Using the Medial Object to Facilitate Automated Toolpath Generation for Wire and Arc Additive Manufacture

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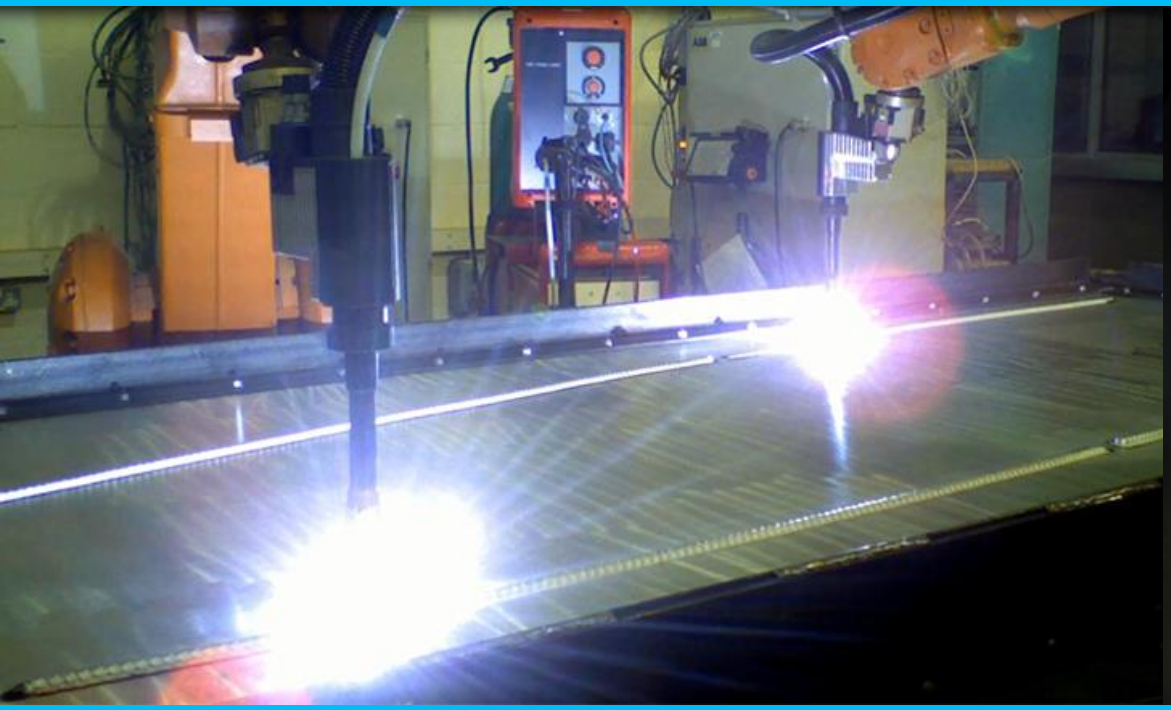

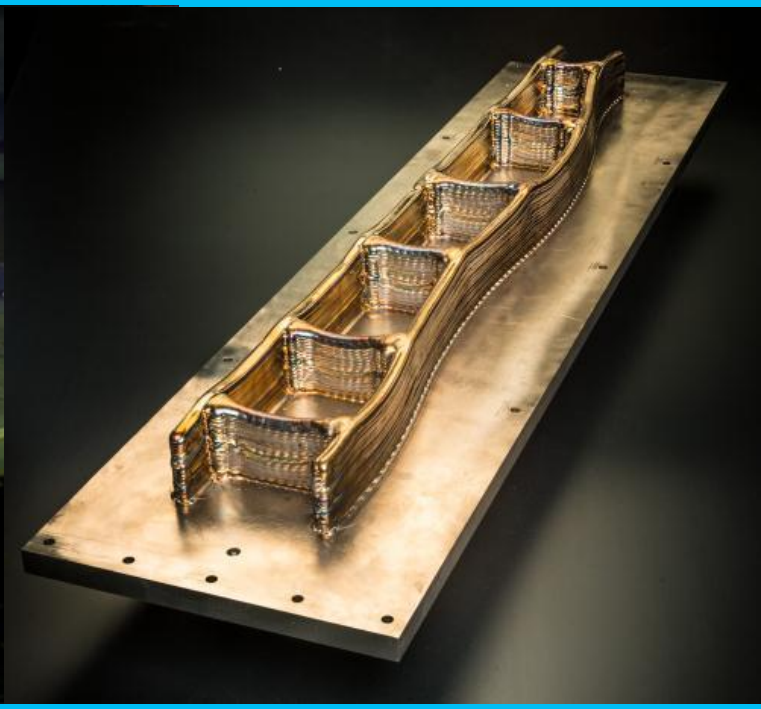

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Medial Object Workshop, The Royal Hotel, Cambridge, England

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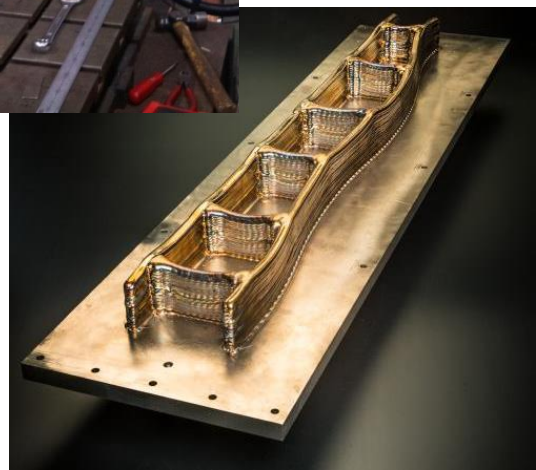
Presentation Overview

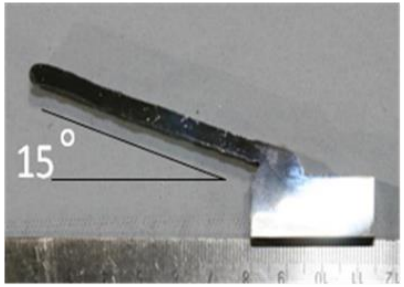
- Introduction to Wire and Arc Additive Manufacture (WAAM)
- Challenges for automating CAD model preparation and toolpath planning for WAAM
- Manufacturing feature recognition from mid-surfaces and the Medial Object
- Proposed application of Medial Object feature recognition to WAAM toolpath planning

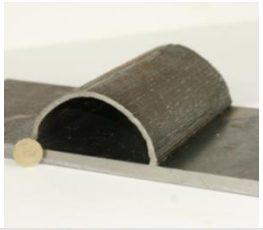
Background to Wire and Arc Additive Manufacture (WAAM)

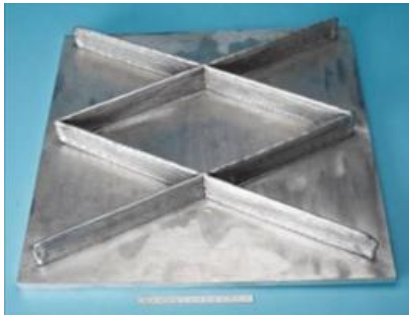
- WAAM is an Additive Manufacturing technology for medium to large scale structural metallic parts in a wide range of metals (including titanium, steel and aluminium alloys)
- Near-net shape parts are produced by depositing material in a layer-wise fashion using a welding torch controlled by a robot
- The final part is produced by machining the deposited part to produce the required surface finish
- Main drivers for WAAM adoption:
  - Reduced cost due to reduction in manufacturing lead time and waste material

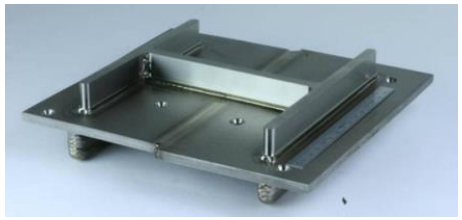


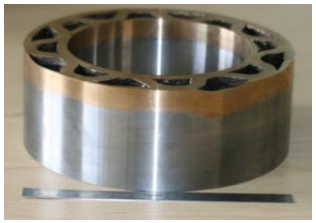
Example WAAM Test Pieces











Manufacturing Planning Requirements for WAAM

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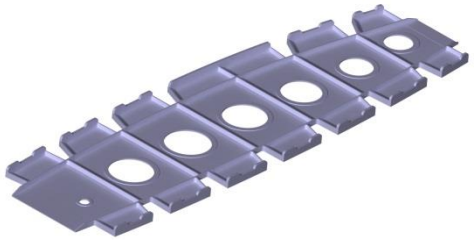
Key steps for WAAM manufacturing planning:

1. Create CAD model of final part
2. Design for Manufacture
   - Remove small features
   - Select position and orientation of substrate
   - Identify regions where additional material must be added for manufacturing or stress relief
   - Identify wall intersections and crossings and add material for start/stops
   - Shell the part to produce near-net shape boundary
3. Toolpath generation:
   - Slice model into layers
   - Identify toolpath centreline, deposition strategy/ parameters and wall width for each layer



Manufacturing Feature Recognition for WAAM

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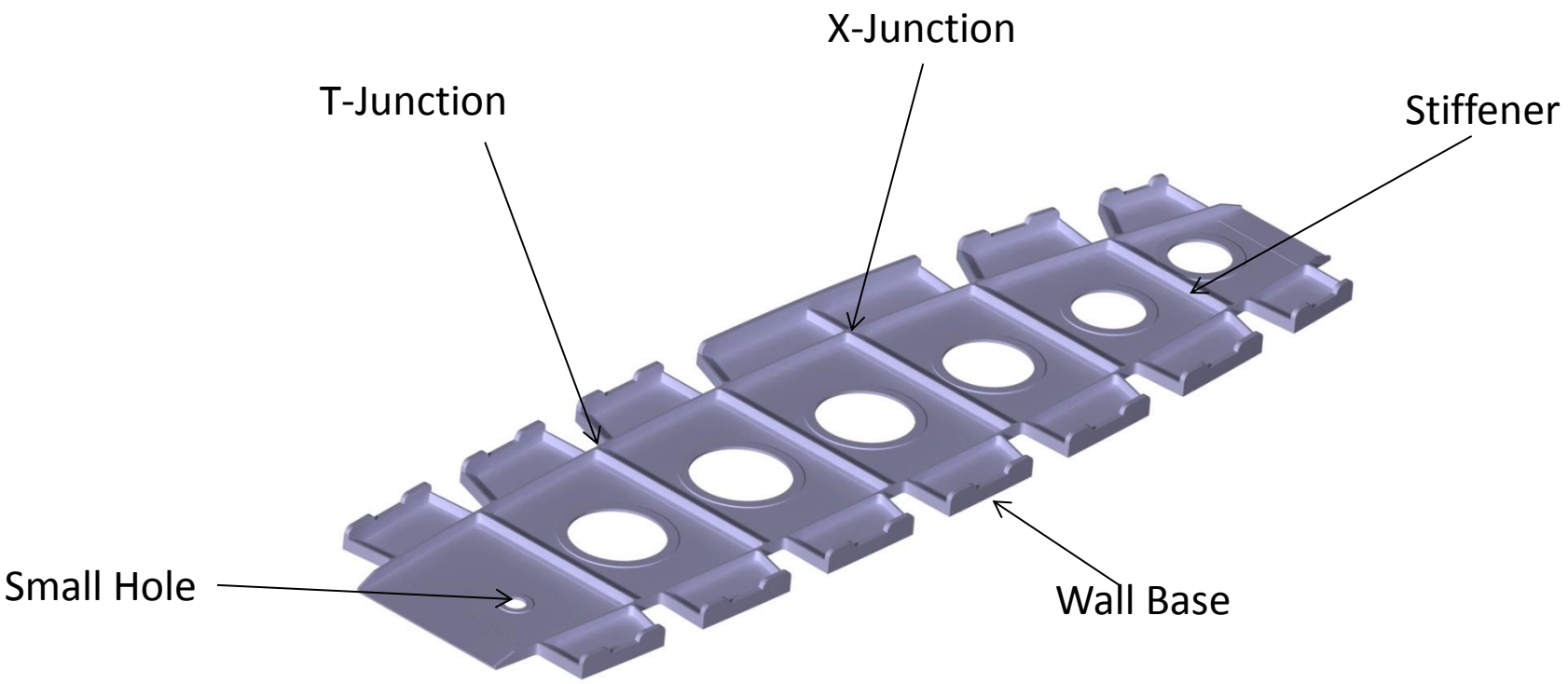
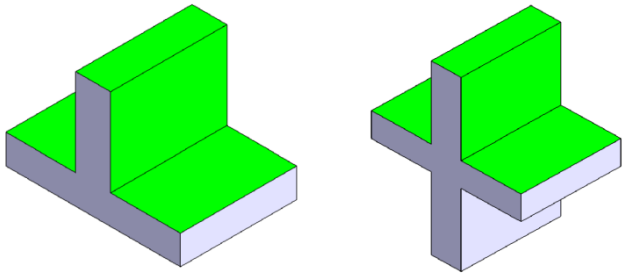


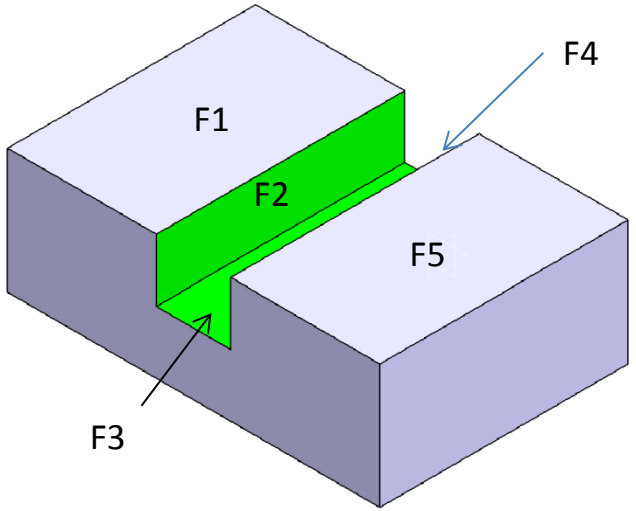
Graph Based Feature Recognition from CAD models

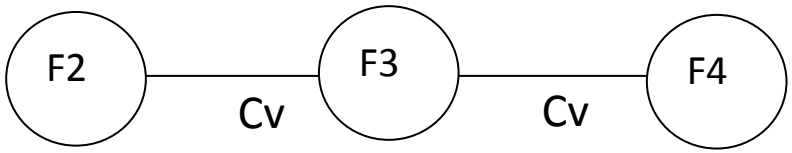
- Negative features can be recognised from a CAD solid model using a **Face Adjacency Graph** (Joshi, 1988)
- Features are identified by traversing a graph of the face connectivity on the Brep
- But this approach does not work well for positive features and intersecting features



Positive Features with identical sub-graphs

Slot Feature





F2 adjacent to F3
F3 adjacent to F4
F2 forms a concave angle with F3
F3 forms a concave angle with F4

Feature Recognition from CAD models using a Mid-surface Representation

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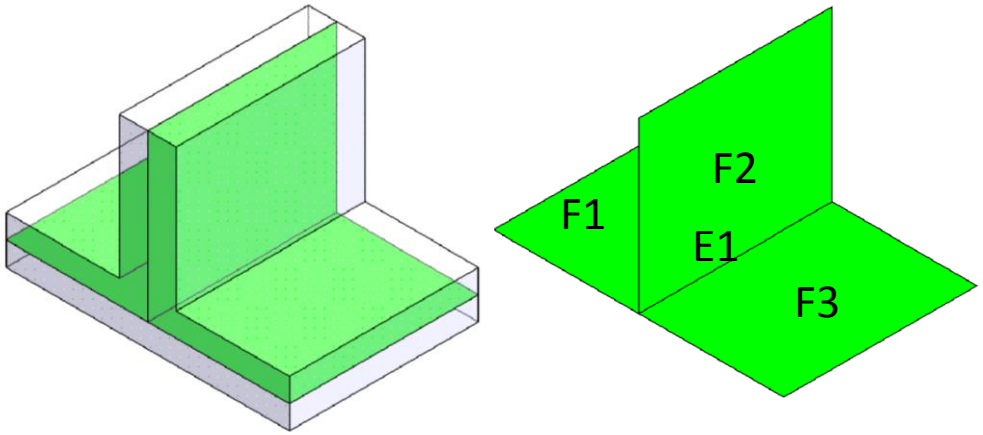
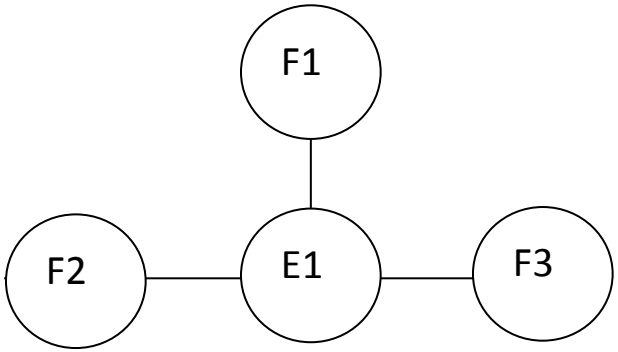
- Feature recognition of positive features can be greatly simplified by using a skeleton or mid-surface representation of the object
- The mid-surface allows positive design features to be directly identified using a **Attributed Mid-surface Adjacency Graph** (Lockett & Guenov, 2005)

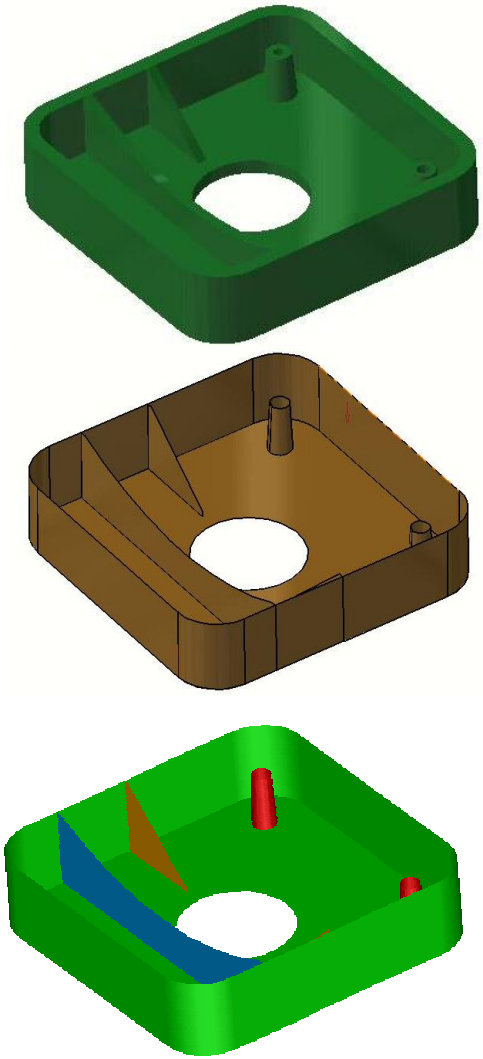




In this example three faces meet along a common edge indicating the existence of a T junction in the solid model.

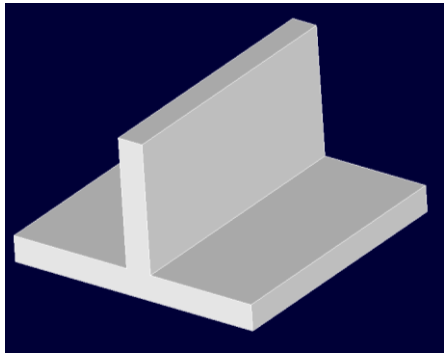
Feature Recognition using SDRC I-DEAS mid-surface function

- Mid-surface feature recognition was implemented as part of a design for injection moulding expert system
- Coded using C++ and the SDRC I-DEAS mid-surface model
- Can successfully recognise a range of manufacturing features including ribs, buttresses, bosses and holes
- Limitations:
  - The I-DEAS mid-surface function did not maintain a link between the mid-surface and solid model
  - The mid-surface generation functionality only worked for fairly simple geometries – manual editing was often required
  - It is no longer supported

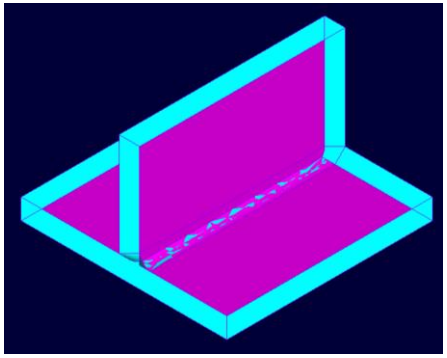


Feature Recognition from the Medial Object

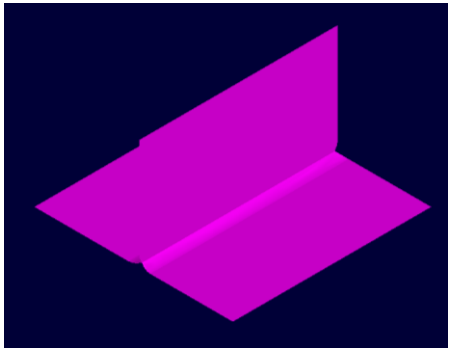
- A student project was undertaken to investigate the ability to recognise features from the 3D Medial Object (Holmes, 2008).



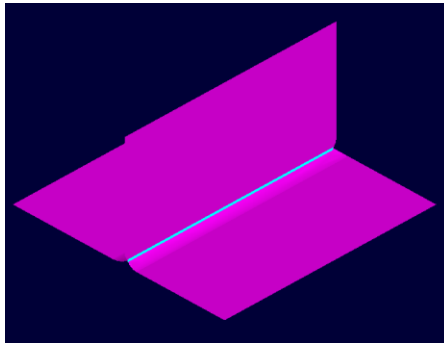
Solid Model of Part



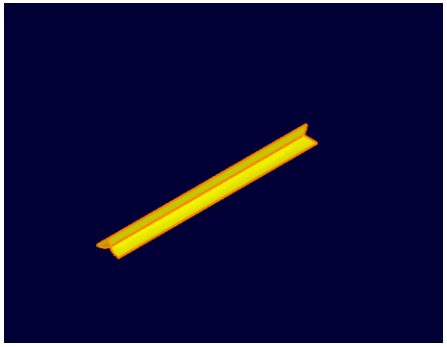
Generate Medial Object



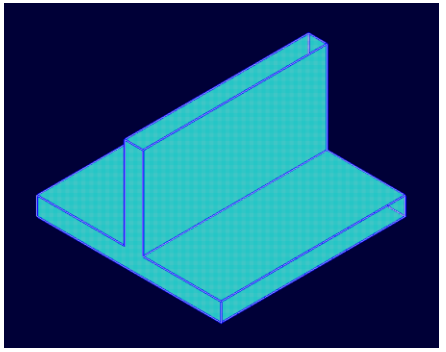
Remove Flaps



Identify High Order Edges



Recognise Junction Faces on Medial Object

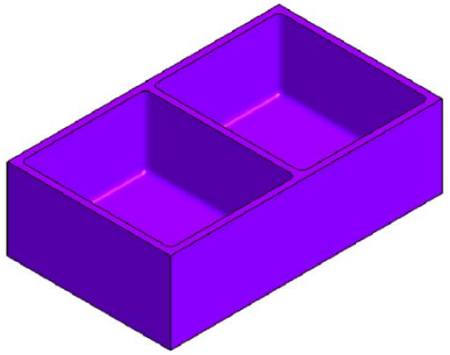


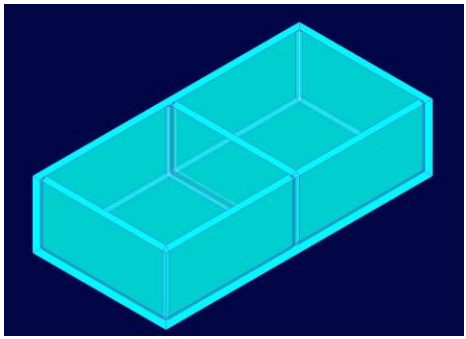
Recognise Junction Faces on Solid Model

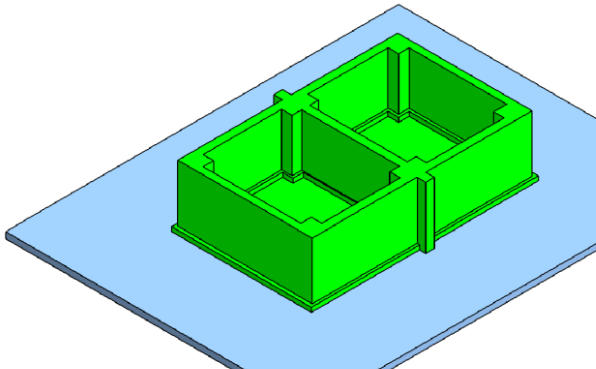
Proposed Application of Medial Object Feature Recognition to WAAM

- It is proposed that feature recognition from the Medial Object could be used to automate the preparation of CAD models for WAAM deposition

Feature Type	Design Change
L-Junction	Add material inside L to ensure fillets can be machined
T-Junction	Identify internal walls and add material for deposition stop-starts
Wall-substrate junctions	Add material for initial deposition layers
Crossings	Flag regions for deposition feed/ speed changes







Proposed Tool Path Generation from Medial Object

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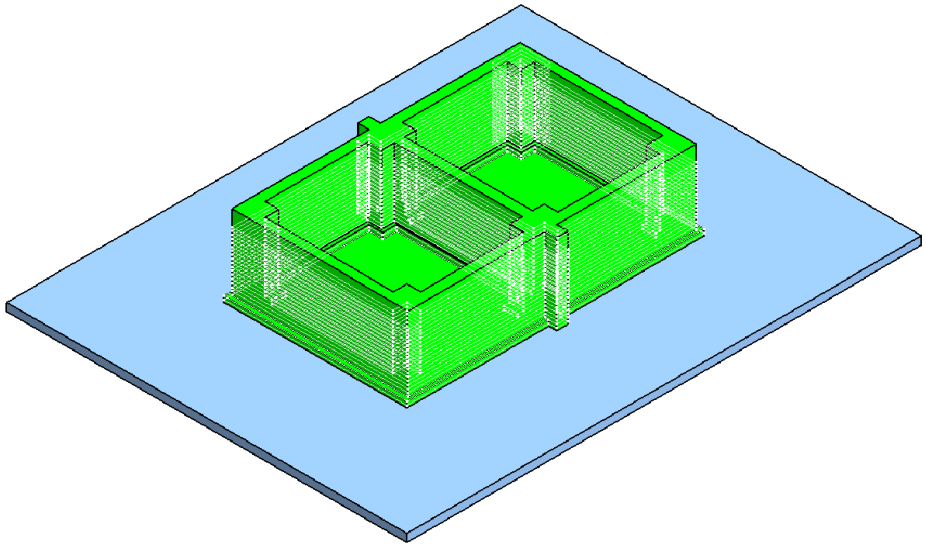
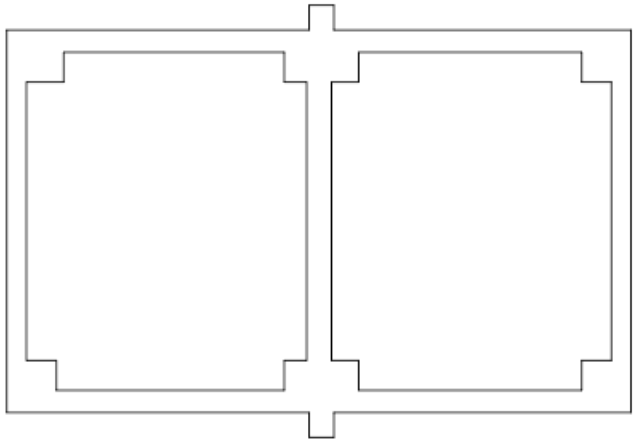
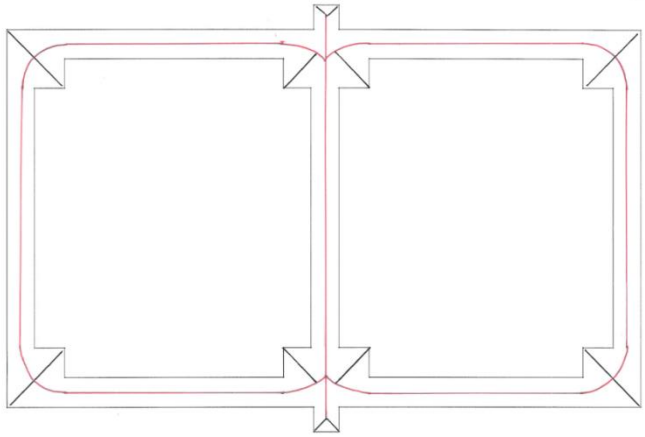
- Model is sliced into layers
- 2D Medial Object is generated for each layer
- Radius function can be used to calculate wall width parameters







Summary

- WAAM is a new technology with the potential to reduce manufacturing lead time and cost for high value metallic components
- One of the biggest road-blocks to WAAM commercialisation is the lack of design tools to automate the model preparation and manufacturing planning tasks
- The Medial Object has the potential to facilitate automation of many aspects of the model preparation and manufacturing planning process
- The next step will be to undertake research to investigate the suitability of the Medial Object for this application