Beautification and Healing

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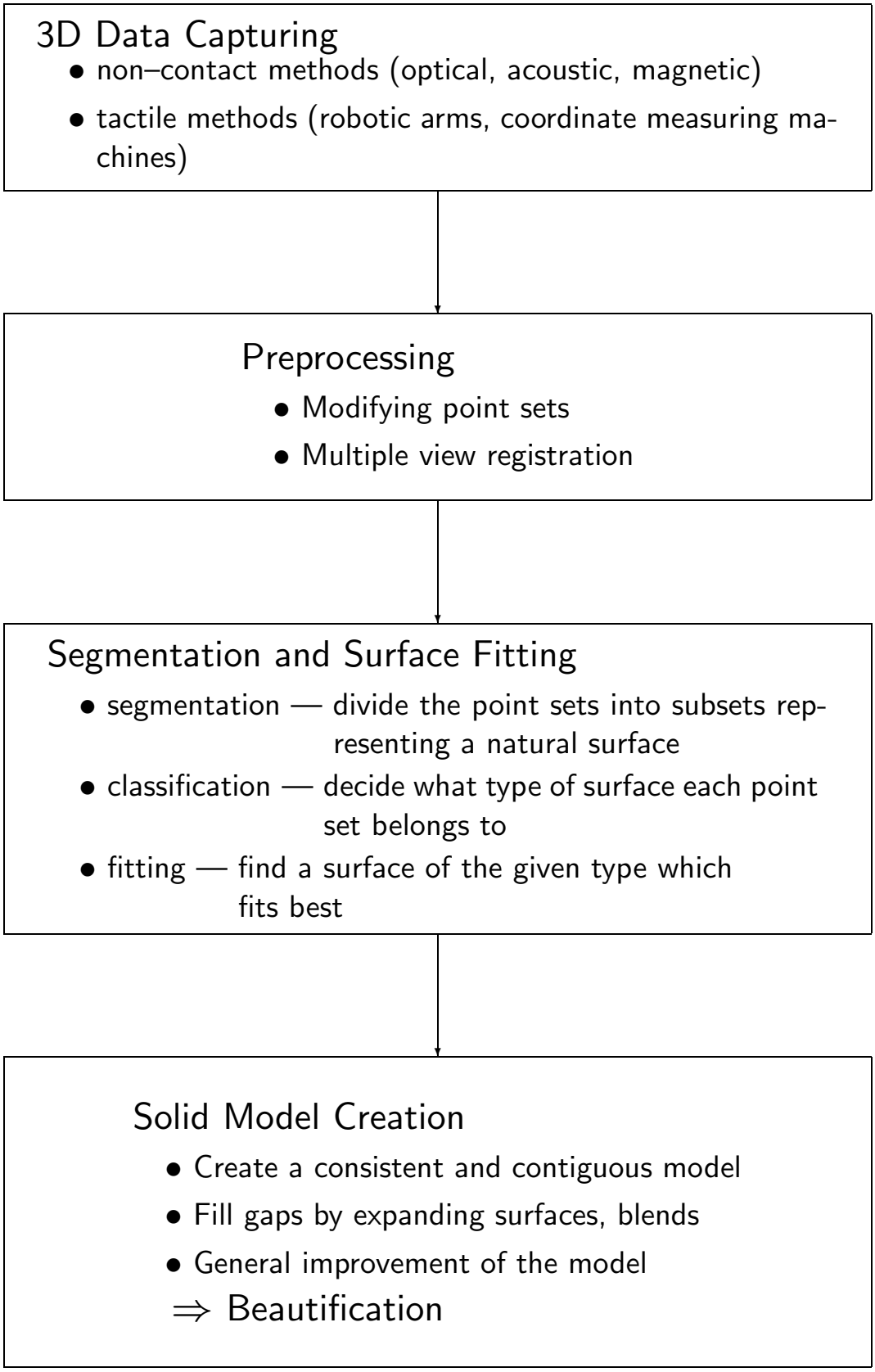
Reverse Engineering

Measure an existing object so that a CAD or solid model can be created



Beautification

Final step in producing a solid model from the point set

- Improve the model created by the segmentation and surface fitting step for some given purpose
- Assume valid model from the model creation step
- Fix inaccuracies created by the 3D scan
  - Remove "small" faces, edges, etc.
  - Adjust the geometry
  - Find almost smooth (C^1, etc.) faces and mark for making smooth
- Impose local regularities on the model
  - Parallel faces
  - Angles between adjacent faces and edges
  - Coaxial features
  - Single part symmetries (rotational, mirror)
- Improve model on a global scale
  - Global arrangement of parts
  - Rotational, mirror symmetries
  - Almost–symmetries

Regularities and Symmetries

- Geometric and topological **properties** of a single part:
  - Centre
  - Orientation
  - Geometry
  - Boundary
- A **regularity** is a property or a relation between properties of parts, which in an informal sense applies to a family of models.
  - Regularities of a single part:
    - Shape (lines, planes, quadrics, analytic curves, . . .)
    - Symmetry (rotational, mirror symmetries)
    - Orientation with respect to coordinate system
  - Regularities between two parts:
    - Relation between the orientation (angle, parallel, . . .)
    - Distance
    - Same geometry
    - Shared boundary segment
    - Shared symmetry axis
  - Regularities between n parts:
    - Structure of adjacent parts
    - Spatial arrangement
    - Global symmetries
- The set of regularities can be derived from a set of test objects (manually or automatically)

Find and solve a set of consistent constraints

- Analyse the model to find existing regularities and almost regularities depending on the domain and application of the model
- Select a maximal set of constraints based on the analysis
- Solve the constraints:
  - solve non–linear system of equations in a least–squares sense
  - apply non–local optimisation techniques
  - use weighted constraints
  - prioritise constraints
  - group constraints and solve groups sequentially
  - base prioritising and grouping on:
    - type of constraint
    - how well constraint is already satisfied
    - how well model builder produces models with this constraint
    - typical objects, "feed in object type"
- Use feedback methods to find a maximal set of constraints that can be satisfied to create a model consistent in the sense of some set of regularities
- Deduce tuning parameters for optimal operation
- Automatic methods to deduce tuning parameters

Healing (based on ACIS)

- Fix imprecisions, tolerance problems in imported data:
  - Geometric errors
  - Gaps between entities
  - Topology errors
- **Light healing**: reintersect parts to get new lower dimensional parts
- **Heavy healing**: adjust shape and position of parts to match positions of lower dimensional parts
- Methods:
  - Geometry simplification
    Convert spline surfaces and curves to analytic representation (plane, cone, torus, sphere, . . .)
  - Stitching
    Stitch surfaces in the absence of connectivity
  - Geometry building
    Build geometry to correct gaps
- Strategy for each method:
  - **Analyse** model and set appropriate tolerances and options for the healing phase
  - **Calculate** new geometry/topology based on the analyse results
  - **Fix** model by applying the results from the calculate phase; splitting calculation and fixing, allows review of operations

Healing / Beautification

Healing	Beautification
Tries to create a valid model using minimal modifications	Starts with a valid model and tries to improve it by making small changes
Fixes local problems, problems between adjacent parts	Also fixes global problems
Regularities are based on analytic shapes and gaps created by imprecisions	More general regularities (like symmetries)
Simply fixes the imprecisions found by setting certain tolerances	Considers (weighted) constraints, feedback techniques, etc.
"Tolerance values" are known from other modellers	"Tolerance values" are harder to deduce due to many upstream processes

Conclusion

- Beautification: interpret designer's intent, fix the model to make it meet designer's requirements
- Healing: fix model just enough to create a valid model for the importing modeller
- Healing addresses some of the problems related to local beautification
- Expanding the meaning of healing could lead to beautification
- Symmetries, orientations, etc., can also be broken by importing data
- A beautification step after a healing step (to create a valid model) could in general produce a "better" model