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Toward the use of Symbolic Monte Carlo for combined heat transfer in complex geometries

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Abstract

The interest of using SMC^(a) method to obtain a transfer function for combined conduction-convection-radiation coupling in complex geometries is presented. The SMC method was successfully used for radiative transfer in a decoupled manner, but no attempt has been yet reported to extend its use to radiation coupled with other modes. The transfer function 1) enables to decrease the computation time when the function needs to be evaluated numerous times for different values of the parameters as in optimization or control algorithms and 2) can be used an analysis tool for inverse problems.

Monte Carlo to Symbolic Monte Carlo

Monte Carlo method:

- ▶ Solves combined heat transfer
- ▶ Handles complex geometries (no mesh needed)

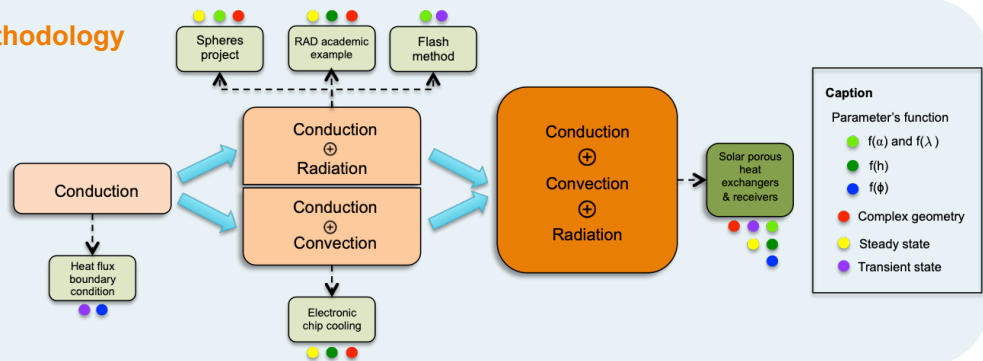
How a quantity depends on **sources, boundary condition, initial condition?**

SMC method:

- ▶ Function connecting the quantity with its parameters
- ▶ Handles combined heat transfer in complex geometries

How a quantity depends on **parameters?**

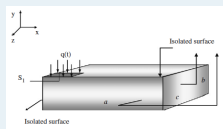
Methodology



Caption
Parameter's function
● $f(u)$ and $f(\lambda)$
● $f(h)$
● $f(\phi)$
● Complex geometry
● Steady state
● Transient state

Heat flux boundary condition

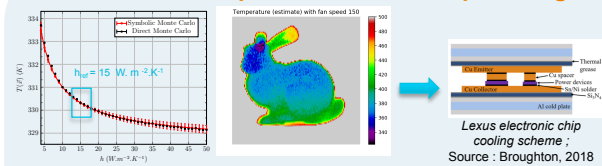
- ▶ **Temperature as a function of the heat flux** Comparison of MC^(b) simulation, SMC simulation and analytical solutions
- ▶ **SMC as an analysis tool for inversion** regarding the quantity and its sensitivity



3D-thermal model
Source : Sousa, 2008



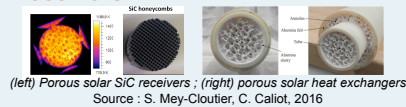
An academic example to electronic chip cooling



SMC and MC simulations for $N=10^6$ realizations (left) ; Thermal image obtained with SMC simulation (right) ; Source : RAD-19 Proceedings, L. Penazzi, 2019

- ▶ **Temperature as a function of the fan speed** Comparison of MC simulation and SMC simulation (heterogeneous $h^{(f)}$).
- ▶ **Function applied to an industrial case** electronic chip cooling in hybrid-electric vehicles

Solar porous heat exchangers & receivers

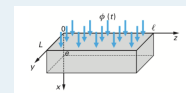


(left) Porous solar SiC receivers ; (right) porous solar heat exchangers
Source : S. Mey-Cloutier, C. Caliot, 2016

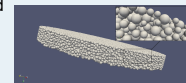
- ▶ **Combined heat transfer** conduction, convection and radiation
- ▶ **Complex geometry** porous media
- ▶ **Temperature as a function of various parameters** $\alpha^{(c)}$, $\lambda^{(d)}$, $\phi^{(e)}$

Flash method & Spheres project

- ▶ **Temperature as a function of the thermal diffusivity** Comparison of MC and SMC simulations with an analytical solution and experimental validation
- ▶ **Temperature as a function of the effective thermal conductivity** Combined conductive-radiative heat transfer in the solid phase of a complex porous medium (moon regolith)



Scheme of flash method
Source : Techniques de l'ingénieur, 2004



Bed of spheres representing regolith
Source : Sphere project, Fournier 2018

Laboratories

(1) **RAPSOEE**

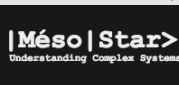
(2) **PROMES**



(3)



(4)



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Contact

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(a): Symbolic Monte Carlo ; (b): Monte Carlo ; (c): thermal diffusivity ($m^2.s^{-1}$) ; (d): thermal conductivity ($W.m^{-1}.K^{-1}$) ; (e) heat flux ($W.m^{-2}$) ; (f): heat transfer coefficient ($W.m^{-2}.K^{-1}$)