A New Version of the ADVANTG Variance Reduction Generator

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INTRODUCTION

The ADVANTG (AutomateD VAriaNce reducTion Generator) code was developed to generate variance reduction parameters for Monte Carlo simulations of shielding and radiation detection problems. In its original form [1], ADVANTG (1) was developed for application to classic source-detector problems, (2) drove the TORT 3-D discrete ordinates code to generate estimates of importance (adjoint) functions, and (3) existed as a modification of MCNP4C3 (an earlier version of Reference 2). In recent work, the code has been completely reorganized and significant new features have been added. This summary highlights the capabilities of a new version of ADVANTG (version 2.0) and describes recent applications of the code.

DESCRIPTION OF THE ACTUAL WORK

The ADVANTG code base now consists of two separate packages. The first is MCNP-DXM, which is a modification of MCNP5-1.40 [2] that maps materials defined within the combinatorial geometry cells of an MCNP model onto a rectangular mesh and outputs lists of material composition information (i.e., nuclide identifiers and number densities). MCNP-DXM can handle any valid MCNP geometry (i.e., including those with repeated structures, transformations, etc.). The implementation is efficient, both in terms of memory consumption and computational speed. The code has been applied to generate maps on the order of 10^8 cells on a single processor within several hours of run time. (The exact speed depends on the complexity of the MCNP model.)

The bulk of the ADVANTG code base is now implemented as a package in the Python scripting language (www.python.org). Input to ADVANTG is accomplished through a user-generated script or from an interactive console. The scripts need not be more complicated than the typical sort of input file. The main benefit is that a great deal of flexibility is obtained at a relatively low cost (for both the developer and the user). For example, users can drive component codes individually, directly access data (e.g., fluxes), and insert new functions into the computational sequence. Other possibilities exist.

The original version of ADVANTG implemented the Consistent Adjoint Driven Importance Sampling (CADIS) method [3] for source-detector problems. ADVANTG 2.0 also implements the Forward-Weighted CADIS (FW-CADIS) method [4] for accelerating the estimation of global and semi-global mesh tallies. In the former, weight-window targets are computed inversely proportional to a deterministically generated importance function. In the latter, a forward deterministic calculation is initially performed to generate an adjoint source (inversely proportional to the forward flux) that is input into the CADIS formalism.

ADVANTG now uses the Denovo 3-D parallel discrete ordinates code [5] to generate estimates of forward and adjoint transport solutions. Denovo offers substantial improvements over TORT with respect to efficiency and robustness. Of particular benefit for weight-window generation are its embedded first-collision source capability and its implementation of Krylov-subspace acceleration, the step characteristics differencing scheme, and the Cesaro transport correction. In addition, Denovo can perform transport sweeps on multiple processors in parallel using the Koch-Baker-Alcouffe algorithm (though only serial Denovo calculations are currently automated within ADVANTG).

RESULTS

Within the past year, the new version of ADVANTG has been applied to three significant problems: portal monitoring, prompt-dose estimation in an urban environment, and ITER (International Thermonuclear Experimental Reactor) shielding analysis. In what follows, the applications and results are briefly described.

ADVANTG has been used to predict the response of neutron and gamma detectors within a portal monitor for screening truck cargos at fixed installations [6]. The geometry of the problem is illustrated in Fig. 1, which presents a view with the back half of the panel removed to expose the ^{3}He tubes and NaI crystals. Behind the panel is a cargo container holding large blocks of polyethylene (at 0.5 or 1.0 g/cm^3) and homogenized iron (at 1.0 g/cm^3).

The CADIS method in ADVANTG was used to generate variance reduction parameters (weight-window bounds and a biased source distribution) for simulations to estimate the (*n*, *p*) capture resulting from a localized ^{252}Cf source at the center of one of the polyethylene blocks and the scalar flux (F4 tally) and pulse-height spectra (F8 tally) over 383 bins of 1-keV width within the NaI crystals resulting from a localized ^{133}Ba source at the center of the container. The ADVANTG-generated variance reduction parameters increased the figures-of-merit (FOMs) by factors of 11,000, 250, and 40 (including the Denovo run time) for the neutron problem and the F4 and F8 gamma tallies, respectively.

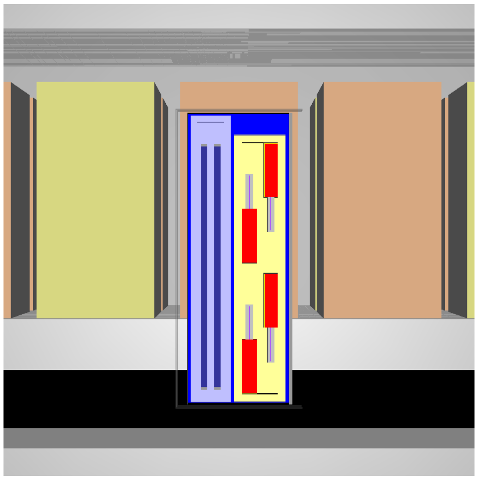

Fig. 1. Portal monitoring model.

The FW-CADIS method in ADVANTG was used to estimate the neutron dose rate distribution in the 2 m of air above ground in a 1.2 × 0.86 km area around Times Square (model shown in Fig. 2) resulting from a nuclear device (idealized as a point source). Results obtained with and without ADVANTG-generated variance reduction parameters in 24-h MCNP simulations were compared. When ADVANTG was used, the fraction of mesh tally cells with relative uncertainties less than 20% was increased from 25 to 77%.

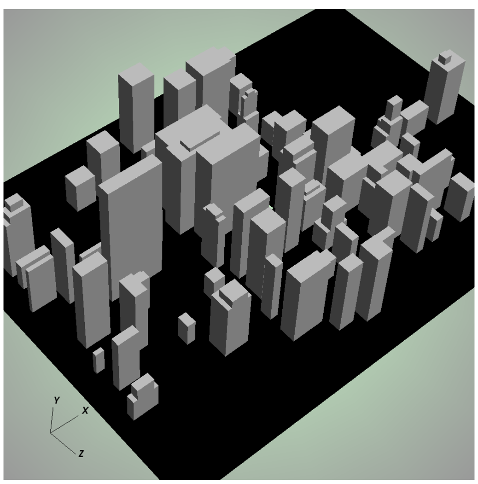

Fig. 2. Times Square model.

The CADIS and FW-CADIS methods in ADVANTG were applied to the shielding analysis of ITER (shown in Fig. 3) [7]. Calculations were performed to estimate (1) the total dose rate at a point outside of the biological shield (CADIS) and (2) the neutron and gamma scalar flux distribution within the entire model (FW-CADIS). In the first calculation, the ADVANTG variance reduction parameters were found to increase the FOM by a factor of about 400. In the second, the fraction of mesh tally cells with a relative uncertainty less than 25% was increased from about 10 to 70% (for neutron fluxes) and 10 to 40% (for gamma fluxes). Additional details can be found in Reference 7.

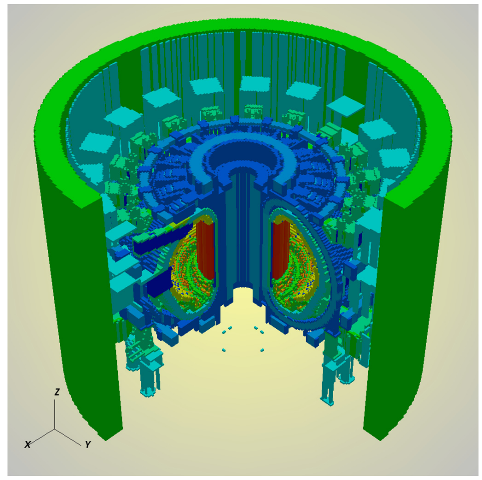

Fig. 3. ITER model.

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