



Greetings from Serpent Developer Team

6th International Serpent UGM, Milan, Italy, Sept. 26-29, 2016

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VTT Technical Research Center of Finland

Serpent developer team at VTT

Source code development:

- ▶ Jaakko Leppänen
- ▶ Tuomas Viitanen
- ▶ Ville Valtavirta
- ▶ Toni Kaltiaisenaho

Applications:

- ▶ Paula Sirén (Fusion neutronics)
- ▶ Riku Tuominen (multi-physics & SMR)
- ▶ Ville Sahlberg, Antti Rintala, Eric Dorval, Pauli Juutilainen, ...

Serpent user community

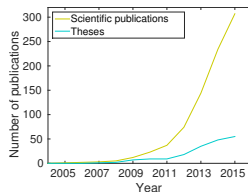
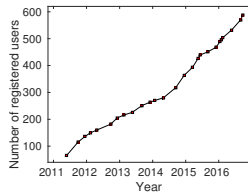
User community in numbers:¹

- ▶ 589 registered users in mailing list
- ▶ 162 organizations (54% universities)
- ▶ 37 countries
- ▶ Typical user: M.Sc. or Ph.D. student
- ▶ More than 60 Theses on Serpent-related topics since 2007
- ▶ almost 400 peer-reviewed journal and conference papers since 2005

Serpent website: <http://montecarlo.vtt.fi>

Serpent discussion forum: <http://ttuki.vtt.fi/serpent>

Serpent Wiki: serpent.vtt.fi/mediawiki/



¹ Previous UGM in Knoxville: 459 users, 142 organizations, 36 countries

Serpent applications

Traditional applications:

- ▶ Group constant generation for reactor simulator codes (DYN3D, PARCS, ARES, TRAB3D, HEXTRAN, HEXBU, APROS, ...)
- ▶ Research reactor modeling
- ▶ Burnup calculations (fuel cycle studies, radioactive inventory and source term calculations)
- ▶ Coupled multi-physics applications (coupling to CFD, thermal hydraulics and fuel performance codes)

Emerging applications:

- ▶ Fusion neutronics (shut-down dose rate calculations, heat deposition, tritium breeding, material damage and activation)
- ▶ Radiation shielding (neutron and photon transport)

On-going and future work

Serpent development is co-funded by VTT and Finnish national research programmes, and the focus areas reflect the topics of these projects:

- i) Advanced methods for spatial homogenization
- ii) Coupled multi-physics calculations
- iii) New applications, including fusion neutronics and radiation shielding

Until August 2016 our main source of funding was the Academy of Finland Nuclear Multi-Physics (NUMPS) project:

- ▶ Covered almost all work related to multi-physics coupling
- ▶ 4 years, total budget 1.3 M€
- ▶ 30 peer-reviewed journal and conference papers
- ▶ 2 doctoral degrees (+2 more to be completed within the near future)

On-going and future work

Recent work on group constant generation:

- ▶ The methodology is finally documented:

Leppänen, J., Pusa, M. and Fridman, E. *"Overview of methodology for spatial homogenization in the Serpent 2 Monte Carlo code."* Ann. Nucl. Energy, **96** (2016) 126-136.

- ▶ New methods for calculating diffusion coefficients (see Emil's presentation tomorrow)
- ▶ Practical demonstration on generating the full set of group constants for fuel cycle simulations (cycle 1 of the MIT BEAVRS Benchmark):

Leppänen, J. and Mattila, R. *"Validation of the Serpent-ARES code sequence using the MIT BEAVRS benchmark – HFP conditions and fuel cycle 1 simulations."* Ann. Nucl. Energy, **96** (2016) 324-331.

9 assembly types, 9 histories per assembly, a total of $\sim 12,000$ coefficient calculations run \longrightarrow all calculations completed within 48 hours

On-going and future work

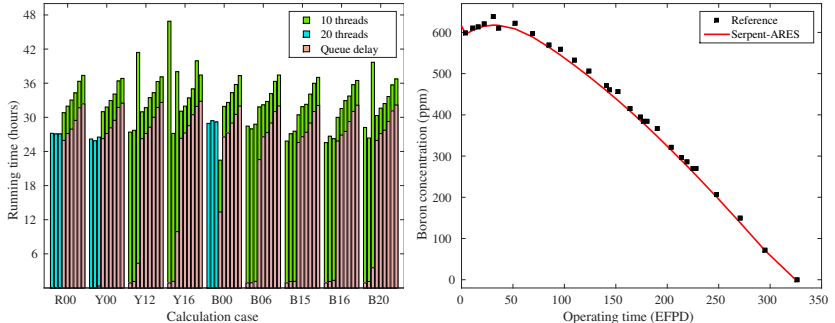


Figure 1 : Left: Wall-clock running times of the 9 history cases (including branch variations) of the 9 assembly types. The longest histories were submitted first and therefore started immediately, while the remaining cases were left in the queue waiting for more computer nodes to become available. Cases with the largest number of branches (all state-point variations + control rod insertion) were run with 20 and the remaining cases with 10 CPU cores. Right: Boron let-down curve for cycle 1 calculated by Serpent-ARES compared to experimental reference data.

On-going and future work

Recently implemented features:²

- ▶ Delayed neutron model in dynamic mode
- ▶ Two new methods for calculating diffusion coefficients consistent with the in-scattering approximation
- ▶ Improved detectors for heat deposition calculations
- ▶ User-defined functions as detector response
- ▶ Weight-window mesh based variance reduction scheme
- ▶ Built-in light-weight importance map solver (very much under development)
- ▶ Continuous reprocessing for MSR's (has some major unresolved issues)
- ▶ Collision history based adjoint methodology (still only in Manuele's special version)

²Current update is 2.1.27, distributed on September 23, 2016.

On-going and future work

Work planned for near future:

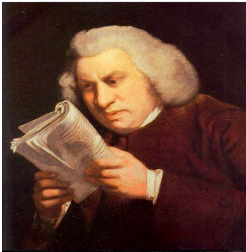
- ▶ Coupled neutron-photon transport mode
- ▶ Improved models to account for prompt and delayed heating
- ▶ Extending the variance reduction capabilities
- ▶ Neutron and photon transport calculations for JET
- ▶ Validation (criticality, shielding, etc.)

2017 and later:

- ▶ New cross section libraries (ENDF/B-VII.1, JEFF-3.2, JENDL-4.0, FENDL-3.0)
- ▶ Photonuclear reactions and electron transport mode
- ▶ More involvement in fusion neutronics and radiation transport

NOTE: These are mainly topics in new application areas, work on reactor physics (homogenization + multi-physics) is also continued.

Commercial use of Serpent 2



Commercial user license for Serpent 2 has been available since early 2016:

- ▶ Separate software license agreement (SLA) by request
- ▶ Removes limitation regarding commercial applications
- ▶ Free of charge until the end of 2017



Since the license is offered for free, VTT has certain terms and conditions that are non-negotiable:

- ▶ IPR issues
- ▶ Liability issues
- ▶ Technical support cannot be guaranteed

Even though the SLA is provisional until the end of 2017, the period will most likely be extended by at least a year or so.

Serpent UGM 2016

Previous International Serpent User Group Meetings:

2011 Dresden, Germany – 2 days, 33 participants, 16 technical presentations

2012 Madrid, Spain – 3 days, 40 participants, 20 presentations

2013 Berkeley, USA – 3 days, 35 participants, 24 presentations

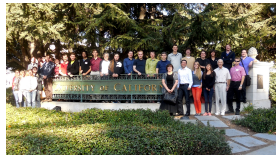
2014 Cambridge, UK – 3 days, 34 participants, 24 presentations

2015 Knoxville, USA – 3 + 1 days, 41 participants, 28 presentations

This meeting:

- ▶ 3 + 1 days, 52 participants, 27 presentations
- ▶ Special session on fusion-related topics (Wednesday morning)
- ▶ ~ 30 minutes reserved for presentation, questions and discussion, but the schedule is flexible
- ▶ Presentations collected at a website after the meeting
(send pdf to Jaakko.Leppanen@vtt.fi)

Serpent UGM 2016



Remember group photo on Thursday, before the technical tour. Group photos from previous International Serpent User Group Meetings: Dresden, 2011; Madrid, 2012; Berkeley, 2013; Cambridge, 2014; Knoxville, 2015.

Enjoy the 6th International Serpent User Group Meeting!

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