Coupling Conduction, Convection and Radiative Transfer in a Single Path-Space: Application to Infrared Rendering

Mégane Bati[1] Stéphane Blanco[2] Christophe Coustet[3] Vincent Eymet[3] Vincent Forest[3] Richard Fournier[2] Jacques Gautrais[4] Nicolas Mellado[1] Mathias Paulin[1] Benjamin Piaud[3]

[1]IRIT, CNRS, Université de Toulouse, UPS

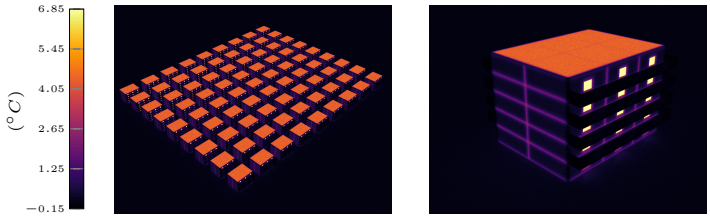
[2]LAPLACE, Université de Toulouse, CNRS, INPT, UPS

[3]Meso-Star

[4]CRCA, CBI, Université de Toulouse, CNRS, UPS

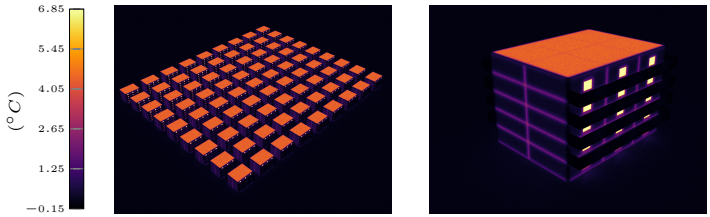
August 2023

Solving heat-transfer for infrared rendering



Conduction Convection Radiation

Solving heat-transfer for infrared rendering



Mesh-based methods

[Goral et al., 1984]

Physical accuracy ✓

Scalability ✗

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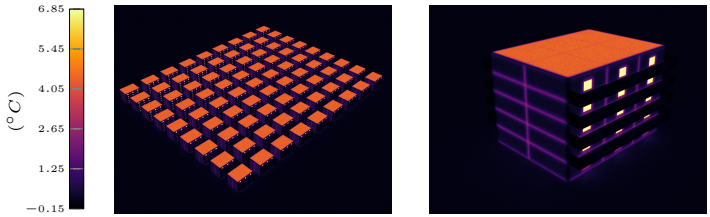

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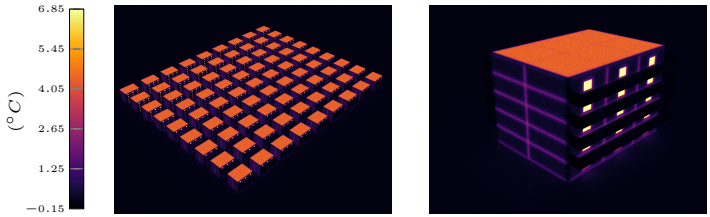

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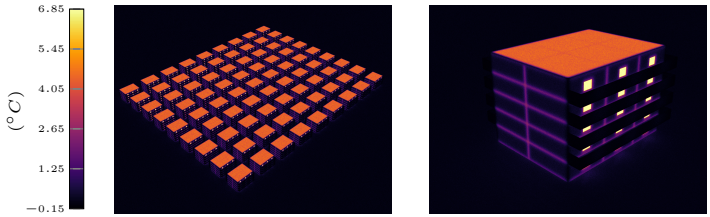
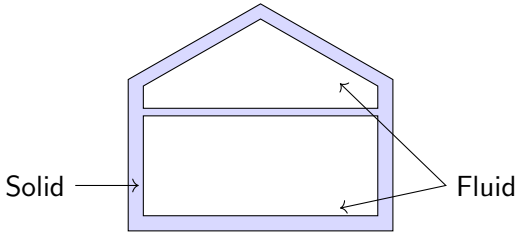


Unique space

Conduction Convection Radiation

Physical model



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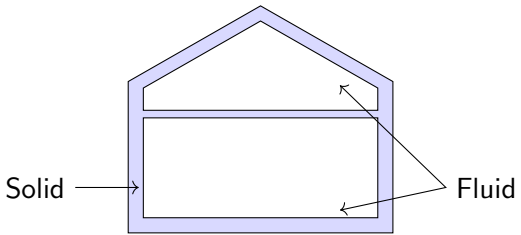
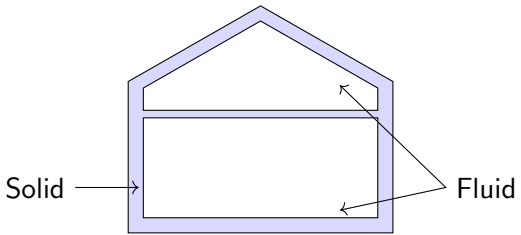


Conduction

Diffusion

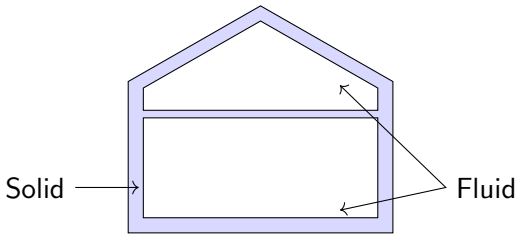
Physical model



Conduction
Diffusion

Convection
Perfectly-mixed cavity

Physical model



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Radiation
Rendering Equation

[Tregan et al., 2023] for radiation in volumes

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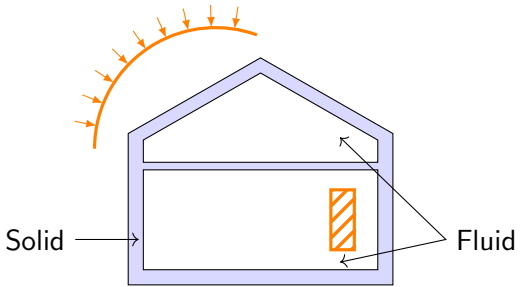

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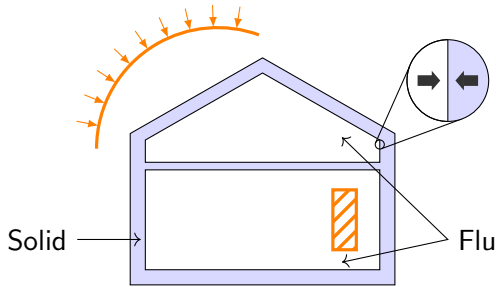

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Coupled path-space construction

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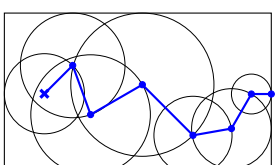
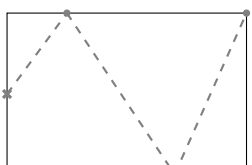
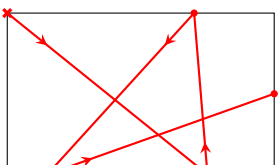


Conduction



Convection



Radiation

Coupled path-space construction

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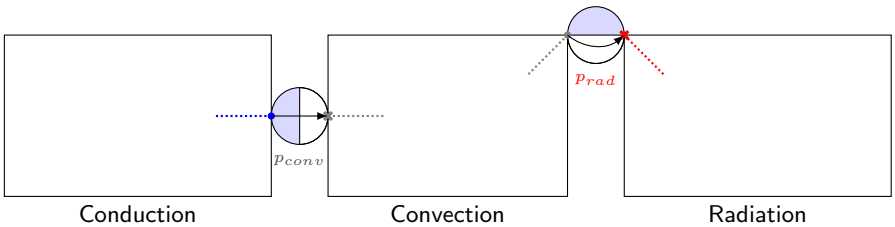
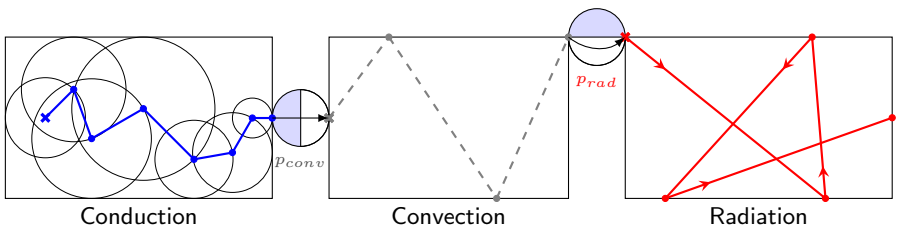
3. Probabilize the coupling between modes

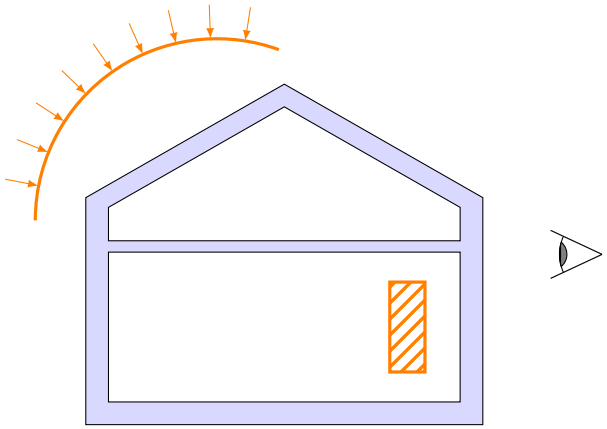


Coupled path-space construction

1. Express all equations on the same quantity
2. For each mode, write the quantity as an expectation of a process
3. Probabilize the coupling between modes
4. Apply Monte Carlo to build a single path-space



Monte Carlo algorithm



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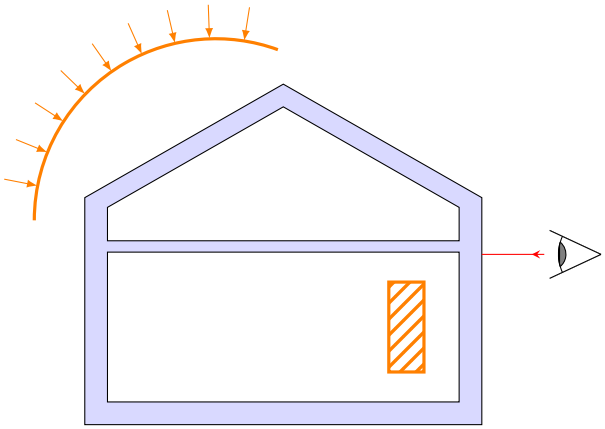

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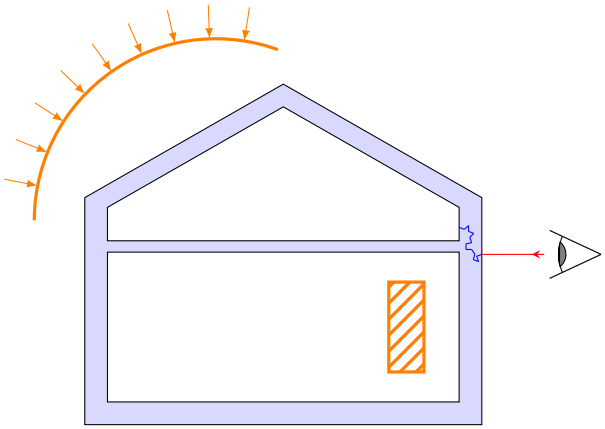

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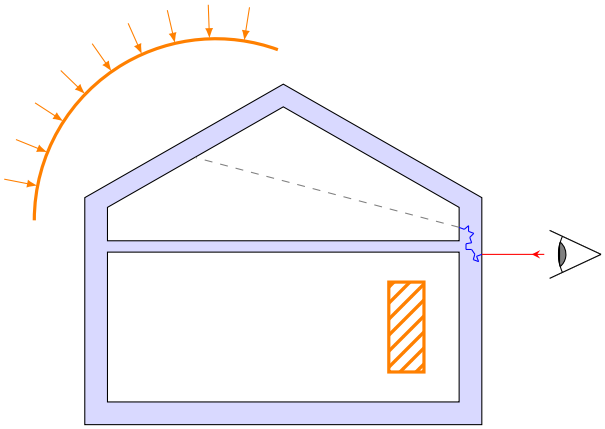

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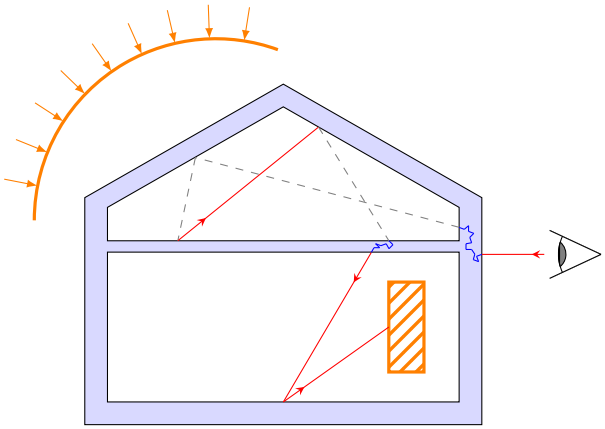

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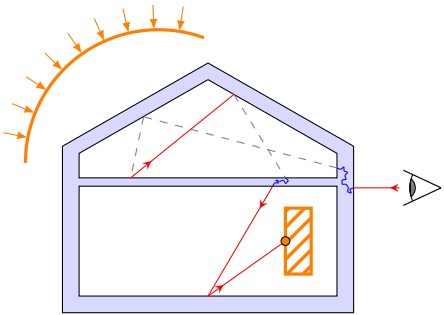
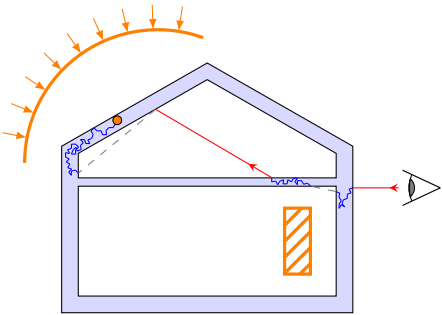
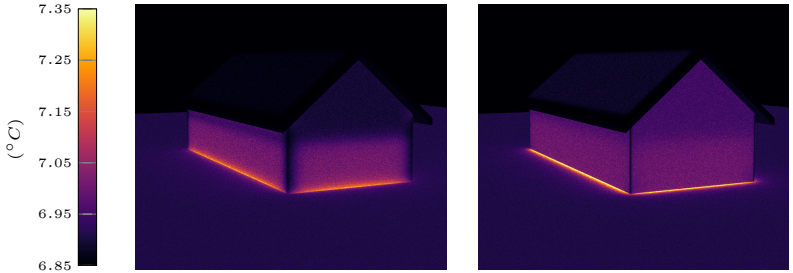


Stop at boundary condition



Stop at initial condition

Applications



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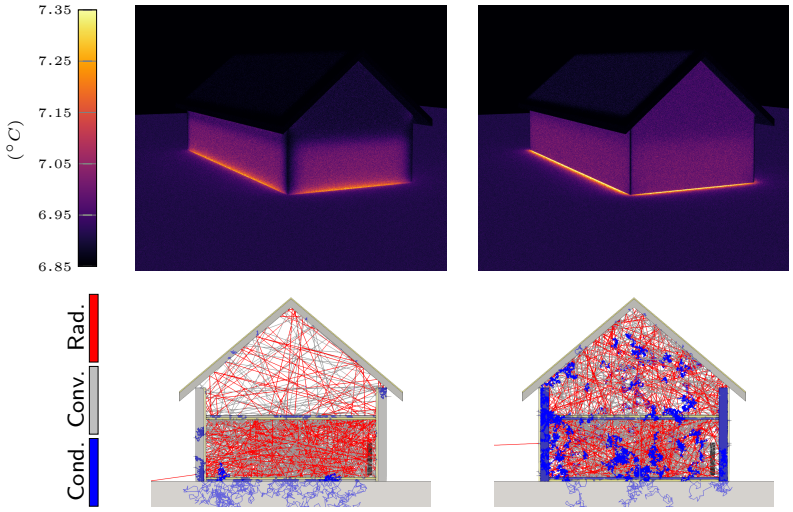
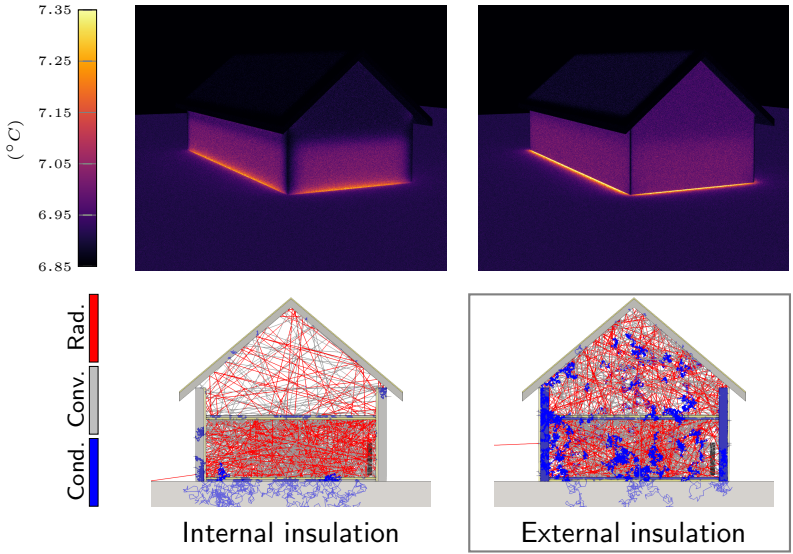


Internal insulation

External insulation

Applications



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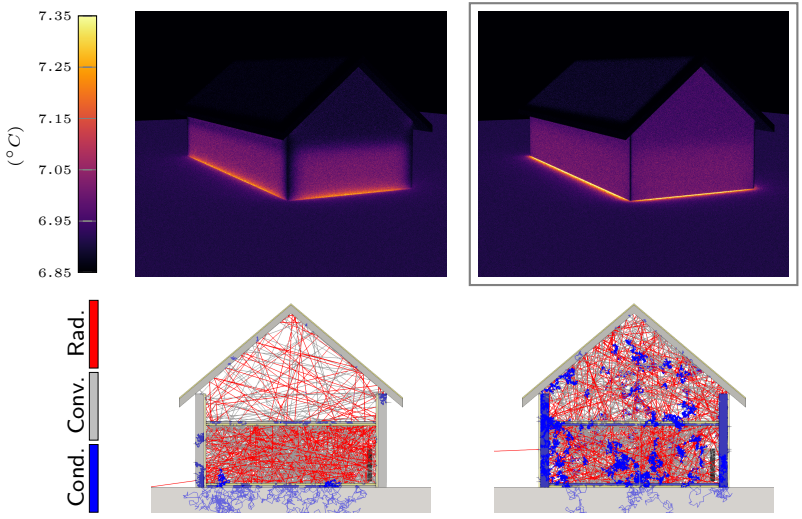

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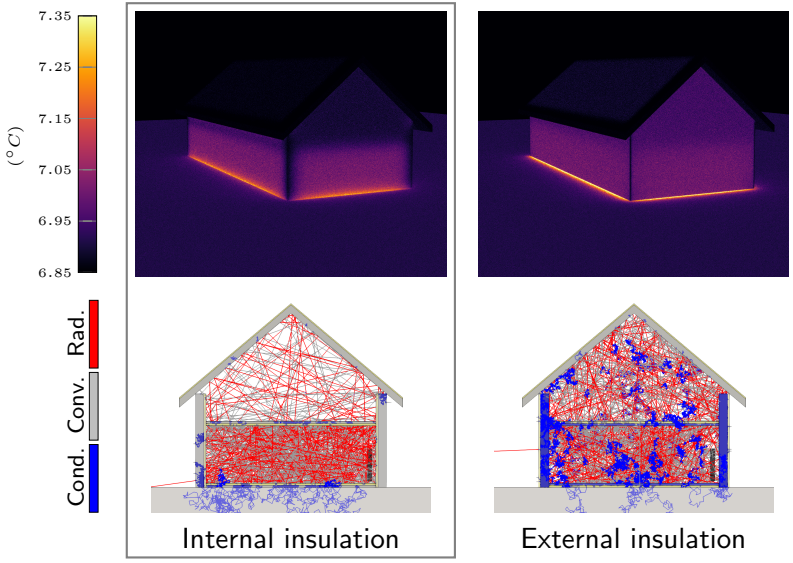

Applications

- Path visualization for analysis
- Fast model through path replay

Change source temperature : store final source identifier

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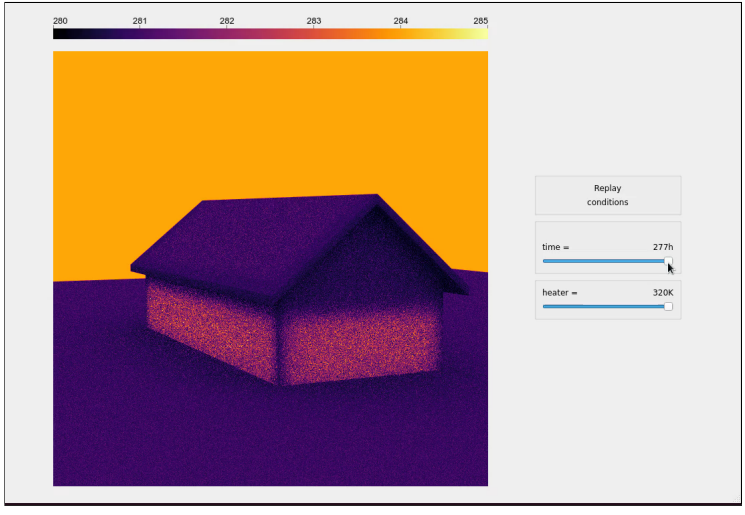
Change source temperature : store final source identifier
or observation time + path duration*

*Under homogeneous initial condition

Applications



Applications

- Path visualization for analysis
- Fast model through path replay
- Parameter sensibility analysis [Penazzi et al., 2022]

Limitations

- High variance for insulated sources (low probability to reach source)
  - [Qi et al., 2022]

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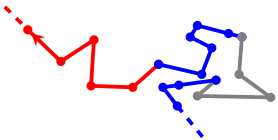
- Path entrapment (low probability to change mode)
- Bias introduced at interfaces
  - [Sawhney et al., 2023; Sugimoto et al., 2023]

Perspectives – towards non-linear situations

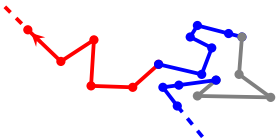


Coupling via the sources

Perspectives – towards non-linear situations

"Monte Carlo methods are not generally effective for nonlinear problems mainly because expectations are linear in character."
[Curtiss, 1953]

Perspectives – towards non-linear situations



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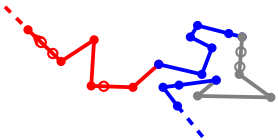
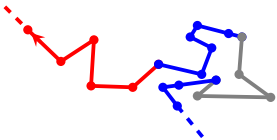


. . . with null-collision
[El Hafi et al., 2021]

$$T = \exp\left(-\int_{\Gamma} \kappa(\gamma) d\gamma\right)$$

Perspectives – towards non-linear situations



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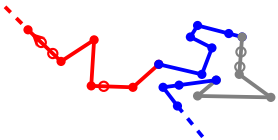

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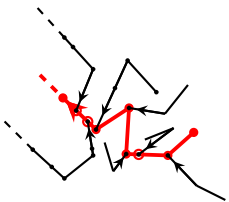
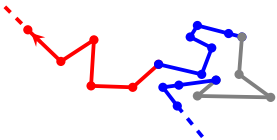


Coupling via the coefficient
[Terrée et al., 2022]

Perspectives – towards non-linear situations



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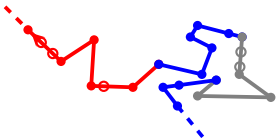

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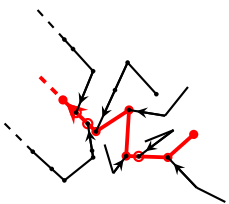

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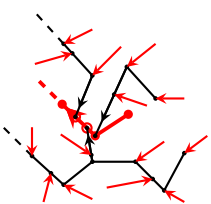

Non-linear coupling
[Rioux-Lavoie et al., 2022]

Conclusion

- A methodology to solve a situation of coupling via the sources in a single path-space

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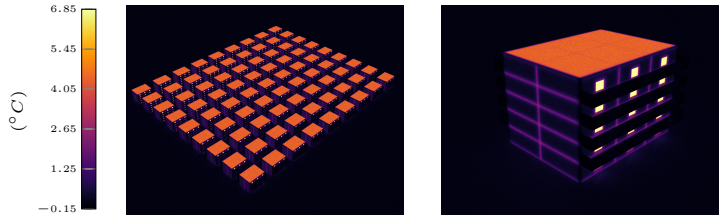

similar computation time

Conclusion

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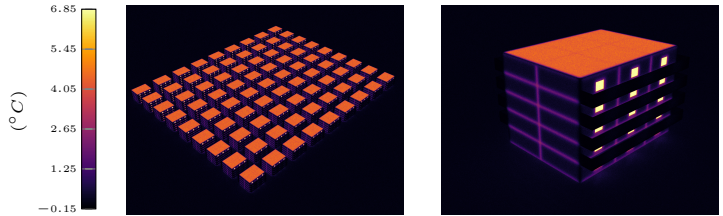

similar computation time

- Perspectives towards the solving of non-linear situations

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