Coarse Mesh Radiation Transport Code COMET
“Radiation Therapy Application* “

Farzad Rahnema
Nuclear & Radiological Engineering and Medical Physics Programs
Georgia Institute of Technology

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Objectives

- Develop an accurate 3-D particle transport method which
  - Is capable of coupled neutron, photon and electron transport
  - Does not require homogenization
  - Contains an accurate and self-consistent global dose reconstruction procedure
  - Its accuracy is independent of the mesh size

Method

- Start from the transport equation with arbitrary boundary condition

$$\hat{\Omega}.\nabla\psi\left(\vec{r},\hat{\Omega},E\right)+\sigma_t\left(\vec{r},E\right)\psi\left(\vec{r},\hat{\Omega},E\right)=Q\left(\vec{r},\hat{\Omega},E\right)$$

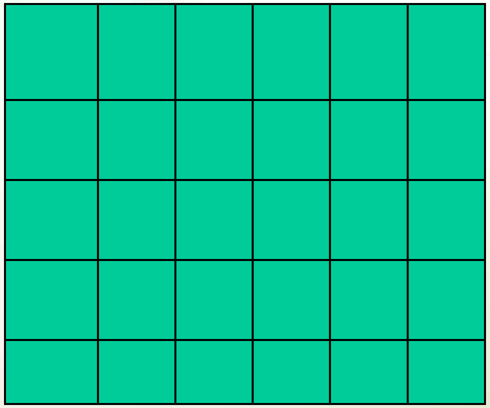
$$+\int_0^{\infty}dE'\int_{4\pi}d\Omega'\,\sigma_s\left(\vec{r},\hat{\Omega}',E'\rightarrow\hat{\Omega},E\right)\psi\left(\vec{r},\hat{\Omega}',E'\right)$$

with boundary condition

$$\psi\left(\vec{r}_b,\hat{\Omega},E\right)=B\,\psi\left(\vec{r}_b,\hat{\Omega}',E'\right)\qquad \vec{n}.\hat{\Omega}<0,\text{ and}\quad \vec{n}.\hat{\Omega}'>0,\ \vec{r}_b\in\partial V$$

Problem Decomposition

- Decompose the global problem exactly as a set of local fixed source problems over non-overlapping coarse meshes V_i



$$\hat{\Omega}.\nabla\psi_i\left(\vec{r},\hat{\Omega},E\right)+\sigma_t\left(\vec{r},E\right)\psi_i\left(\vec{r},\hat{\Omega},E\right)=Q_i\left(\vec{r},\hat{\Omega},E\right)$$

$$+\int_0^\infty dE'\int_{4\pi}d\Omega'\,\sigma_s\left(\vec{r},\hat{\Omega}',E'\to\hat{\Omega},E\right)\psi_i\left(\vec{r},\hat{\Omega}',E'\right)$$

$$\psi_i^-\left(\vec{r}_{ij},\hat{\Omega},E\right)=\psi_j^+\left(\vec{r}_{ij},\hat{\Omega},E\right),\quad \vec{r}_{ij}\in\left\{V_i\cap V_j\right\}\text{for all}\quad V_j \text{ bounding } V_i$$

Method - Approximation

•An approximation is performed on the angular flux at the boundary of the coarse meshes

$$HR_{is}^{m}(w_i) = Q(w_i)$$

$$\text{with} \quad R_{is}^{m}(w_{is}^{-}) = \begin{Bmatrix} \Gamma^{m}(w_{is}^{-}), & \text{for } \vec{r} \in \partial V_{is} \\ 0, & \text{otherwise} \end{Bmatrix}$$

•Γ is the m[th] member of a set of functions orthogonal on the half-space, expansion becomes; examples:

- Discrete Legendre polynomial
- Continuous Legendre polynomial

Method Summary

- Library Generation:
  - Precomputed response functions as a function material density (CT index) – Expansion coefficients with the maximum desired order in phase space
- Define the mesh grid in the problem
- Sweep through the mesh to converge on the dose distribution by coupling meshes through angular currents (expansion coefficients)
- Use low order solutions to accelerate the high order solution

Medical Physics Benchmark Problem – A Homogeneous Problem

30 cm

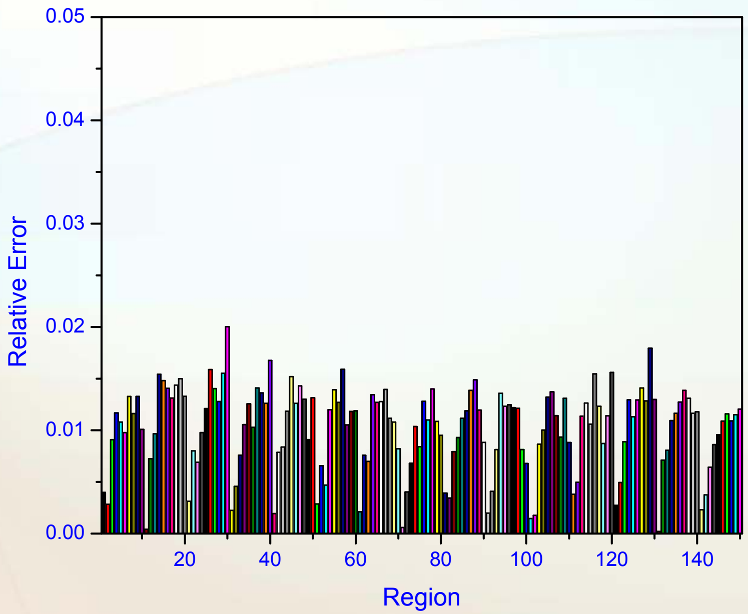
1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130
131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150

20 cm

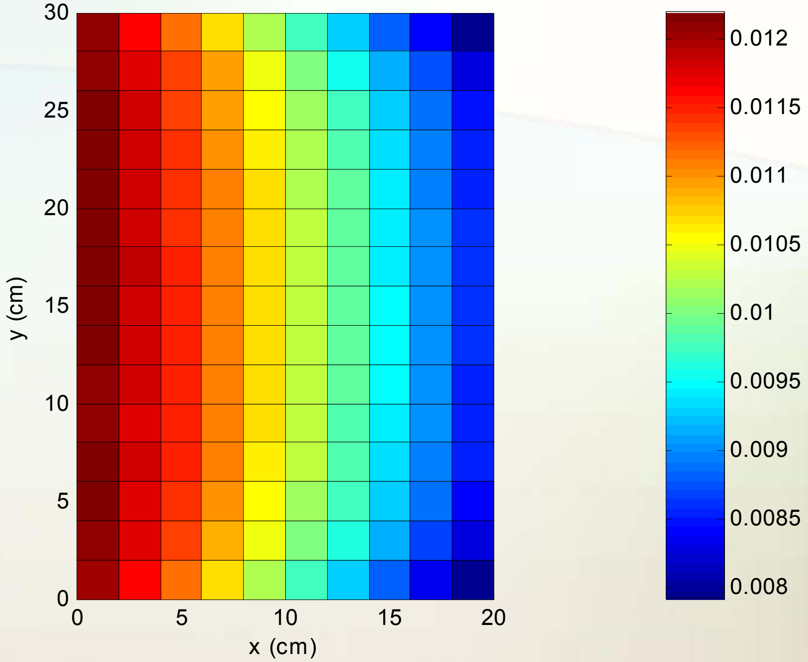
- 10X15 regions
- Mesh dimension: 2 cmX2 cm
- Homogeneous medium
- Incident photons impinges normally
- Initial energy: 4-5 Mev
- Secondary electrons are assumed to deposit energy locally in both EGS and Coarse Mesh calculations

Comparison

Relative error between EGS and Coarse Mesh (E3X2U2DP3) calculations



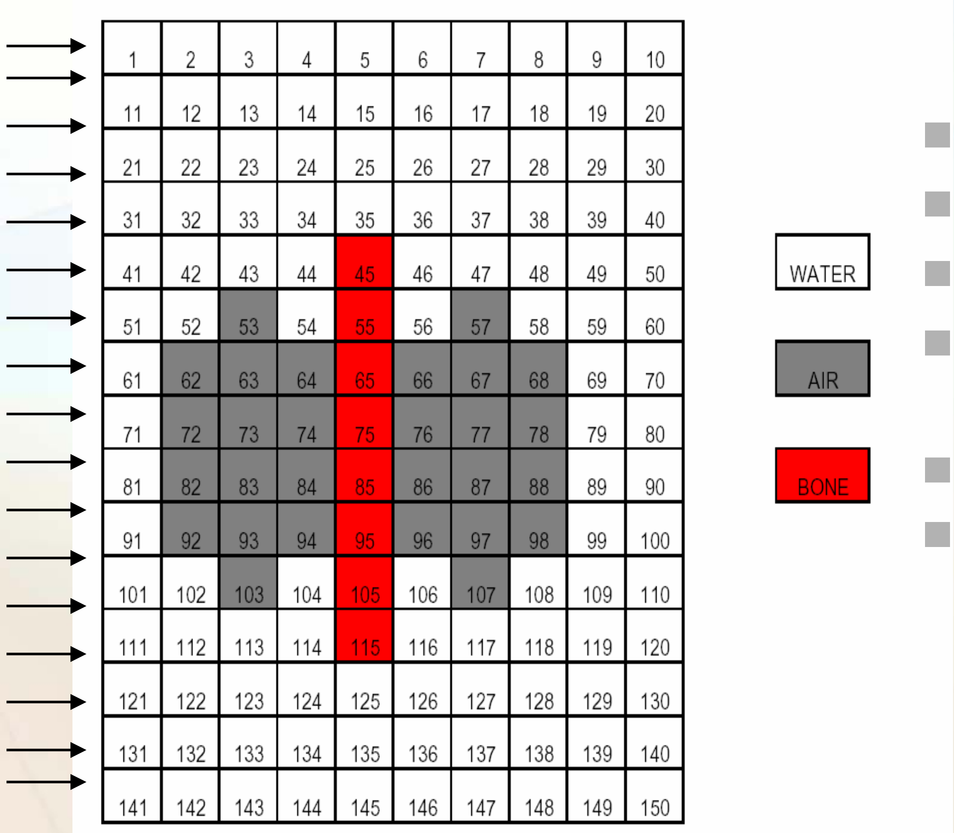
Distribution of energy deposition (Mev)



- EGS
  - 160 million particles
  - Uncertainty<0.3%
  - CPU time: 3700 sec

- Coarse Mesh (E3X2U2DP3)
  - Average RE=1%
  - Maximum RE=2%
  - CPU time: 122 sec

A Heterogeneous Problem – includes lung and bone



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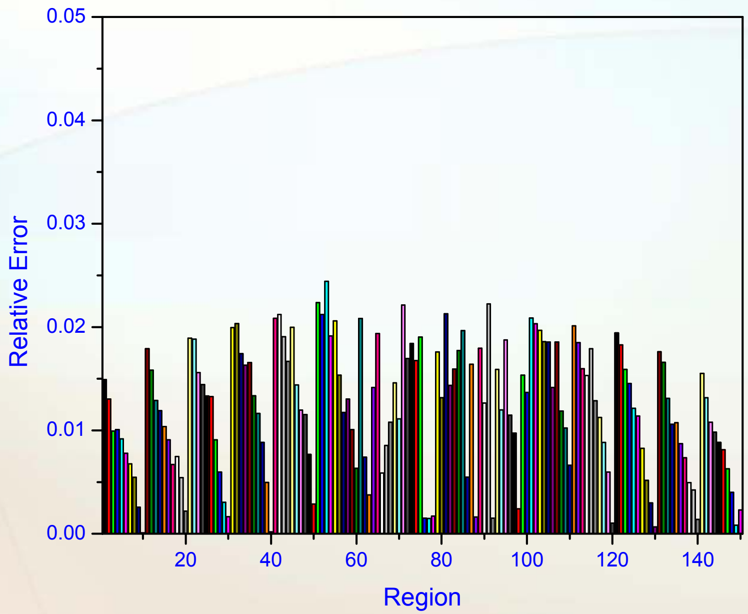
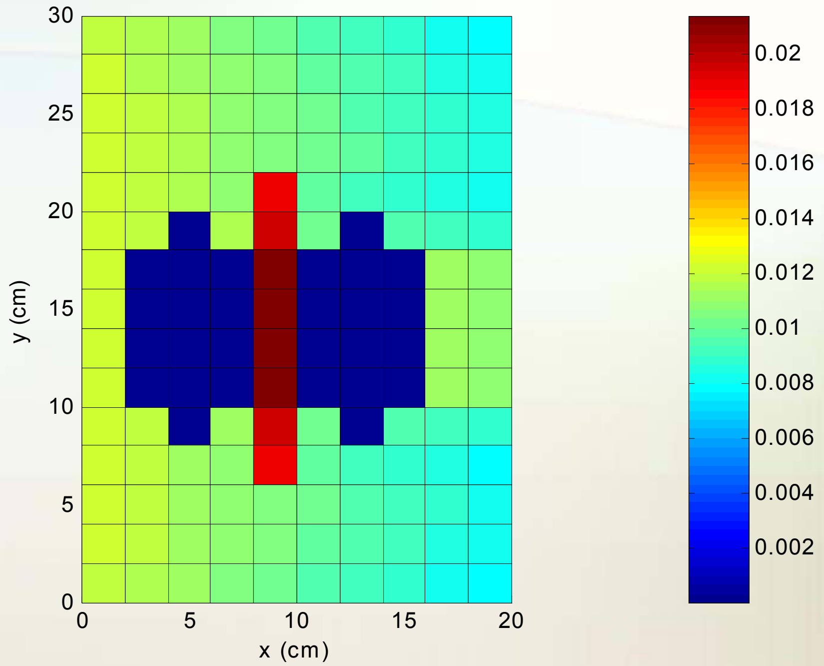


- EGS
  - 2.0 billion particles
  - Uncertainty<1.4%
  - CPU time: 47,800 sec

Distribution of energy deposition (Mev)



- Coarse Mesh (E3X2U2DP3)
  - Average RE=1.2%
  - Maximum RE=2.4%
  - CPU time: 122 sec

Computational Reactor and Medical Physics Group

Planned Experimental Benchmark Problems

Homogeneous Water Phantom

•Coarse-Mesh composed of only water

•Comparisons made to 3D experimental results calculating dose deposition in water phantom at Emory

Slab Benchmark

•Slabs composed of H2O, Al, and Lung

•Actual energy deposition will be determined by 3D experimental results obtained by using slab phantoms at Emory

CT Data

•A CT dataset of an anthropomorphic phantom will provide the data for the coarse-mesh calculations

•The results will be compared to the dose deposition found experimentally in the phantom

Conclusion and Future Work

- Conclusions
  - COMET provides very accurate results for photon transport in both homogeneous and heterogeneous media
  - Results are comparable to fine mesh
  - Substantially faster than fine mesh deterministic transport and Monte Carlo
- Future work
  - Create new numerical and experimental benchmark problems (2D and 3D)
  - Coupled photon, electron and neutron transport
  - Extension to 3D
  - Improved sweeping techniques

Questions?