles of the parts are used instead of the triangles mesh during the whole packing process.



BVHs

Bounding Volume Hierarchy

Using BVHs for each voxelized profile is possible to optimize the collision detection between parts during the placement steps.



Part Placement

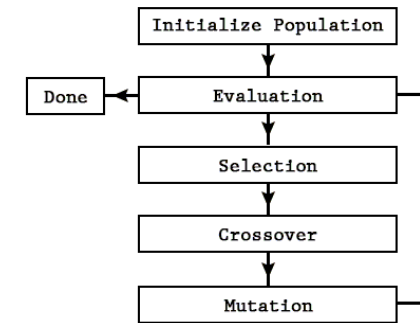
Optimized part placement steps.
Bottom-Front-Left strategy to place parts.



Genetic Algorithm



To evolve solutions (individuals) and converge to a near-optimal one through generations.



Parts Classification



Possibility to classify and separate subsets of parts (usually big parts) and pre-process them in order to improve packing density.



Profile Voxelization

- Part

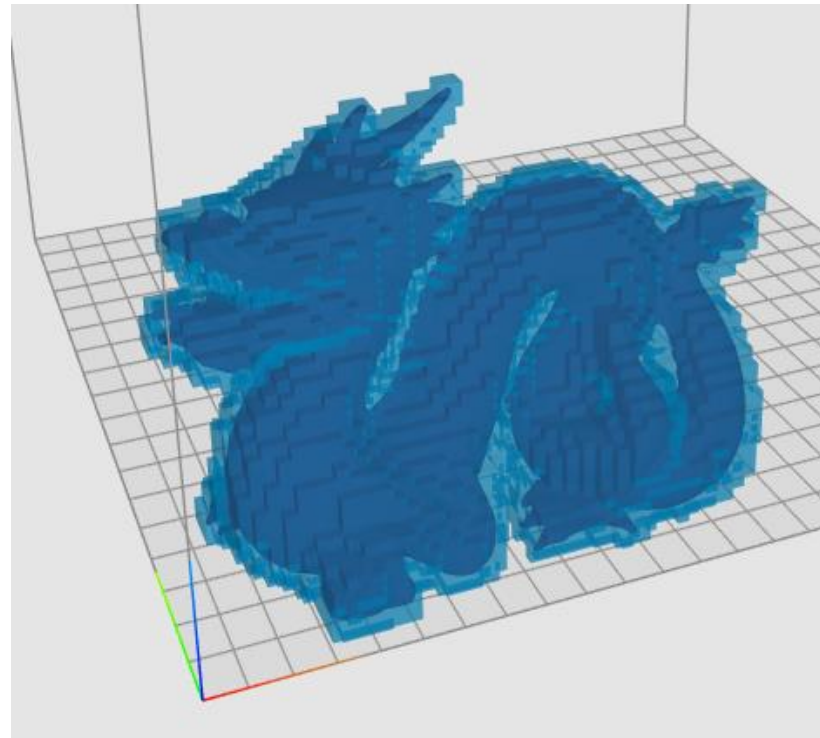
A 3D model in its original representation (.stl or .3mf)



- Part profile

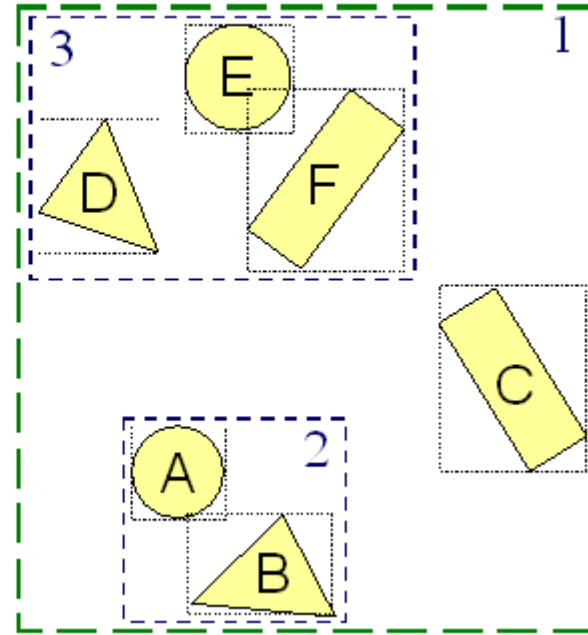
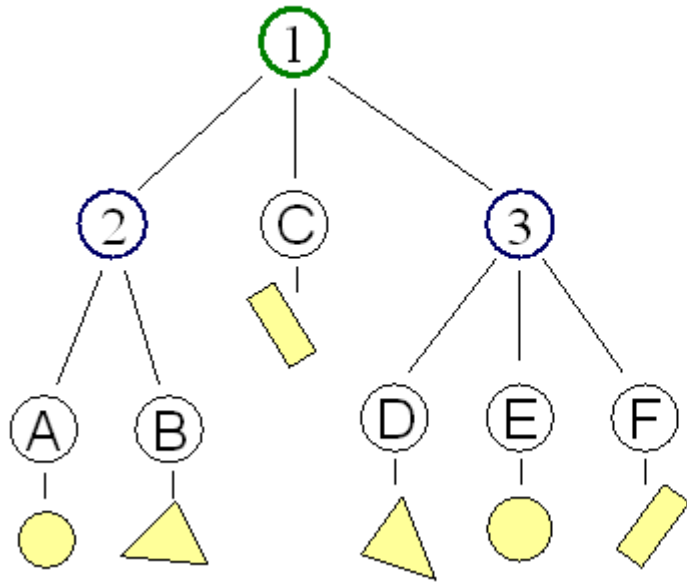
It's a voxel-based representation of a part.

Allows to apply on it several techniques to optimize the placement process, and collision detection.



Collision detection

- BVHs structure helps to optimize collision detection between parts during the placement stage.

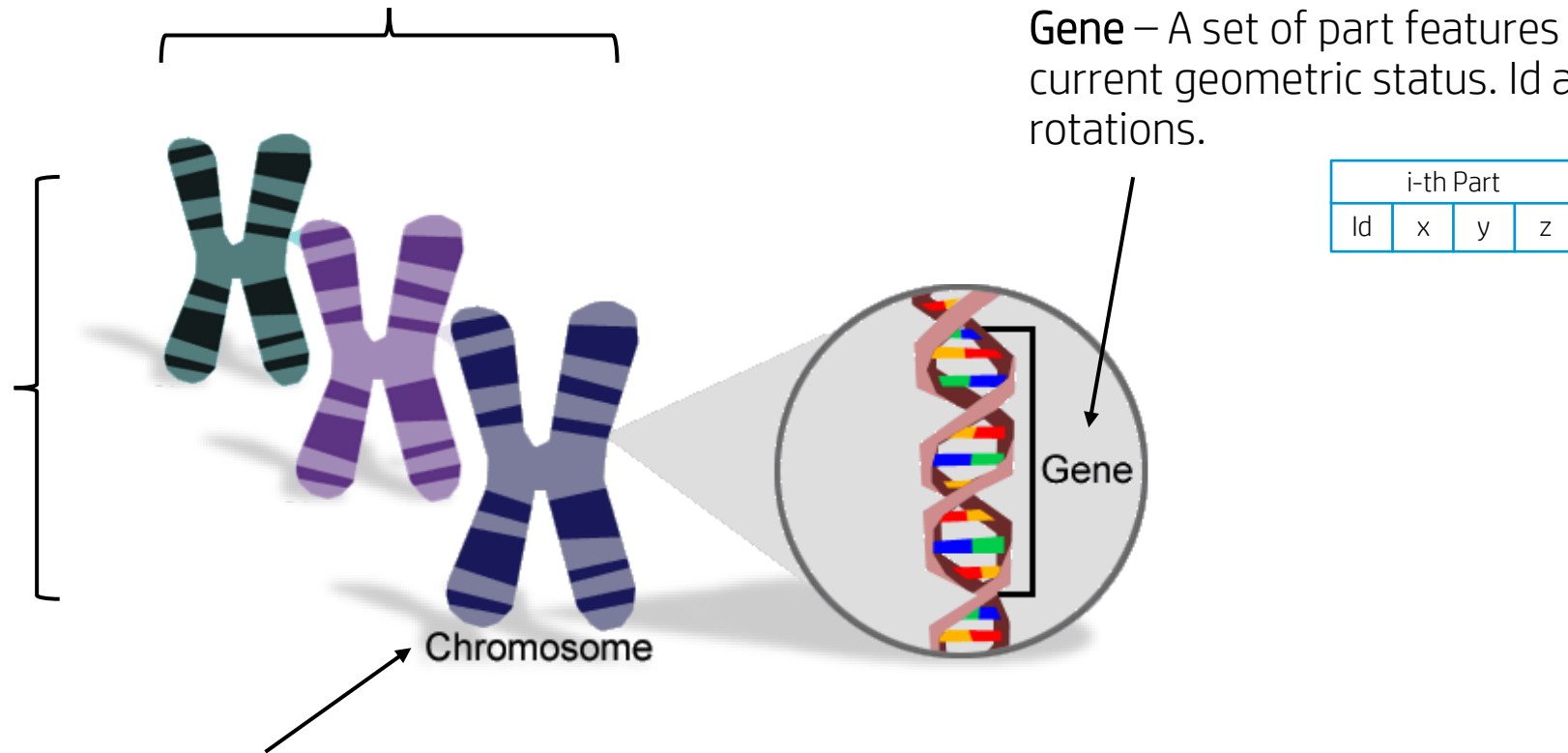


Genetic Algorithm Applied to 3D Nesting Problem

Population – A set of chromosomes (solutions).

Gene – A set of part features for identifying current geometric status. Id and X, Y, Z rotations.

Generation – A set of chromosomes, either initial or evolved chromosomes

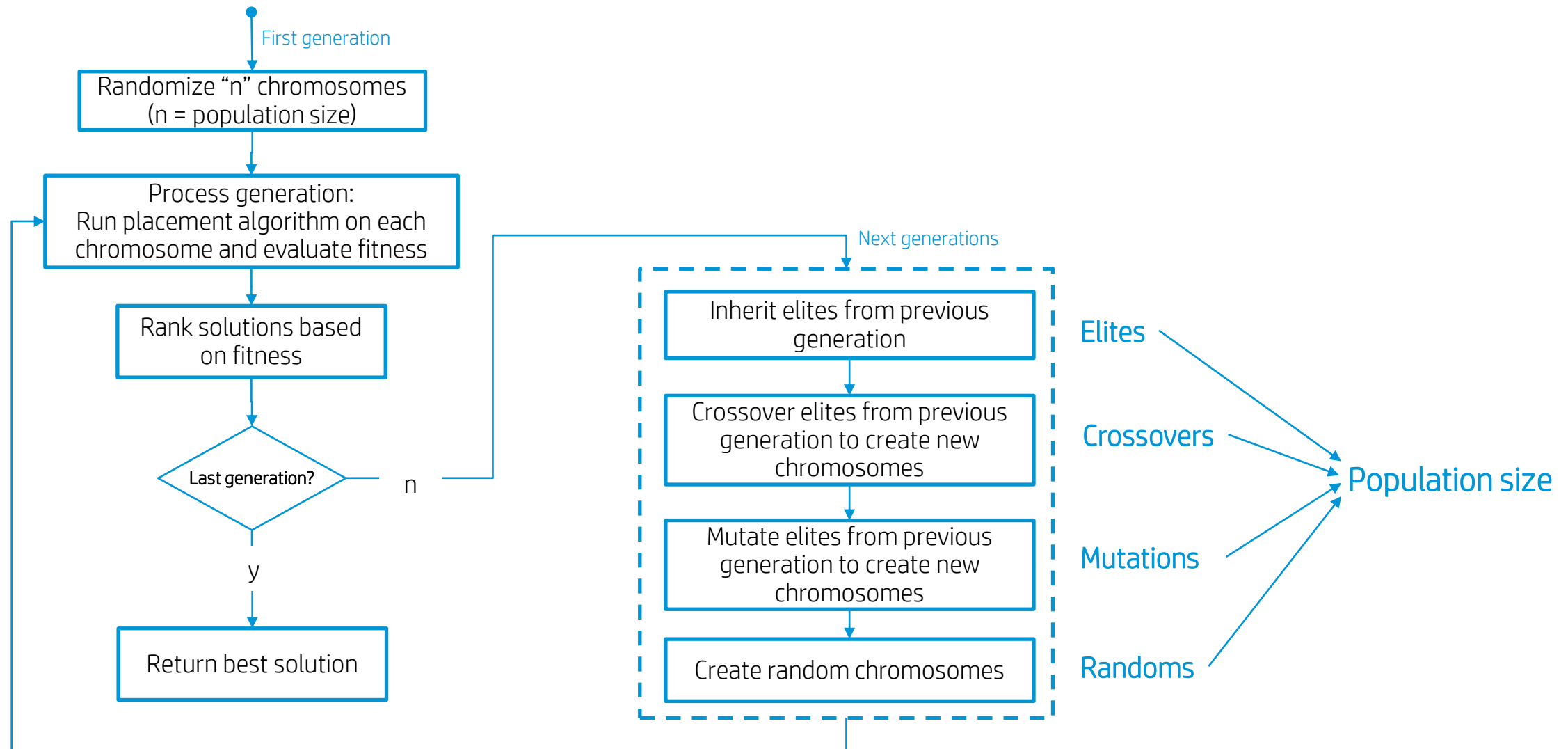


Chromosome – A sequence of genes. The actual gene order represents one packing solution.

Part 1				...	Part n				...	Part 1				...	Part n			
Id	x	y	z		Id	x	y	z		Id	x	y	z		Id	x	y	z

*Id, x, y and z are float numbers representing the part id and X, Y and Z rotation steps for that part

Genetic Algorithm Compute Flow



BFL placement

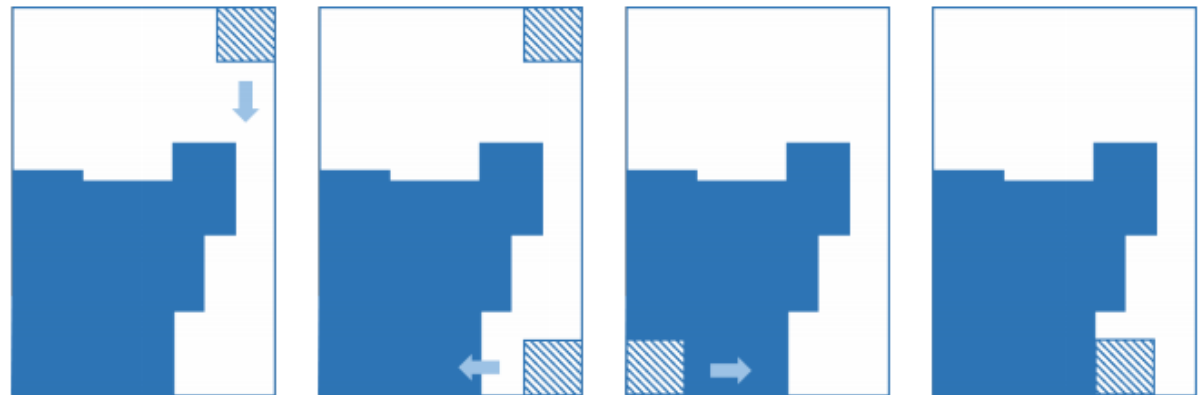
- Bottom-Front-Left placement strategy leads optimizing part placement inside the build volume.

Part 1				...	Part n				Part 1				...	Part n				
Id	x	y	z		Id	x	y	z		Id	x	y	z		Id	x	y	z

*Id, x, y and z are float numbers representing the part id and X, Y and Z rotation steps for that part

Chromosome induce an entering order into the build volume

Parts are entered from corners and “continuously” moved along the X,Y,Z axis, up to densely populate the packing space



HPL in Full Gear Support Business Commercialization

Implement new features

Incorporate diagnostic parts

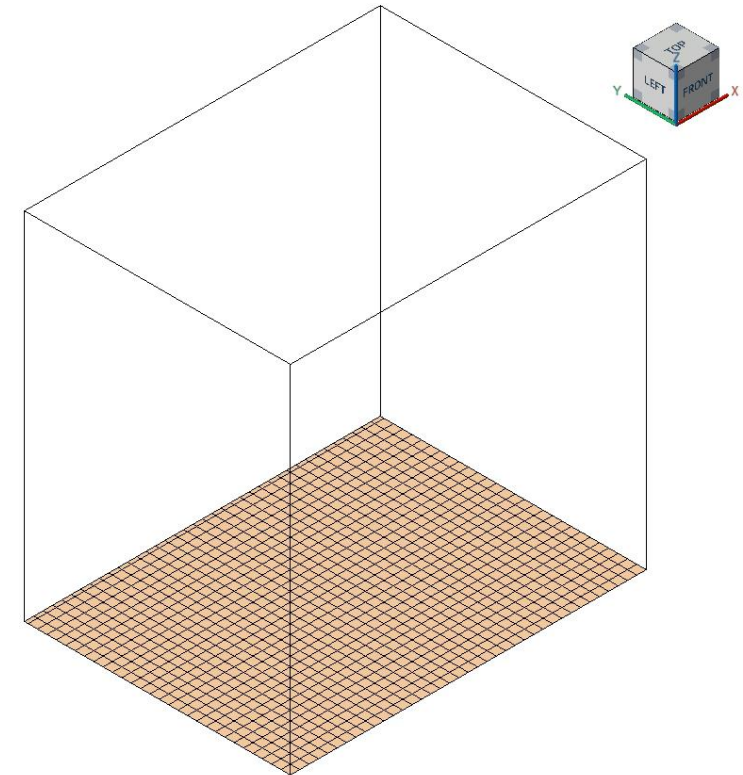
HP's writing systems' diagnostic parts are adopted by our customers.

- Thermal plate (aka. "Disco Negro") that monitors thermal profile to adjust lamp
- Z-Hollow that monitors geometrical accuracy for a layer of parts.

Incorporate business logic

Parts may need to be grouped for post-processing and/or shipping/handling. These parts are preferred to be positioned:

- within the same build volume
- close to each other
- same z-height, for example, be monitored by the same Z-Hollow.



Single part packing

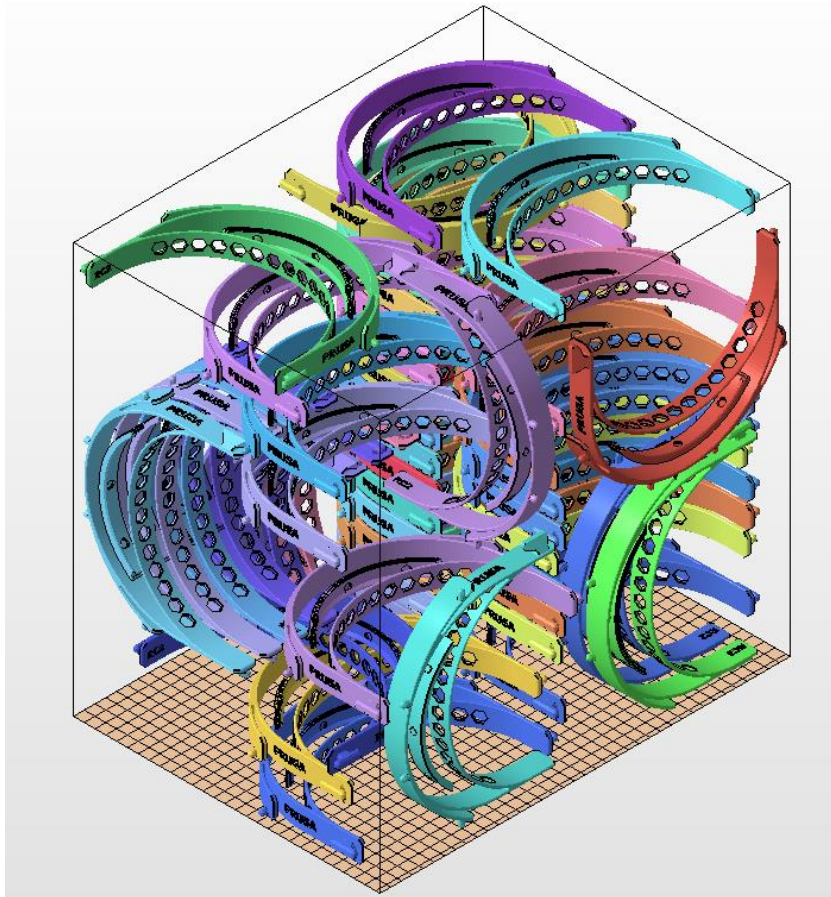


Part properties

Name	covid19_headband_rc2_1pc s_1_2.3mf
Triangle count	21,408

Running specs

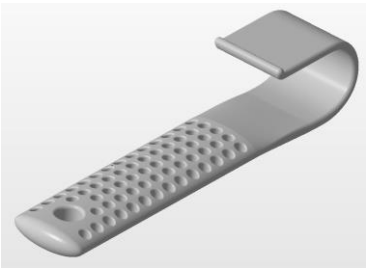
Parts to pack	50 copies
Voxel size	2 mm
Inter-part margin	Dynamic 3-7 mm
Rotations	Default
Generations	50
Population (E/C/M)	100 (40-20-20)



Result pack specs

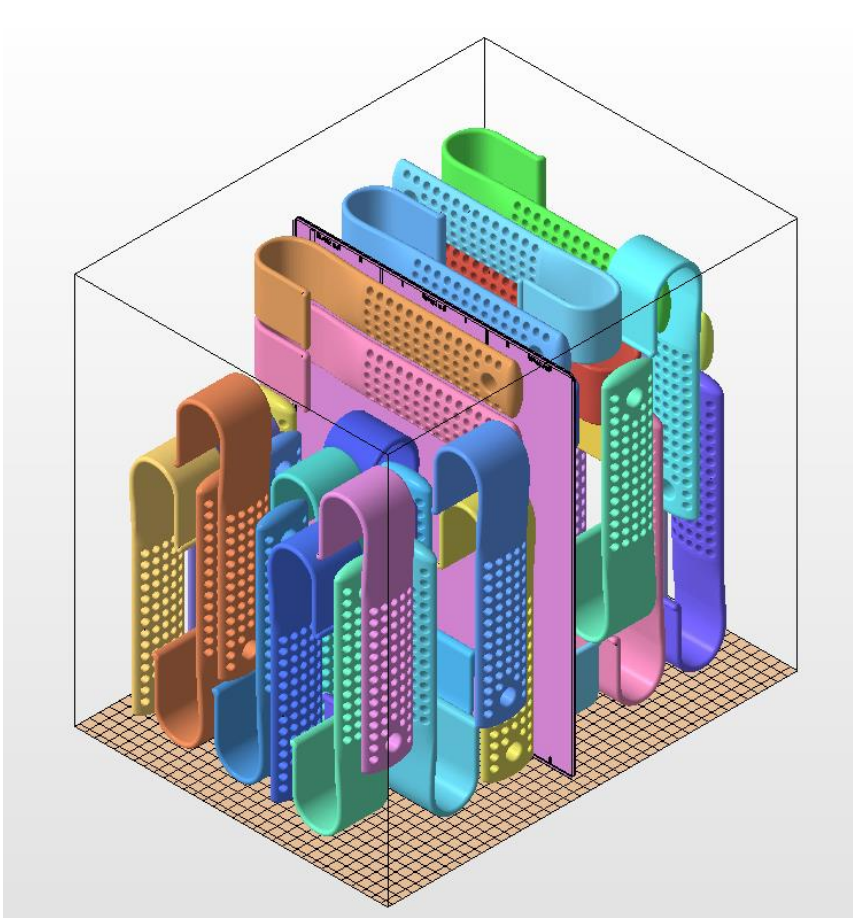
Packing density	4.7 %
Parts packed	47 parts
Z-height	375.5 mm
Mesh loading time	85 msecs
Voxelization time	38 msecs
Packing time	22 secs
3mf generation time	1 secs
Total execution time	24 secs

Stationary part



Part properties	
Name	HP_PersonalDoorOpener_lig htweight_v4_no logo.3mf
Triangle count	364,404

Running specs	
Parts to pack	50 copies + 1 stationary part
Voxel size	2 mm
Inter-part margin	Dynamic 3-7 mm wall margin 2 mm
Rotations	Default
Generations	50
Population (E/C/M)	100 (40-20-20)



Result pack specs	
Packing density	12.1 %
Parts packed	40 copies +1 stationary part
Z-height	349 mm
Mesh loading time	1.3 secs
Voxelization time	3.5 secs
Packing time	20 secs
3mf generation time	22 secs
Total execution time	50 secs



keep reinventing

Gracias