Advanced computational strategies for fast and reliable gate arrangement pre-design of resin infusion processes

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Introduction

Resin Infusion (RI) process is frequently used for large composite parts production. Mould filling strategy can be based on the continuous deformation of the **vent-oriented flow pattern** due to the vacuum driving pressure from the inlet gate. In RI, the **flow front shape progression is mainly conditioned by the initial arrangement of the injection and vent gate line allocations** and the permeability of the preform that can evolve along the flow path. The main awareness of this research is **to develop computational tools based on the geometry of the part**. A suitable assumption of flow front's shapes constrained by RI process can be based on that the **flow front filling time can be related to the distance** of the flow path from the inlet to the outlet gate. Here is assumed that in RI the **allocation of the injection gate depends on the distance to the vent contour** located in the perimeter of the part and on the flow path.

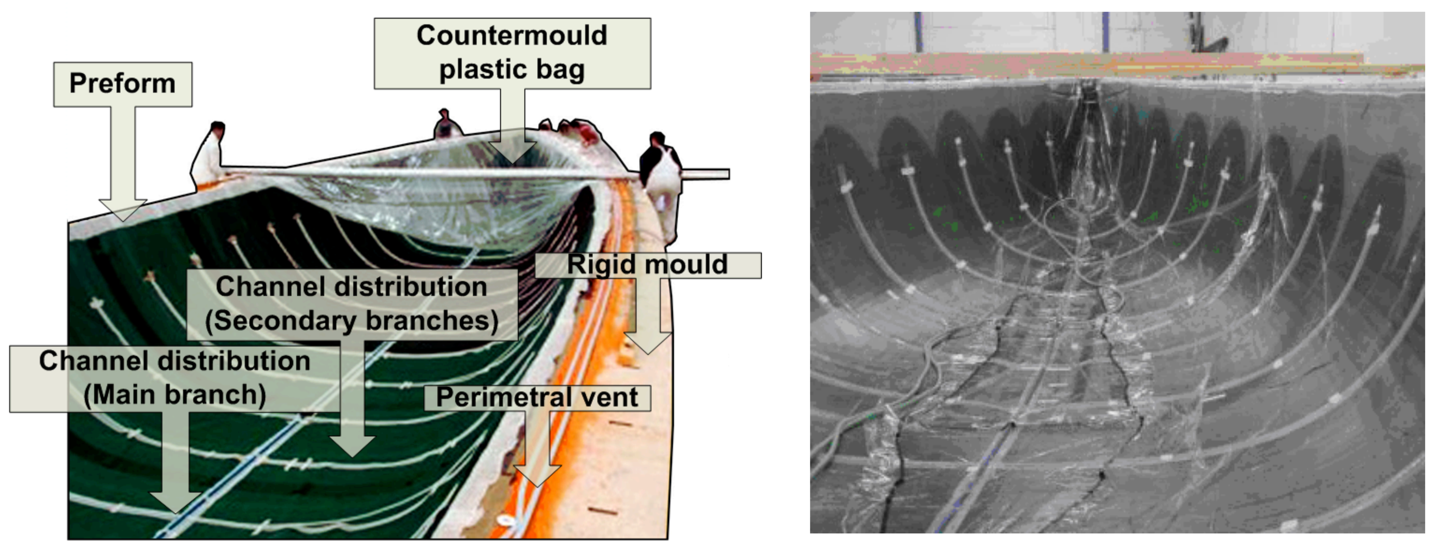

Figure 1: Resin Infusion Process and the Gate arrangement for a one-shoot filling strategy.

A Fast Marching-Level Sets approach for the distance field computation

A fast marching - level set approach **is used to compute the gate distance field of a given part geometry** by modelling non-physically the front shape evolution during filling as the zero set of an implicit function $z = \phi(x,y,t)$. The Main concept is to evolve the embedding function $\phi(x,y,t)$ and keep track of its zero level set. Its evolution under an external velocity field is solved with (where the sub-index indicates a partial derivative),

$$\phi_t + v \cdot \nabla\phi = 0$$

and assuming that the **velocity field at the interface front is normal** to the implicit function ϕ itself, with **V_n is constant** and ϕ_0 is defined as **a signed function (inside-outside)**.
All level sets of ϕ are evolving and can be solved with

$$\phi_t + V_n|\nabla\phi| = 0$$

We only track zero level set. The **front interface coordinates (x,y) can be obtained computing the implicit function $\phi(x,y,t)=0$ for each instant *t*.**
One can now define **geometric operators for the whole domain:**

- ***Distance Pattern function Θ***, is defined as a **scalar field** $\Theta(x,y)$ where $\phi(x,y,\Theta(x,y)) = 0$, so the level sets of $\Theta(x,y)$ correspond with the zero level set of $\phi(x,y,t)$. The distance pattern function $\Theta(x,y)$ is then constructed as the **accumulative distance evolution** to the location defined by $\phi(x,y,t=0)=0$. In $\Theta(x,y)$, the edges correspond to the set of points equidistant to at least two points of $\phi(x,y,t=0)=0$.
- ***Edge Pattern function Λ***, is defined as a **scalar field $\Lambda(x,y)$**, where $\Lambda(x,y)>0$ at the edges of $\Theta(x,y)$ and $\Lambda(x,y)=0$ elsewhere. It can be computed by means the **Laplacian of $\Theta(x,y)$** defined by $\Lambda=\Theta_{xx}+\Theta_{yy}$
This function **$\Lambda(x,y)$** corresponds to the **Medial Axis** in the case of having an homogeneus domain.

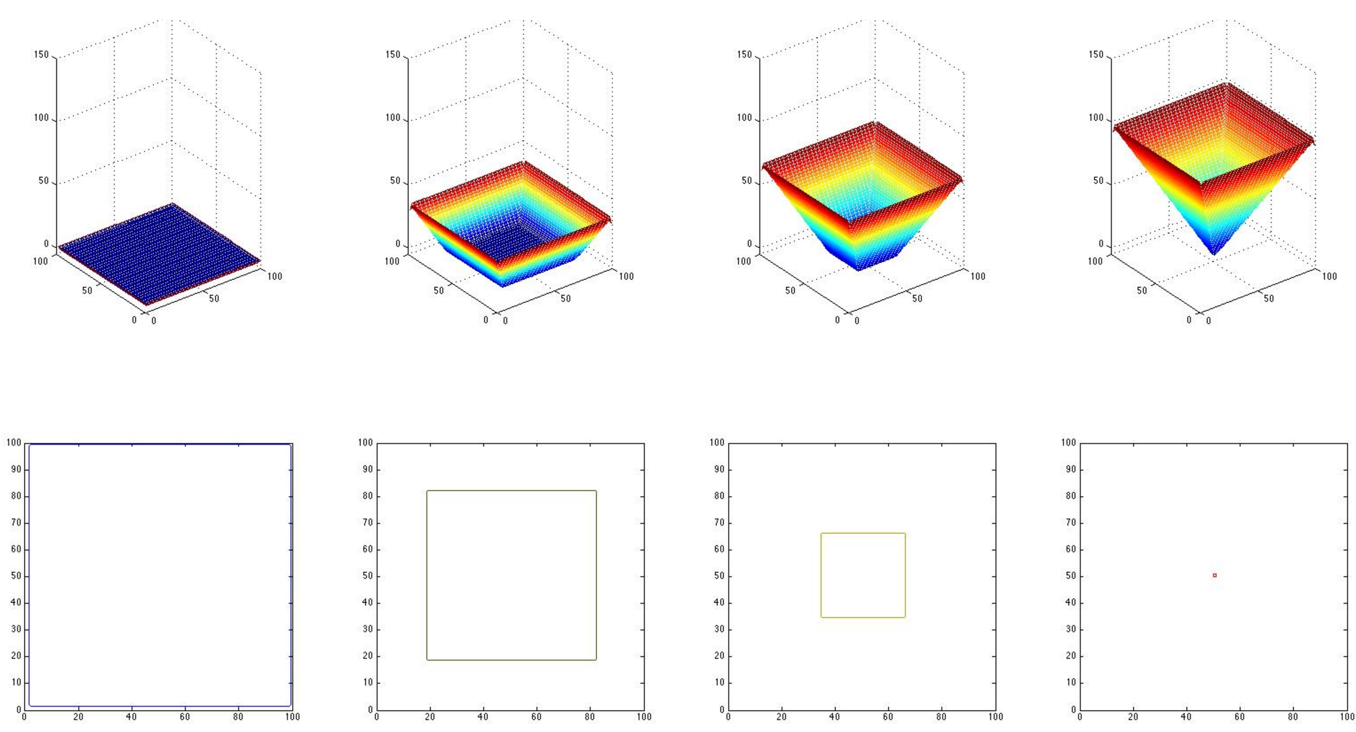

*Figure 2: **Level Set function $\phi(x,y,t)$** evolution and **zero Level sets**. Computed inwards from the vent gate*

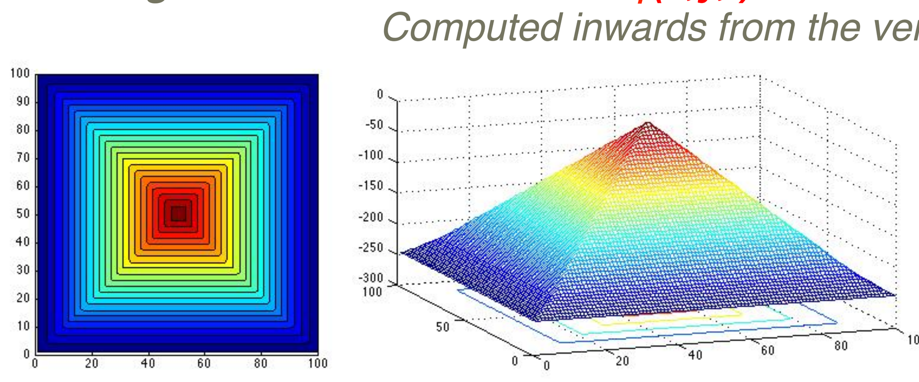

*Figure 3: **Distance Pattern function $\Theta(x,y)$** computed inwards from the vent contour*

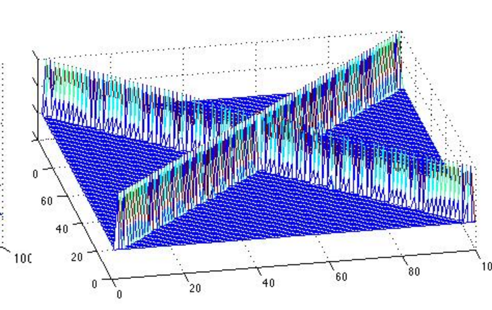

*Figure 4: **Edge Pattern function $\Lambda(x,y)$** Computed from $\Theta(x,y)$*

Results. Application in the Resin Infusion gate arrangement pre-design

The **numerical procedure computes** a pre-design 'one shoot' filling strategy with a continuous connected injection gate arrangement preserving the RI assumptions. In order to show the capabilities of the proposal, we work out an example where we assume the vent vacuum line is located on the contour of a 2D-rectangular part. An interior obstacle (upper right) defines a hole and, in this case, is treated also as vent line. Moreover, the part has two discontinuous regions of different permeability (middle left band permeability is double) that yields complex flow advancement (Figure 5).

Application example:

1. We compute for the whole domain the **Distance Pattern $\Theta(x,y)$ Inwards** from the vent contour (Figure 6).
2. The **Edge Pattern $\Lambda(x,y)$** is then obtained and a preliminary arrangement of the **mould Main Branch** is defined (Figure 7).
3. In order to obtain an appropriate filling strategy, the injection line has to guarantee that the resin achieves the vent line at the same time and avoiding dry spots and flow encounters. In this sense, to overcome the lacks of the Main Branch, it is necessary to upgrade the injection line arrangement with more **Secondary Branches.** The algorithm computes for the whole domain the **Distance Pattern $\Theta(x,y)$ Outwards** from the inlet obtained previously (Fig. 8a) defining independent regions (Fig. 8b).
4. New secondary branches are defined with **Edge Pattern $\Lambda(x,y)$** (Fig.8c).
5. Steps 3,4 are computed iteratively in order to optimize the inlet arrangement (Fig. 8d)

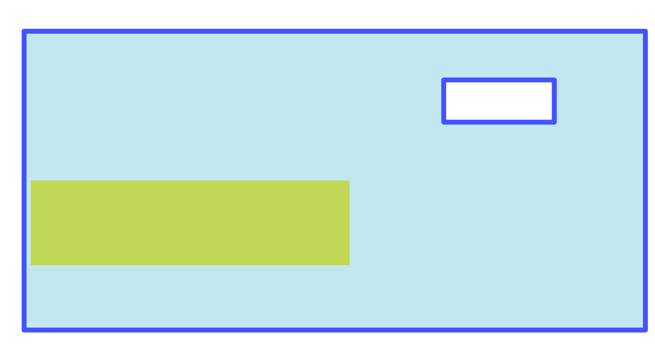

*Figure 5: **Part Geometry and textile regions***

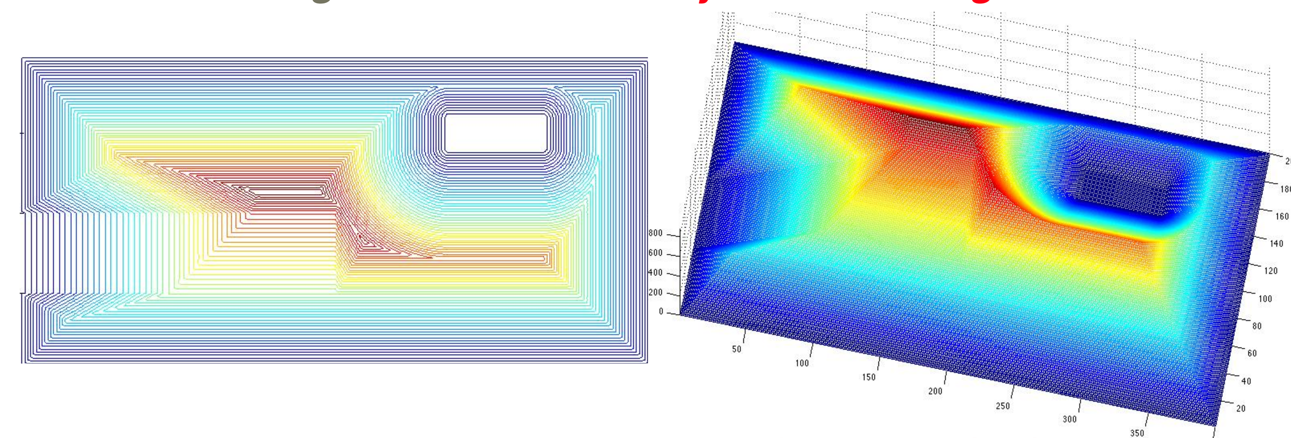

*Figure 6: **Distance Pattern function $\Theta(x,y)$** computed inwards from the vent contour*

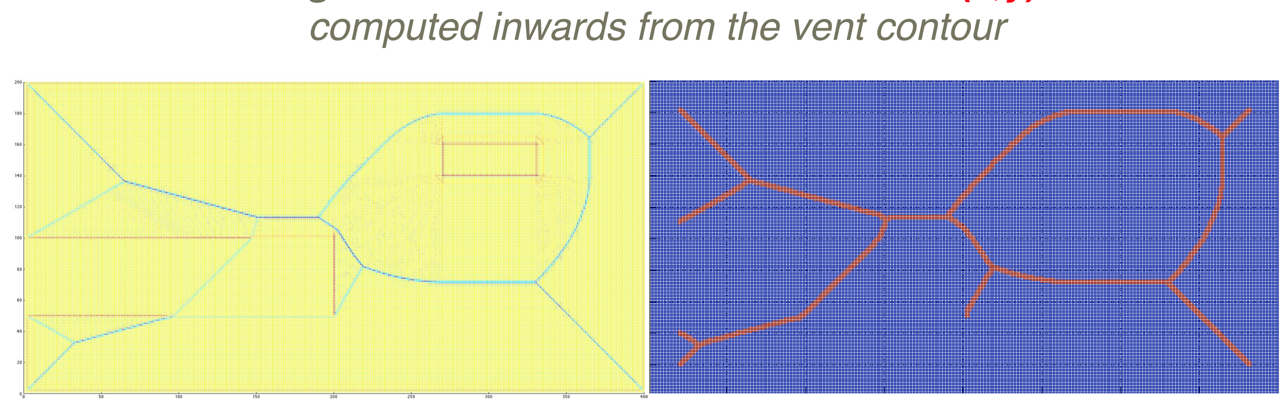

*Figure 7: **Edge Pattern function $\Lambda(x,y)$** (Left) Defining the Mould **Main Branch** (Right)*

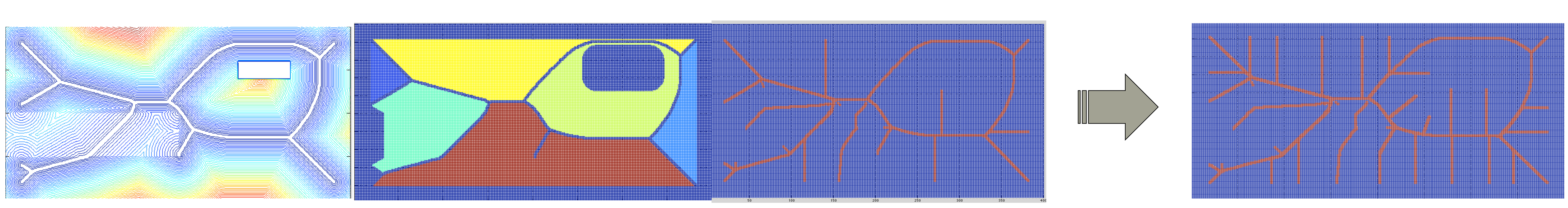

*Figure 8 **Secondary Branch Generation**. a) **Distance Pattern Outwards** b) **independent Regions** c) d) Initial and final **Edge Pattern defining secondary branches iterations***