UCLouvain

miro
molecular imaging, radiotherapy & oncology

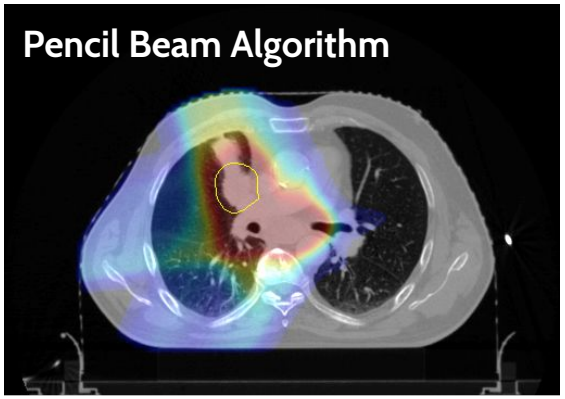
Fast Monte Carlo simulations of proton therapy treatments

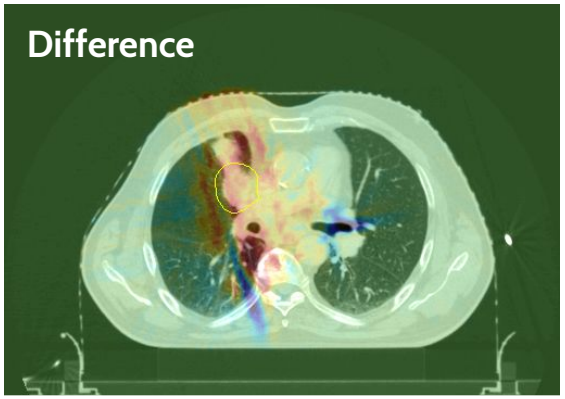
Kevin Souris, Marie Cohilis

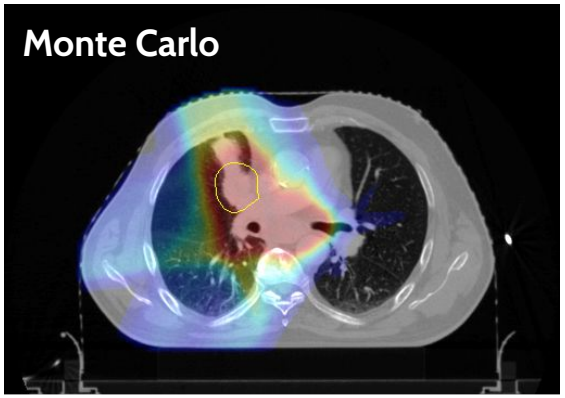
Disclosure

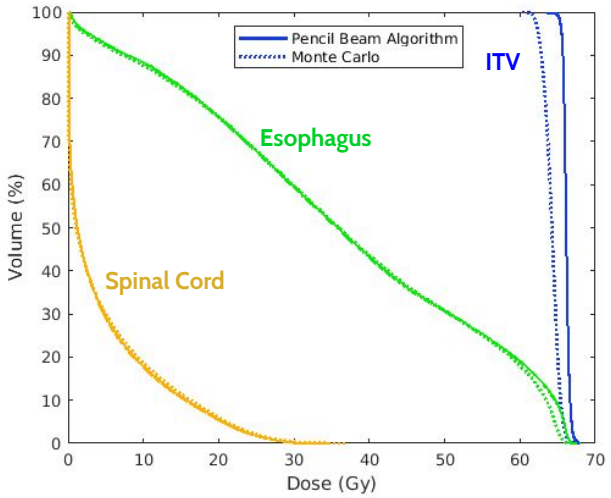
Kevin Souris is supported by a research grant from Ion Beam Application (IBA s.a.)

Proton therapy dose calculation
Impact of heterogeneities

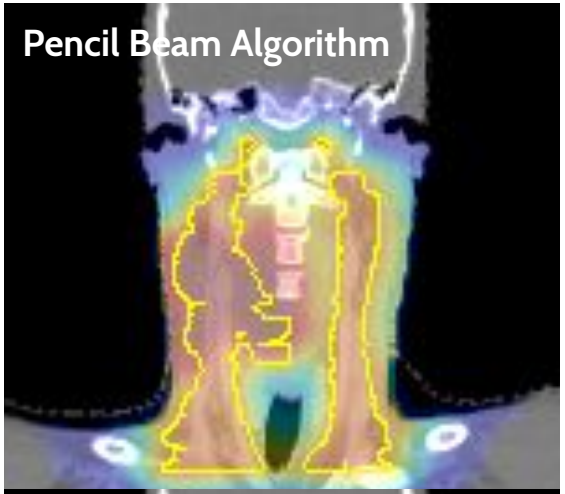


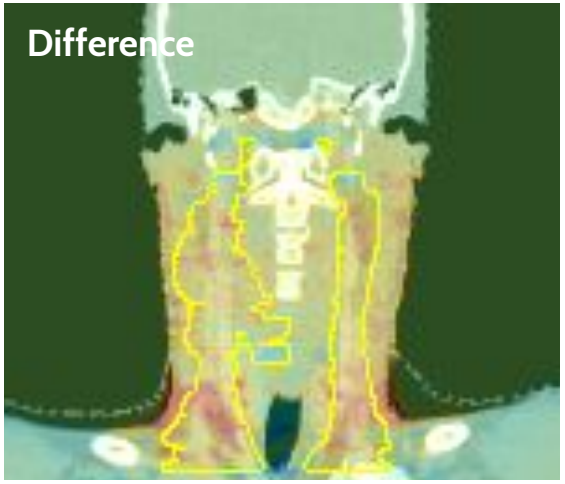


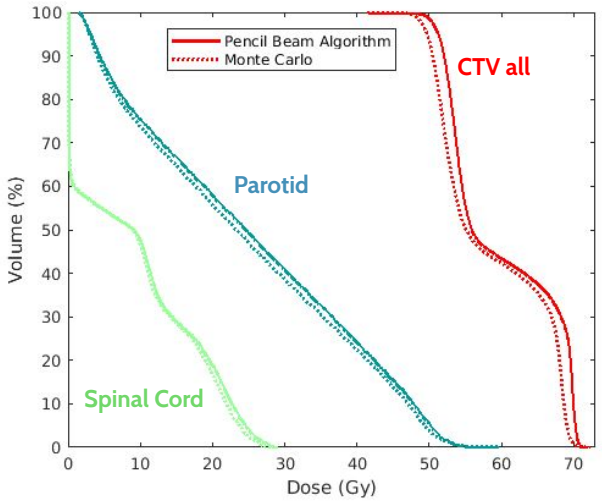




Proton therapy dose calculation
Impact of range shifters





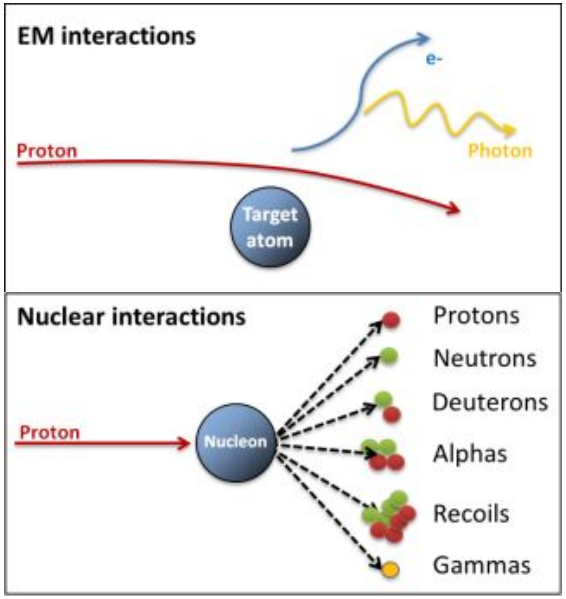


Proton therapy dose calculation
Algorithms

Pencil Beam algorithm

- Macroscopic models
- Approximate method
- Fast computation
  RayStation: ~ 30 s

Monte Carlo algorithm



- Microscopic models
- Most accurate method
- Slower computation
  GATE/Geant4: ~ 1-5 h

MCsquare: fast Monte Carlo simulations

Need to speed-up the calculation for use in clinical routine:

openmcsquare.org

- Fast Monte Carlo code
- Optimized for PBS proton therapy simulations
- Open source

MCsquare: fast Monte Carlo simulations

Simplified transport algorithm: voxelized geometry

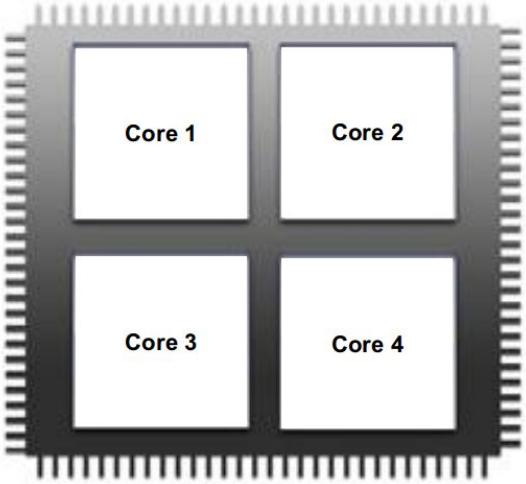
Simplified physical models:

Fully simulated	**Not simulated**
• Proton EM interactions • Proton nuclear interactions • Secondary heavy charged particles (protons, alphas, deuterons)	• Secondary electrons • Neutral particles (photons, neutrons)

MCsquare: fast Monte Carlo simulations

Fully exploits CPU ressources:

- Multi-core calculation



Computation time: < 10 min (Laptop)
< 1 min (Computation server)

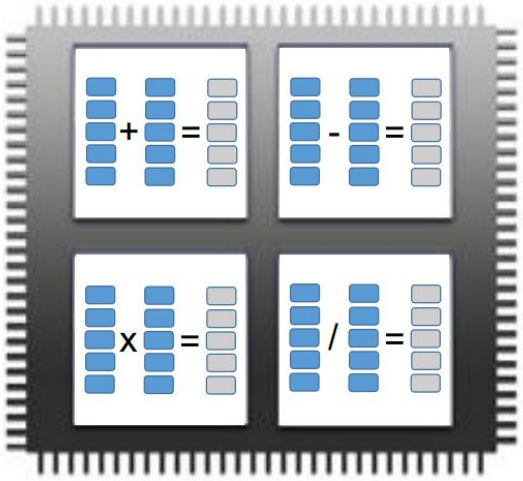
for the simulation of a typical treatment
with 10 millions primary protons

MC SQUARE many | monte core | carlo

MCsquare: fast Monte Carlo simulations

Fully exploits CPU ressources:

- Multi-core calculation
- Vector calculation



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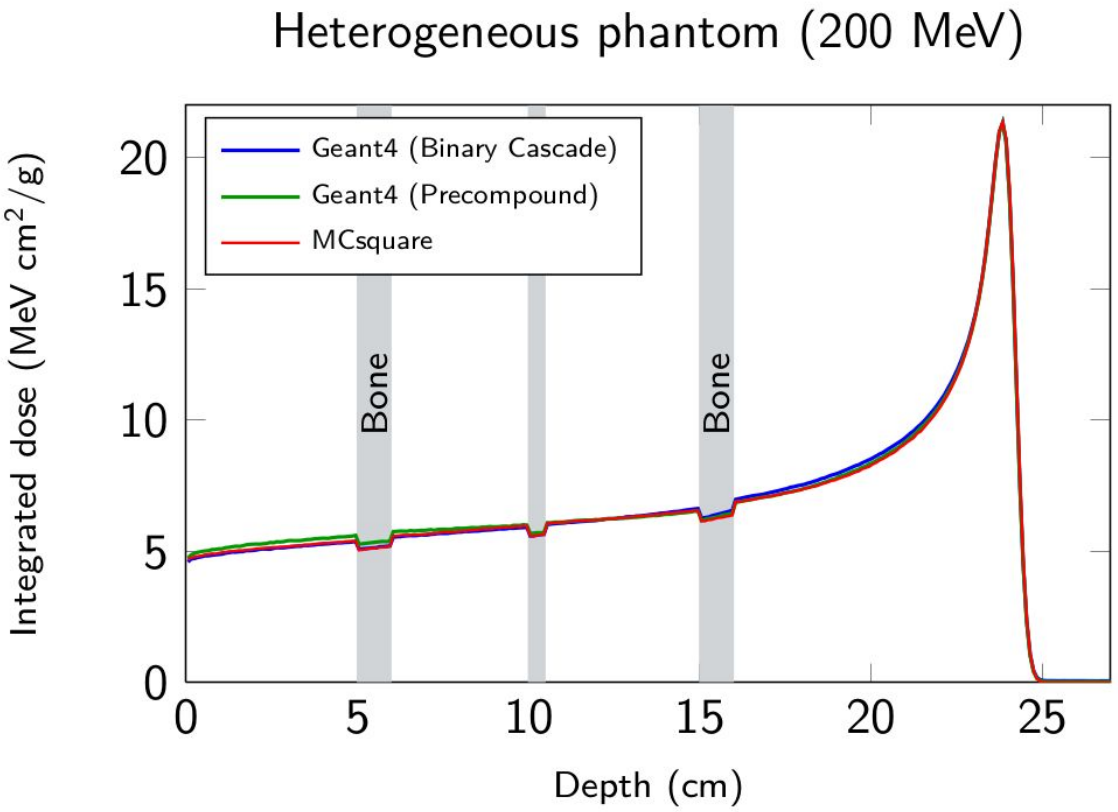
Validation with GATE/Geant4



Different nuclear models:

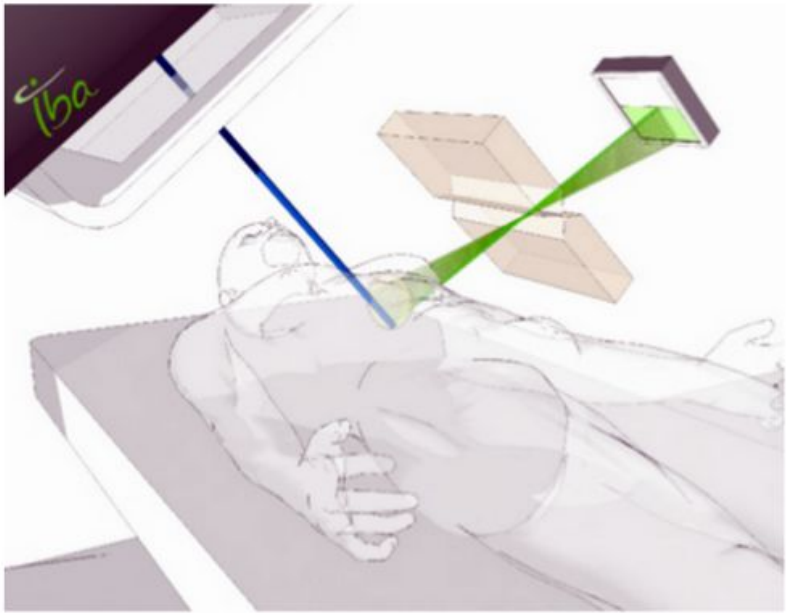
Geant4:
Binary Cascade, Precompound

MCsquare:
ICRU63 cross sections

GATE version 6.2
Geant4 version 9.5 p2

Validation with GATE/Geant4

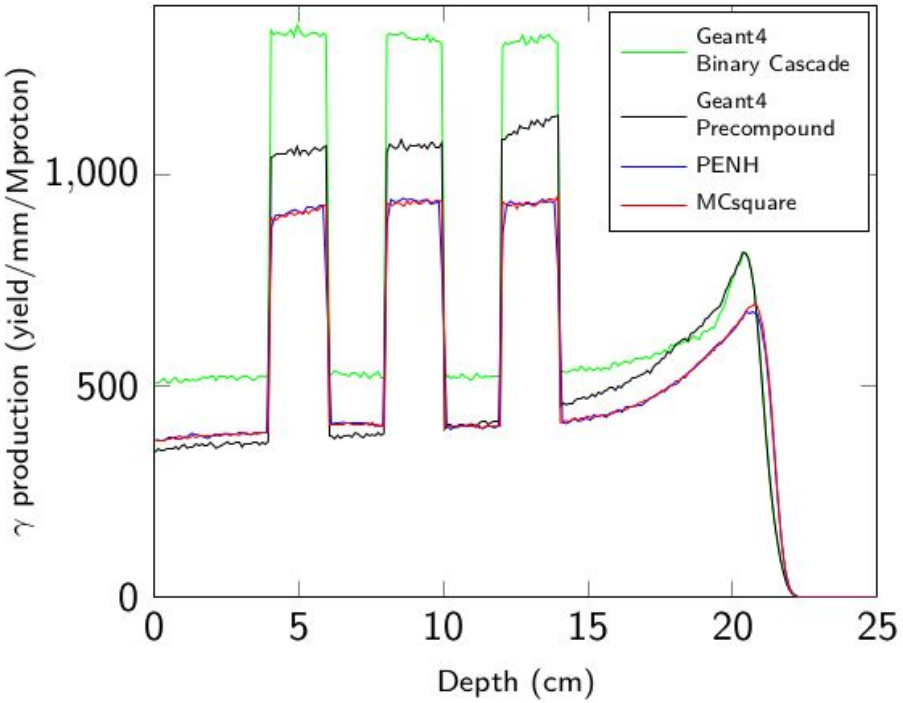
Prompt gamma imaging



Smeets, Phys. Med. Biol. 57, 2012

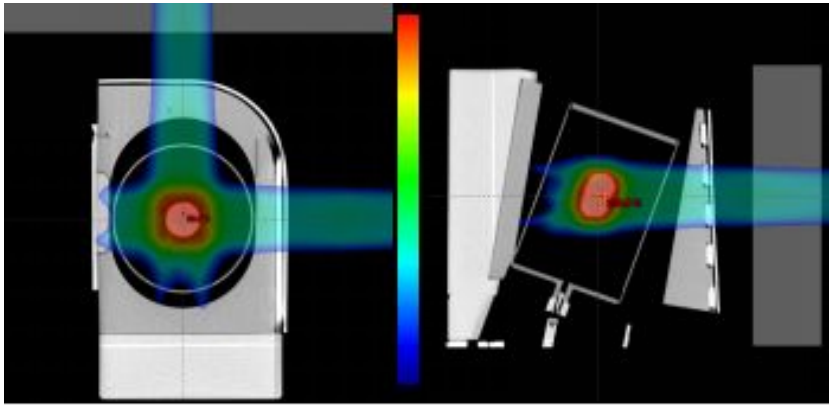
Simulated prompt gamma profiles

(200 MeV - Heterogeneous phantom)



Simulation of prompt gammas is more sensitive to nuclear models !

Validation with measurements



	Film Plane (Gamma Index)			TLD	
	Axial	Coronal	Sagittal	Sup	Inf
TPS	66%	82%	83%	0.96	0.96
TOPAS	93%	98%	99%	0.99	0.99
MCsquare	96%	99%	98%	0.99	0.99

Measurements performed in the IROC Lung phantom
by Sheng Huang (UPenn)

MCsquare I/O

Inputs:

CT image (MHD format)

PBS plan (GATE format)

Config file (MCsquare format)

Beam model (GATE format, or look-up table)
-> commissioning tool open source

HU conversion model (GATE format)

Outputs:

Dose / energy / LET / PG images:
- MHD format
- text format
- sparse matrix format

DVH (text format)

Most inputs / outputs are compatible with GATE

The OpenPATh initiative

Proton Adaptive Therapy Platform
OpenReggui

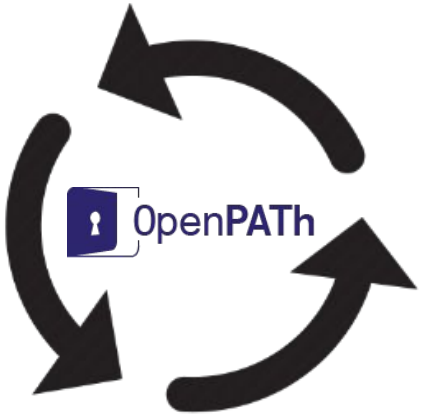
Graphical interface
Image processing
Workflow management

aptain
automated PT platform

Workflow automatisation
Web interface

RTK

Image reconstruction toolkit



MIROpt

Treatment plan optimizer

MCSQUARE
many | monte
core | carlo

Monte Carlo simulations
Commissioning tools

ORTHANC

Dicom server

open source

Applications

Examples of OpenPATh applications:

- Log-based QA of proton therapy treatments
- Adaptive therapy workflows
- Robust treatment optimization and evaluation
- 4D CBCT reconstruction and motion analysis
- Prompt gamma imaging and analysis

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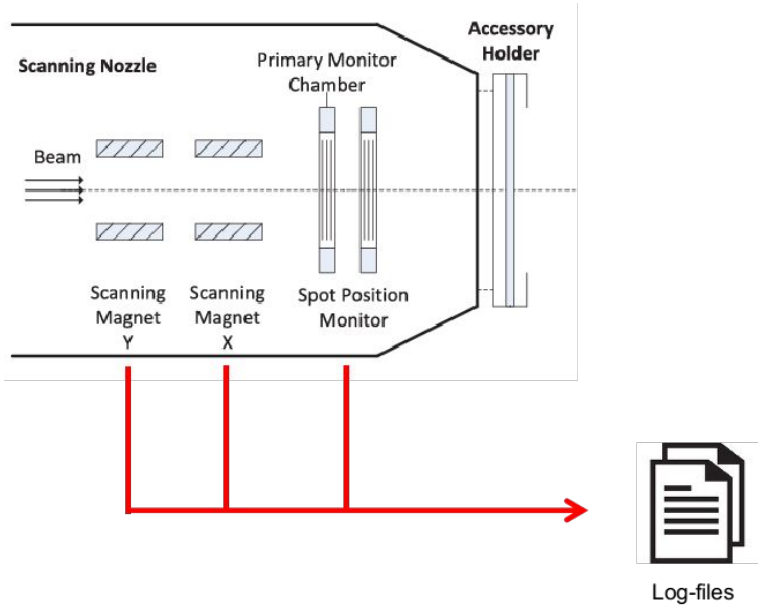

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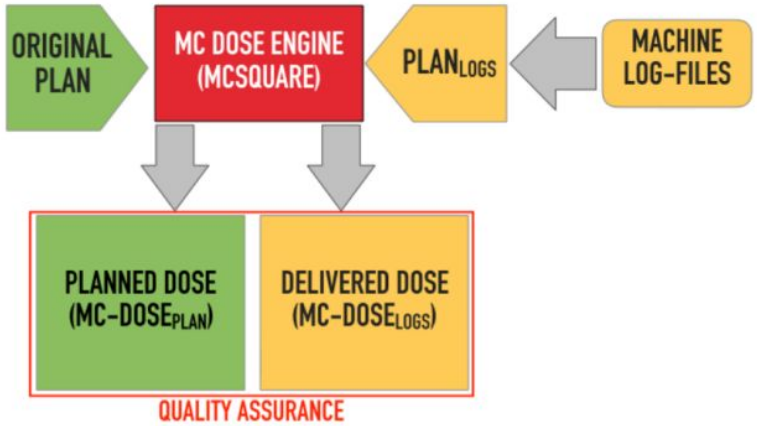

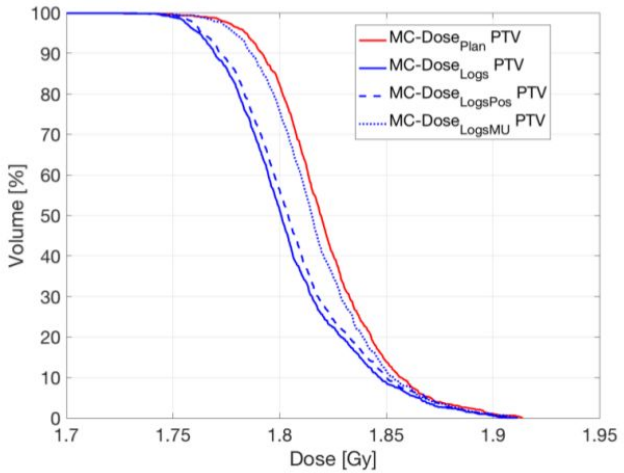

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myQA iON product released by IBA dosimetry

Conclusions

MCsquare:

- Fast Monte Carlo simulations
- Dedicated to PBS proton therapy

openmcsquare.org

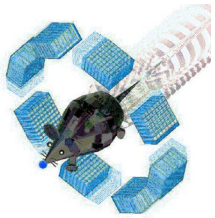
The OpenPATh initiative:

- Accelerates research
- Helps the transition from research to the clinic

http://openpath.software

Perspectives:

- Interface GATE with OpenPATh tools



Thank you

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