SoftWare for the Optimization of Radiation Detectors (SWORD)

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Outline

• Introduction to SWORD
  – Motivation
  – User Interface
  – Standard Library
  – Analysis tools

• SWORD Extensions in Progress
  – MCNPX/6 Adapters
  – ADVANTG Adapters
  – Conversion of GIS data into SWORD
  – Radiography tools
  – Backtrace (GEANT4)

• SWORD in Operational Use

• Conclusions
SWORD Motivation

- Simulation allows evaluating and optimizing performance before devoting resources to creating an instrument
- Typically, simulation has been an exercise for the expert user
- SWORD attempts to bring the power of simulation to everyday users
SWORD Motivation

• What it looks like in GEANT4 ...

```cpp
G4VPhysicalVolume const* pCurrentVolume = pTrack->GetVolume();
G4String currentVolumeName = pCurrentVolume->GetName();
TVolumeId currentVolumeId = gVolumeRepository->getVolumeId( convertFromString< size_t >( currentVolumeName ) );

track.setVolumeName( currentVolumeId.getName() );

const G4StepPoint* g4PreStepPoint = stepData->GetPreStepPoint();
const G4ThreeVector g4PreStepPos = g4PreStepPoint->GetPosition();
TPoint preStepPoint( g4PreStepPos.getX() / cm, g4PreStepPos.getY() / cm, g4PreStepPos.getZ() / cm );
preStepPoint.setEnergy( g4PreStepPoint->GetKineticEnergy() / keV );
preStepPoint.setTime( g4PreStepPoint->GetGlobalTime() / s );
track.setPreStepPoint( preStepPoint );

const G4StepPoint* g4PostStepPoint = stepData->GetPostStepPoint();
const G4ThreeVector g4PostStepPos = g4PostStepPoint->GetPosition();
TPoint postStepPoint( g4PostStepPos.getX() / cm, g4PostStepPos.getY() / cm, g4PostStepPos.getZ() / cm );
postStepPoint.setEnergy( g4PostStepPoint->GetKineticEnergy() / keV );
postStepPoint.setTime( g4PostStepPoint->GetGlobalTime() / s );
track.setPostStepPoint( postStepPoint );

uint64_t eventNumber = runManager.GetCurrentEventNumber();
if( gDetectorRepository.isDetector( currentVolumeId ) ) {
    gEventRepository.saveEvent( eventNumber );
}

if( gEventRepository.loggingSupportedParticlesOnly() ) {
    if( gParticleNames.isSupported( particleName ) ) {
        if( gDetectorRepository.loggingDetectorHitsOnly() ) {
            if( gDetectorRepository.isDetector( currentVolumeId ) ) {
                gEventRepository.addTrack( eventNumber, track );
            } else {
                G4VPhysicalVolume const* pNextVolume = pTrack->GetNextVolume();
                if( pNextVolume != 0 ) {
                    G4String nextVolumeName = pNextVolume->GetName();
                    TVolumeId nextVolumeId = gVolumeRepository->getVolumeId( convertFromString< size_t >( nextVolumeName ) );
                    if( gDetectorRepository.isDetector( nextVolumeId ) ) {
                        gEventRepository.addTrack( eventNumber, track );
                    }
                }
            }
        }
    }
}
```
SWORD Motivation

• What it looks like in MCNPX/6 …
SWORD Motivation

- What it looks like to the new users …
SWORD Motivation

• What you’d really like is …
SWORD User Interface

- Graphically set up geometries, sources, detectors
  - Main and Orthogonal Views
  - Wireframe and Solid Rendering
  - Eight primitive shapes
- User can define new materials not included with SWORD
- Add motion to objects
Multiple MC Engines

SWORD

MCNPX

GEANT4
SWORD Standard Library

- Extensive standard library of objects for use in simulations
  - Detectors (neutron, gamma)
  - Vehicles (Land, Sea, Air)
  - Containers
  - Rail cars
  - Environmental Objects
  - Spectra
    - Threat objects
    - NORM backgrounds
    - Medical isotopes
- SWORD library is expandable
  - Objects can be imported into various projects
  - Spectra from sources or backgrounds of interest can be added
SWORD Standard Library
Commercial Detectors

• Several COTS detectors
  – 3”, 6”, 4x2x16, 4x4x16 NaI
  – HPGe PopTop
  – identiFinder
  – GR-135+
  – RadPack
  – Plastic Scintillator
  – 2” CLYC
SWORD Standard Library

Specialized Detectors

- MISTI
- SuperMISTI
- MARS
SWORD Standard Library
Land Vehicles

- Tour Bus
- Tractor Trailer
- Pickup Truck
- Compact Car
- Minivan
SWORD Standard Library

Ships

- Chalmers, Titus, Avatar
- Atlas, Diane-G, Stiletto, Yacht
- Guardian, Pacific Venture, RHIB
SWORD Standard Library
Helicopters

- Firescout UAV
- Eurocopter AS350 Ecureuil
- Blackhawk UH-60
- Bell 412
SWORD Standard Library
Aircraft

- Bell Boeing V-22 Osprey
- NASA ER-2
- Cessna Skycatcher
• Locomotive
• Box Car
• Well Car
• Gondola
• Tanker
SWORD Standard Library

Neighborhood

- Created entire neighborhoods
  - Townhouses
  - Strip Mall
  - Stand alone homes
Library of Background Sources

- Background simulation crucial for simulating instrument performance
- SWORD provides background spectra including
  - Concrete
  - Fresh water
  - Salt water
  - Common cargo found in shipping containers:
    - Fertilizer, limestone, cat litter, brazil nuts
- Developed mechanism for rapid deconvolution of new concrete spectrum given a measured spectrum

Figure: Simulated spectrum (magenta) vs. detected spectrum using HPGe (blue)
SWORD Analysis

- Spectrum produced in ANSI 42.42 format
- Spectra displayed with and without detector response
SWORD Analysis

- SpectrumAnalyzer
  - Analyzes spectra from SWORD (or data in .spe or N42.42 format)
  - Line fitting using MPFIT
  - Isotopic line identification
SWORD Analysis

- Images produced in NASA FITS format
- Limited imaging performance analysis
- Can also use standard FITS tools such as SAOImage/DS9 or FV
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MCNPX/6 Adapters

- Improve integration with MCNPX/6
  - Tallies applied to surfaces (F1, F2) or volumes (F4, F6, F8) for any defined detector
  - Tree-view displays user-defined tallies
  - Energy, Time, Cosine ranges and particle type may be defined
- Results viewable using SWORD analysis tools
- Working on mesh tallies, auto-funneling of tallies and “physics wizard”
ADVANTG

- **AutomateD VAriaNce reducTion Generator (ADVANTG)**
  - Developed at ORNL
  - Automatically generated weight-window map for use in MCNP

- Uses ORNL deterministic code (Denovo) to generate weight-windows
  - Can also be used as front end to simulate scenarios deterministically
Simulating Cities

- NRL has developed capabilities to ingest the GIS database of entire cities for use in simulation
  - Building, Elevation, Water, and Trees
Railroad Radiography

- Simulate radiography with SWORD
- Uses built-in moving objects capability
- Extensive CPU resources may required

Simulated radiographic image
Backtrace

- Backtrace shows the tracks where an interaction occurred in a defined detector
  - Includes energy, particle species, and time information
  - Currently only works with GEANT4
- Example with neutron source
  - 1e6 neutrons fired isotropically from a point source
  - Detector array in a container, on a truck
  - Top Right: cyan tracks show the neutrons that interacted in the detector
  - Bottom Right: green tracks show secondary photons that interact in the detector
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Detection in Urban Environment

- Seattle buildings created with GIS data
- Source placed in one of the buildings
Detection on Sea Simulation

• Vessel with large area detector
  – 100%-efficient HPGe detectors
  – 6” NaI detectors
  – Moving at 6 knots

• Yacht with source
  – Shielded SNM
  – Moving at 5 knot
Conclusions

• NRL developed SWORD to bring the power of simulation to the non-expert user
• Ease of use along with standard library allows for efficient setup and simulation
• Continually developing SWORD
  – Adding new functionality (suggestions welcome)
  – Improving interface to MC engines
  – Adding interfaces to new engines
• Developing user base (~100 users)

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