# Development of an automated CAD model parameterization scheme for Fontan Circulation

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## INTRODUCTION

The Fontan circulatory loop is a complex system that contains many different variables that need to be tuned and implemented manually with many different experimental configuration. The manual implementation of the designs of the experiment is extremely inefficient due to the number of variations stemming from its factorial nature. To solve this, we propose an automated (computer aided design) CAD model parametrization scheme that could produce all possible combinations from the design of the experiment. Thus, the automation of CAD models will allow rapid and efficient experimentation of various configurations for the experiment.

## OBJECTIVE

To produce an efficient way of CAD model production for Fontan Circulation through the parametrization and automation of CAD models and their respective assembly development.

## METHODS

- **Automation Algorithm** has been developed by separating it into three main tasks of pre-processing, parametrization and assembly. Each of the tasks have been divided into sub-processes for every individual adjustment of the CAD model and all of the adjustments have been programmed in iLogic that has been developed by Autodesk. This algorithm produces same part with the same parameters multiple times to allow manual edit to the part without affecting assemblies of other experiments.
- **Pre-Processing**
  - **Geometry** synthetic 3D model of a fenestrated total cavopulmonary connection (TCPC) was generated, with average dimensions matching those of a 2–4-year-old patient.
  - **IJS and Fenestration blocks** are developed initially in Autodesk Inventor by taking a negative of the baseline geometry. To produce two individual blocks, the ΔTCPC portion is removed.
  - **IJS block** is edited by adding input connector and an ability to mount it to a full assembly.
  - **Fenestration block** is edited by merging RPA and LPA lines into a single line while respecting the effective area of the lines. The new lines follow human-like curved geometry.
  - **Design of experiment** is preformed by using MATLAB script that requests individuals or ranges of combinations of experiments. The algorithm outputs a .csv file with all possible combinations.
  - **Assembly** the initial assembly file is developed and constrained using fixed planes and axis. These constrains are made with unparametrized parts.
- **Parametrization**
  - **IJS** is parametrized by selecting the average area of the defined path and increasing or decreasing it as desired while keeping the IJS wall thickness constant.
  - **IJS Nozzle Geometry** is parametrized by developing parametrized sketches with desired geometries as noted in Figure 2 in IJS shape. The effective diameter of geometries is parametrized as well while keeping constant nozzle wall thickness.
  - **Fenestration** is parametrized by selecting the average area of the original fenestration that comes from the patient and increasing or decreasing it as desired.
  - **ΔTCPC** is parametrized by defining the desired length of the block.
- **Assembly** is produced by importing and replacing originally constrained unparametrized parts while keeping constrains form initial part.

| | | | | | |
|---|---|---|---|---|---|
| IJS_Shape$_0$ | IJS_Diameter$_0$ | Geometry$_0$ | ΔTCPC$_0$ | Fen_Diameter$_0$ | Name$_0$ |
| IJS_Shape$_{...}$ | IJS_Diameter$_{...}$ | Geometry$_{...}$ | ΔTCPC$_{...}$ | Fen_Diameter$_{...}$ | Name$_{...}$ |
| IJS_Shape$_n$ | IJS_Diameter$_n$ | Geometry$_n$ | ΔTCPC$_n$ | Fen_Diameter$_n$ | Name$_n$ |

**Table 1** – Structure of matrix and .csv file.

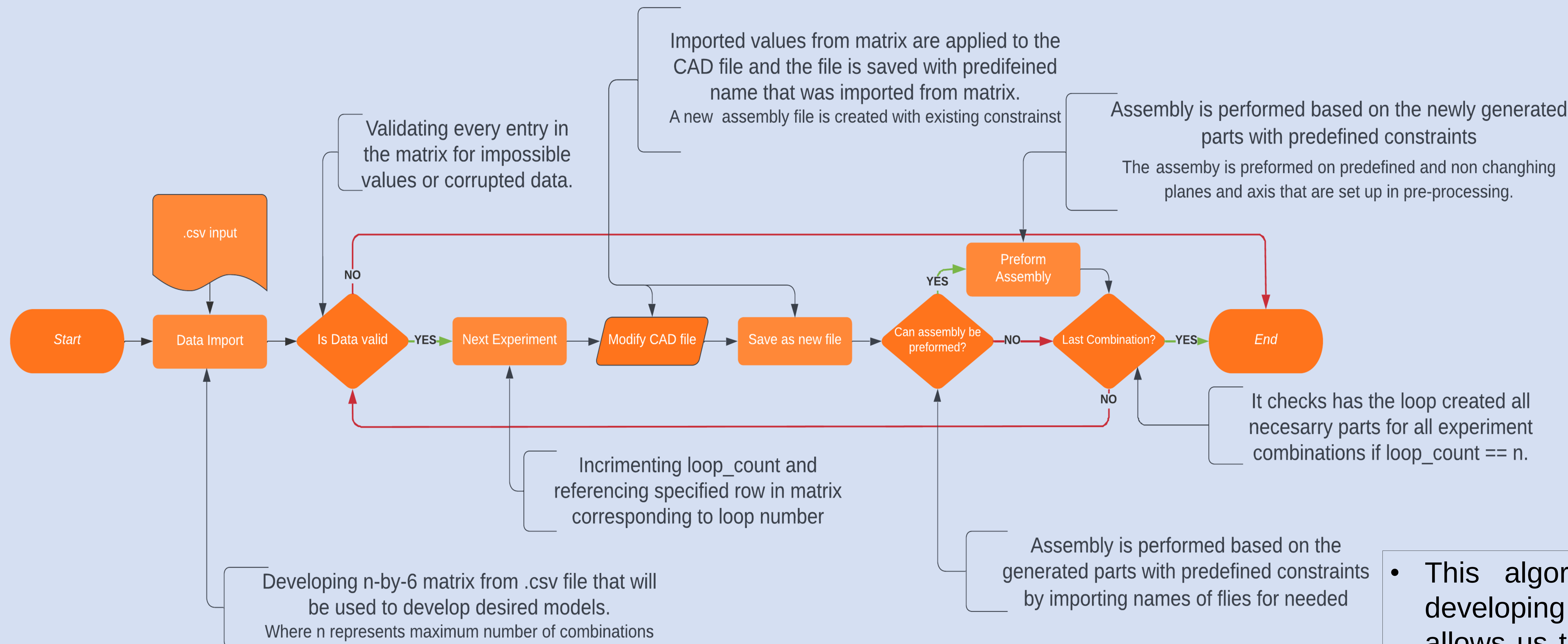


**Figure 1** – Simplified flowchart of automation algorithm

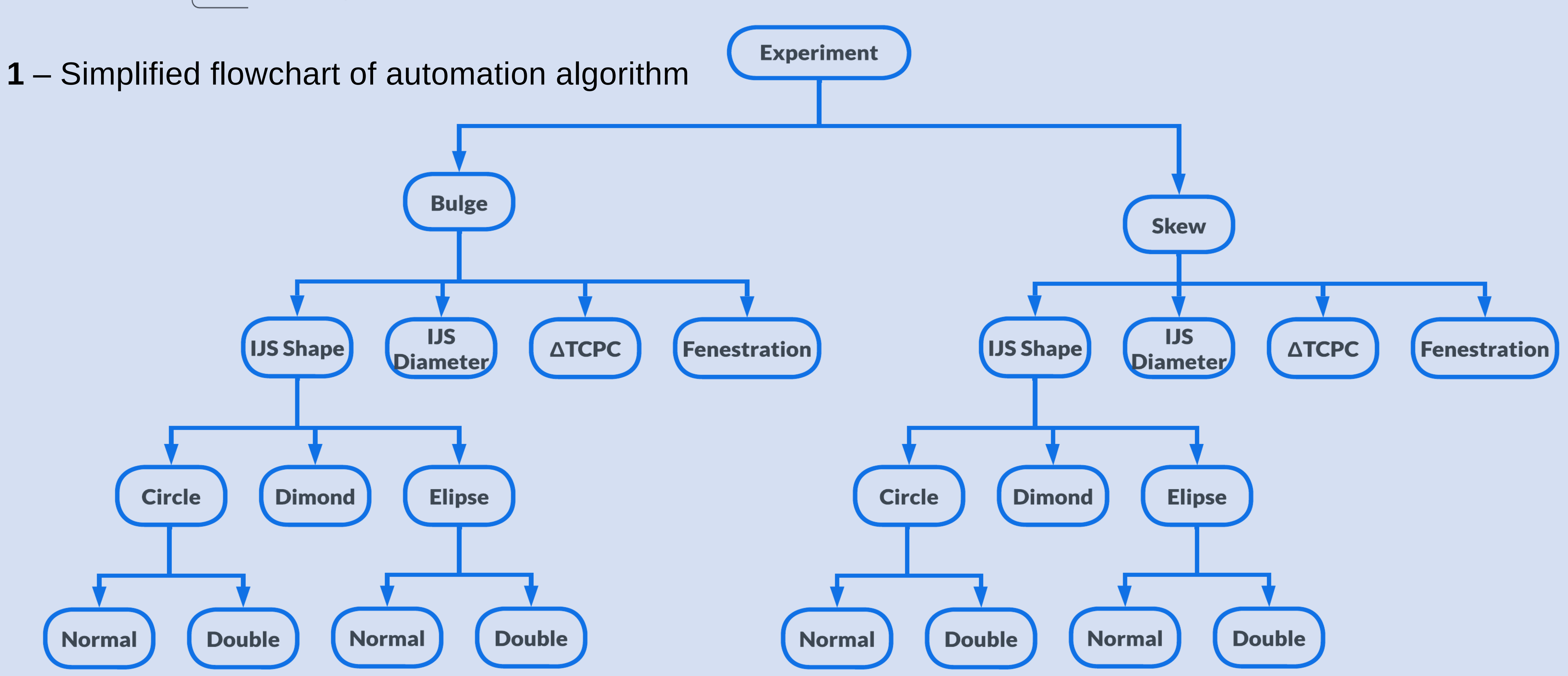


**Figure 2** - Binarry tree showing possible changhes of model parameters in design of experiment.

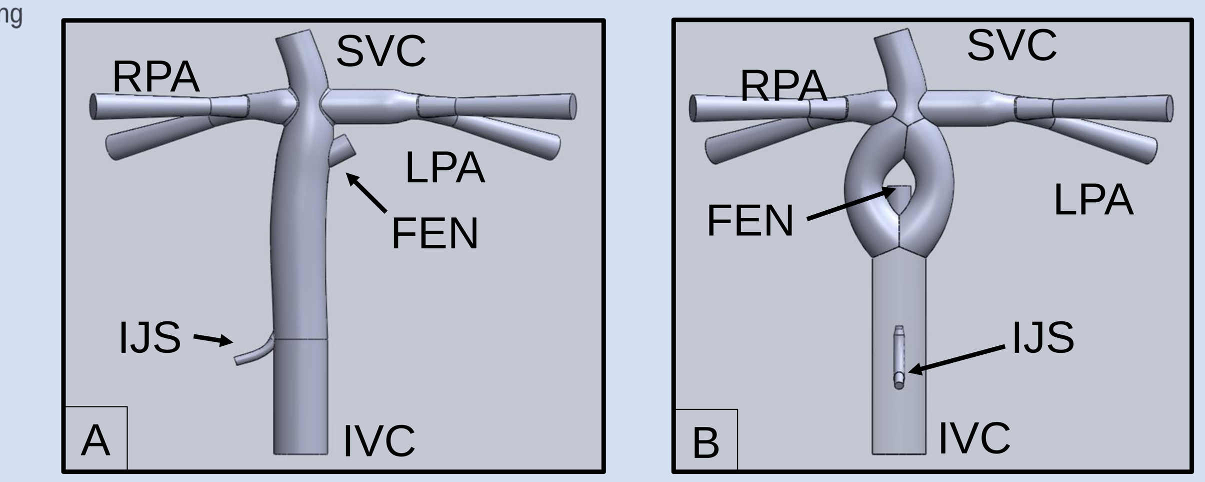


**Figure 3** – (A) Skew baseline geometry and (B) Bulge baseline geometry

- This algorithm has been an important part in researching and developing mock flow loop and experimenting with Fontan Circulation. It allows us to develop new and modify existing experiments significantly faster.
- This algorithm can generate one unique assembly with individually parametrized parts every 35 seconds, thus significantly expediting our workflow.
- This algorithm has proved to eliminate most of the possible user errors that can occur during the manual development of the nozzle geometries.

## RESULTS

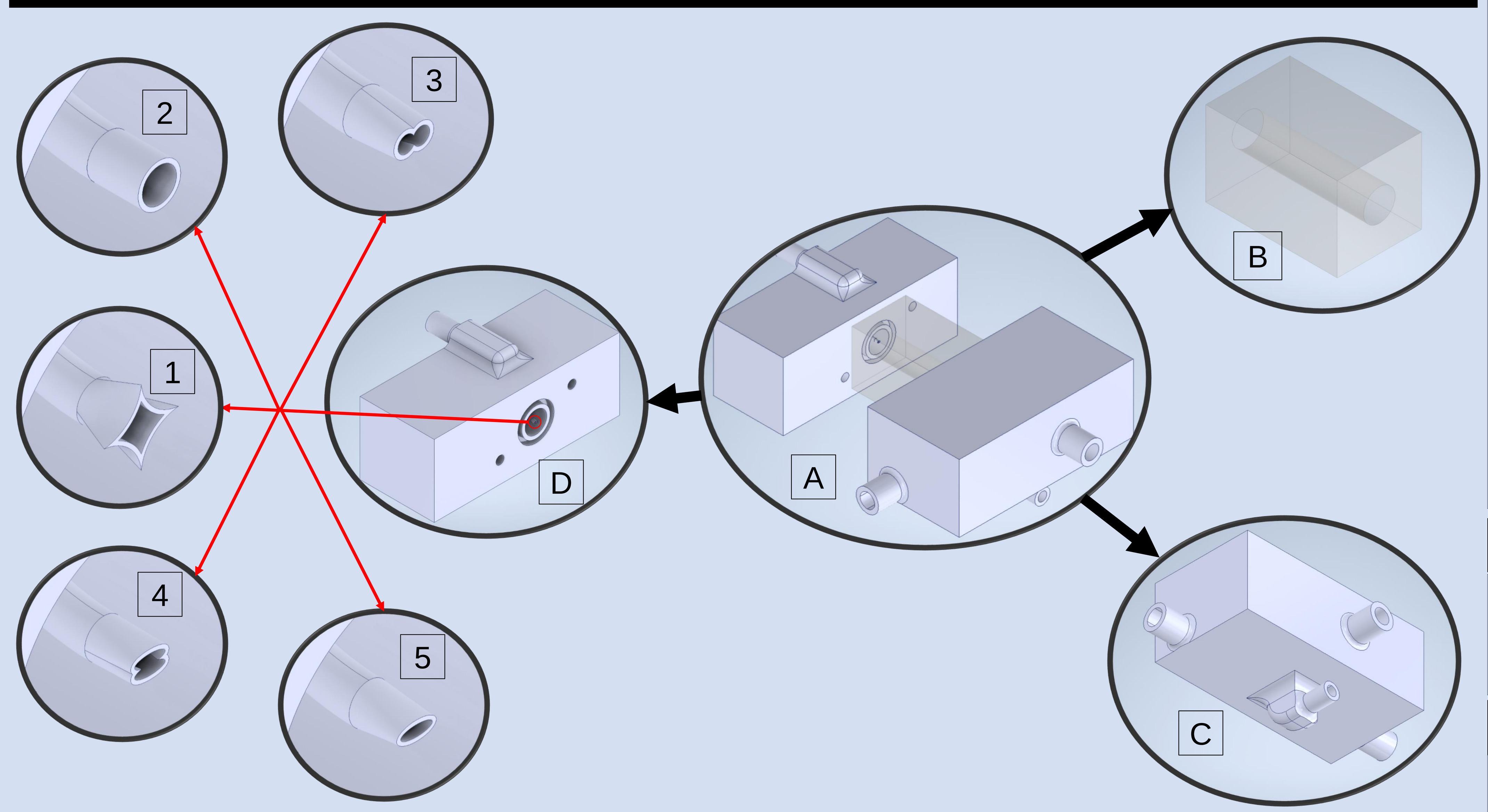


**Figure 4** – (A) Final assembly with all parts: (B) ΔTCPC, (C)Fenestration and (D) IJS. With IJS containing all possible IJS nozzle geometries: (1) Diamond, (2) circle, (3) double circle, (4) ellipse and (5) double ellipse.

## CONCLUSIONS

**This study demonstrates the potential for automated development of CAD models for the Fontan circulation** and research in this area in general. Firstly, this algorithm has proved to be able to demonstrate the advantages of automated CAD development by significantly reducing time and possible human errors. Secondly, the algorithm has showed a great potential in its adaptability and may be extremely useful for future research, as it can be adopted with different geometries.

## LIMITATIONS

- Fenestrations diameters are incapable of being reduced to less then 1.5 [mm] due to conflicting geometries and intersecting planes between them.
- Bulge Fenestration diameter cannot exceed the diameter of 8.5 [mm] due to the interference with the walls of the bulge.
- The algorithm is incapable of detecting conflicting geometries.
- The algorithm requires manual preprocessing that is time-consuming.
- The algorithm is incapable of producing diamond geometries that are under 1.0 [mm] due to intersecting planes.
- The algorithm is incapable of producing double ellipse geometries that are under 1.0 [mm] due to conflicting geometries.
- File names of individual parts and assemblies need to be specified in the .csv file and later extracted by the algorithm.

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## REFERENCES

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