Geant 4

User Application

http://cern.ch/geant4

The full set of lecture notes of this Geant4 Course is available at
http://www.ge.infn.it/geant4/events/nss2004/geant4course.html

How to use Geant4

- User Requirements
- Design of a Geant4 application
- Implementation

Focus on :

- User initialisation classes
- User action classes

Useful links:

http://cern.ch/geant4/

http://www.ge.infn.it/geant4/

Capture User Requirements

Define the scope of the software system to be built ("what it should do")

The application developer must study:

- Experimental set-up
- Functionality needed
- Physics involved

1. General

UR 1.1 Configure the **Run**
UR 1.2 Configure the **Event** Loop

2. Description of the experimental set-up

UR 2.1 Describe a **geometrical set-up**: a Si-W tracker, a CsI calorimeter and an anti-coincidence system made out of plastic scintillators.
UR 2.2 Record **the coordinates of impact** of tracks in the layers of the tracker. Record the energy release in the strips of the tracker.
UR 2.3 Record the **energy deposited** in each element of the **calorimeter** at every event.
UR 2.4 Record the **energy deposited** in each element of the **anticoincidence** at every event.
UR 2.5 **Digitise** the hits, setting a threshold for the energy deposit in the tracker.
UR 2.6 Generate a **trigger** signal combining signals from different detectors.

3. Physics

UR 3.1 Generate **primary events** according to various distributions relevant to gamma astrophysics
UR 3.2 Activate **electromagnetic** processes appropriate to the energy range of the experiment.
UR 3.3 Activate **hadronic** processes appropriate to the energy range of the experiment.

4. Analysis

UR 4.1 Plot the **x-y distribution** of impact of the track.
UR 4.2 Plot **histograms** during the simulation execution.
UR 4.3 Store significant quantities in a **ntuple** (energy release in the strips, hit strips) for further analysis.
UR 4.4 Plot the **energy distribution** in the calorimeter.

5. Visualisation

UR 5.1 Visualise the experimental **set-up**.
UR 5.2 Visualise **tracks** in the experimental set-up.
UR 5.3 Visualise **hits** in the experimental set-up.

6. User Interface

UR 6.1 **Configure the tracker**, by modifying the number of active planes, the pitch of the strips, the area of silicon tiles, the material of the converter
UR 6.2 **Configure the calorimeter**, by modifying the number of active elements, the number of layers.
UR 6.3 **Configure the source**.
UR 6.4 **Configure digitisation** by modifying threshold
UR 6.5 **Configure the histograms**

7. Persistency

UR 7.1 Produce an intermediate **output** of the simulation at the level of hits in the tracker.
UR 7.2 **Store** significant results in FITS format.
UR 7.3 **Read in** an intermediate output for further elaboration.

User Requirements

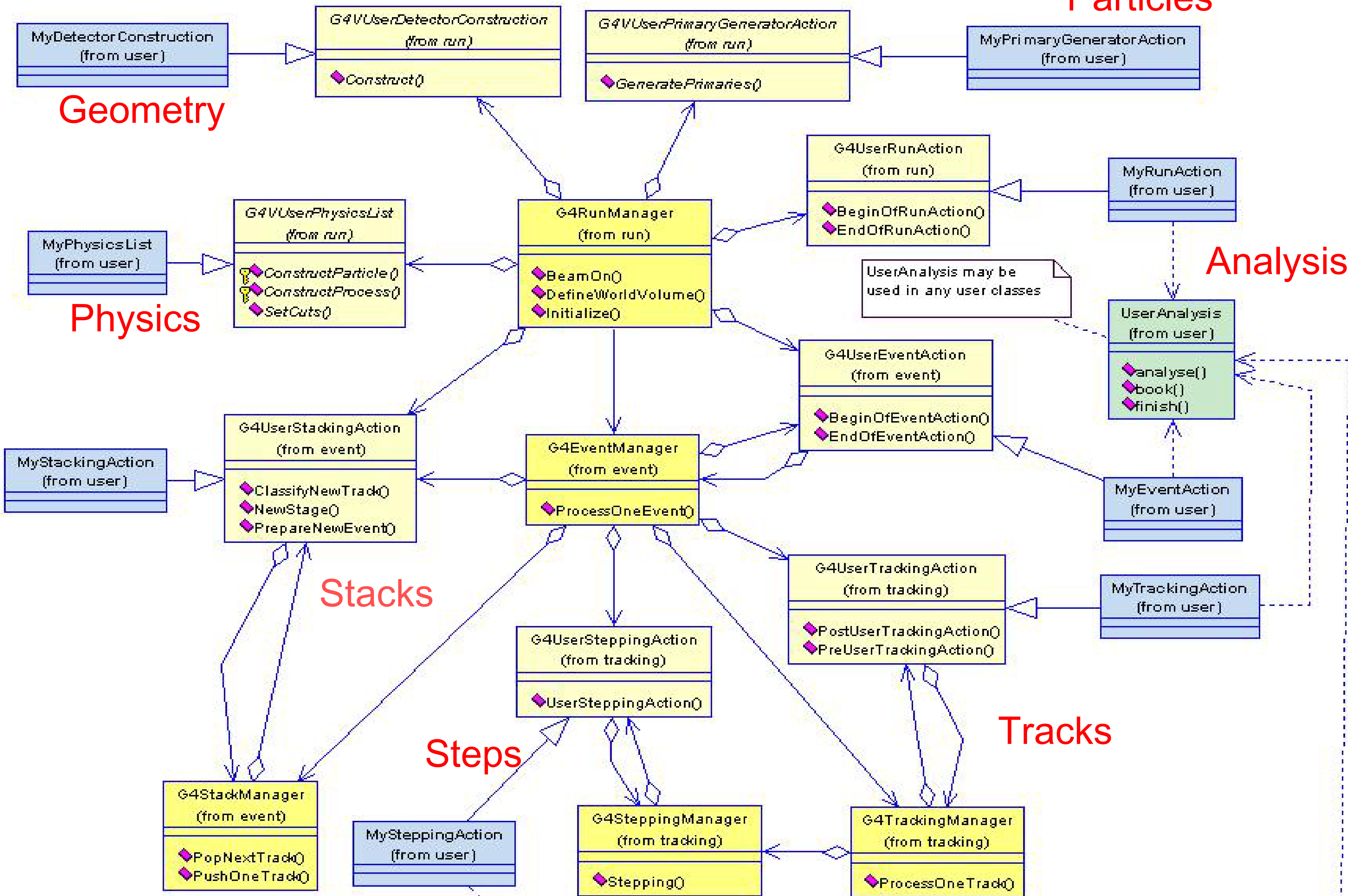
Identify a candidate architecture

How the components (geometry, physics, detector, etc.) collaborate in order to satisfy the User Requirements

Documentation:

- G. Booch, OO analysis and design with applications, Addison-Wesley, 1994
- R. Martin, Designing OO C++ applications using the Booch method, Prentice Hall, 1994
- E. Gamma et al., Design Patterns, Addison-Wesley, 1995

Overview of Geant4 advanced examples



User classes

Initialisation classes

- *G4VUserDetectorConstruction*
- *G4VUserPhysicsList*

Action classes

- *G4VUserPrimaryGeneratorAction*
- G4UserRunAction
- G4UserEventAction
- G4UserTrackingAction
- G4UserStackingAction
- G4UserSteppingAction

Mandatory classes:

- *G4VUserDetectorConstruction* describe the experimental set-up
- *G4VUserPhysicsList* select the physics you want to activate
- *G4VUserPrimaryGeneratorAction* generate primary events

The main program

- Geant4 does not provide the main()

- In his/her main(), the user must
  - construct G4RunManager (or his/her own derived class)
  - notify the mandatory user classes to G4RunManager
    - *G4VUserDetectorConstruction*
    - *G4VUserPhysicsList*
    - *G4VUserPrimaryGeneratorAction*

- The user can define
  - VisManager, (G)UI session, optional user action classes
- in his/her main()

The main program

```
{…
  // Construct the default run manager
  G4RunManager* runManager = new G4RunManager;

  // Set mandatory user initialization classes
  MyDetectorConstruction* detector= new MyDetectorConstruction;
  runManager->SetUserInitialization(detector);
  runManager->SetUserInitialization(new MyPhysicsList);

  // Set mandatory user action classes
  runManager->SetUserAction(new MyPrimaryGeneratorAction );

  // Set optional user action classes
  MyEventAction* eventAction = new MyEventAction();
   runManager->SetUserAction(eventAction);
  MyRunAction* runAction = new MyRunAction();
   runManager->SetUserAction(runAction);
…}
```

Describe the experimental set-up

- Derive your own concrete class from the G4VUserDetectorConstruction abstract base class

- Implement the Construct() method

  - construct all necessary materials
  - define shapes/solids required to describe the geometry
  - construct and place volumes of your detector geometry
  - define sensitive detectors and identify detector volumes to associate them to
  - associate magnetic field to detector regions
  - define visualisation attributes for the detector elements

How to define materials 1

Different kinds of materials can be defined

- Isotopes
- Elements
- Molecule
- compounds and mixtures isotopes

Lead / Xenon gas

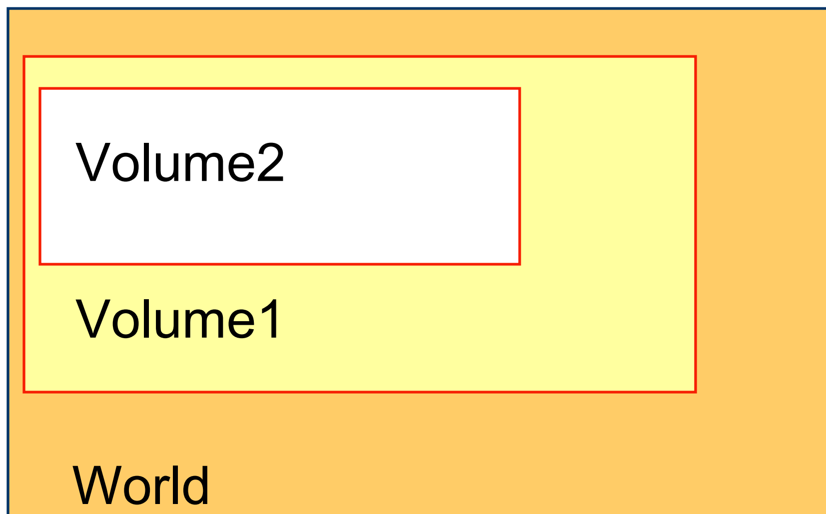
```
PVPhysicalVolume*  MyDetectorConstruction::Construct()
{…
  a = 207.19*g/mole;
  density = 11.35*g/cm3;
  G4Material* Pb = new G4Material(name="Pb", z=82., a, density);
  density     = 5.458*mg/cm3;
  pressure    = 1*atmosphere;
  temperature = 293.15*kelvin;
  G4Material* Xenon = new G4Material(name="XenonGas", z=54.,
    a=131.29*g/mole,   density, kStateGas , temperature ,pressure);
……. }
```

How to define materials 2

```
G4double a = 1.01*g/mole;
G4Element* H  = new G4Element(name="Hydrogen",symbol="H" , z= 1., a);

a = 12.01*g/mole;
G4Element* C  = new G4Element(name="Carbon"  ,symbol="C" , z= 6., a);

G4double density = 1.032*g/cm3;
G4Material* Sci = new G4Material(name = "Scintillator", density,
ncomponents = 2);

Sci -> AddElement(C, natoms = 9);
Sci -> AddElement(H, natoms = 10);
```

Define detector geometry

- Three conceptual layers
  - G4VSolid -- shape, size
  - G4LogicalVolume -- material, sensitivity, magnetic field, etc.
  - G4VPhysicalVolume -- position, rotation
- A unique physical volume (the world volume), which represents the experimental area, must exist and fully contain all other components



Mother volume: containing volume

Ex: Volume1 is mother of Volume 2

The mother must contain entirely the daughter volume

How to build the World …

```
solidWorld=newG4Box("world",HalfWorldLength,HalfWorldLength,HalfWorldLength);
logicWorld=new G4LogicalVolume( solidWorld, Air, "World", 0, 0, 0);
physiWorld= new G4PVPlacement (0,  //no rotation
                              G4ThreeVector(), // at (0,0,0)
                              logicWorld,      // its logical volume
                              "World",         // its name
                              0,               // its mother  volume
                              false,           // no boolean operations
                              0);              // no magnetic field
```

How to build a volume inside the World …

```
solidTarget = new G4Box("target",targetSize,targetSize,targetSize);
logicTarget = newG4LogicalVolume(solidTarget,TargetMater,"Target",0,0,0);
physiTarget = new G4PVPlacement(0,              // no rotation
                               positionTarget,  // at (x,y,z)
                               logicTarget,     // its logical volume
                               "Target",        // its name
                               logicWorld,      // its mother  volume
                               false,           // no boolean operations
                               0);              // no particular field
```

Select physics processes

- Geant4 does not have any default particles or processes

- Derive your own concrete class from the G4VUserPhysicsList abstract base class
  - define all necessary particles
  - define all necessary processes and assign them to proper particles
  - define production thresholds (in terms of range)

- Pure virtual methods

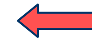
to be implemented by the user in his/her concrete derived class

Physics List 1

```
MyPhysicsList :: MyPhysicsList():  G4VUserPhysicsList()
{
    defaultCutValue = 1.0*cm;
```

define production thresholds
(the same for all particles)

```
}
MyPhysicsList:: ~MyPhysicsList(){}
        void MyPhysicsList :: ConstructParticles()
        {
            G4Electron::ElectronDefinition();
            G4Positron::PositronDefinition();
            G4Gamma::GammaDefinition();
        }
```



define particles involved

```
void MyPhysicsList :: SetCuts()
{
  SetCutsWithDefault();
}
```

Set the cut

Physics List 2

```
MyPhysicsList :: MyPhysicsList():  G4VUserPhysicsList()
{
    cutForGamma = 1.0*cm;          define production thresholds
    cutForElectron = 1. *mm;
    cutForPositron = 0.1*mm;
} ;

void MyPhysicsList :: SetCuts()
{
   SetCutValue(cutForGamma, "gamma");
   SetCutValue(cutForElectron, "e-");
   SetCutValue(cutForPositron, "e+");
}
```

the user can define different cuts!

Physics List 3

```
void MyPhysicsList :: ConstructParticles()
{

if (particleName == "gamma") {
    pManager->AddDiscreteProcess(new G4PhotoElectricEffect());
    pManager->AddDiscreteProcess(new G4ComptonScattering());
    pManager->AddDiscreteProcess(new G4GammaConversion());

  } else if (particleName == "e-") {
    pManager->AddProcess(new G4MultipleScattering(), -1, 1,1);
    pManager->AddProcess(new G4eIonisation(), -1, 2,2);
    pManager->AddProcess(new G4eBremsstrahlung(), -1,-1,3);

  } else if (particleName == "e+") {
    pManager->AddProcess(new G4MultipleScattering(), -1, 1,1);
    pManager->AddProcess(new G4eIonisation(), -1, 2,2);
    pManager->AddProcess(new G4eBremsstrahlung(), -1,-1,3);
    pManager->AddProcess(new G4eplusAnnihilation(),  0,-1,4);
    }
}
```

select physics processes to be activated for each particle type

Primary events

- *Derive your own concrete class from the G4VUserPrimaryGenerator Action abstract base*

- *Define primary particles in terms of:*
  - Particle type
  - Initial position
  - Initial direction
  - Initial energy

- *Pure virtual methods:*
  GeneratePrimaries()

Generate primary events

```
MyPrimaryGeneratorAction :: My PrimaryGeneratorAction()
{
  G4int n_particle = 1;
  particleGun = new G4ParticleGun (n_particle);
  G4ParticleTable* particleTable = G4ParticleTable::GetParticleTable();
  G4ParticleDefinition* particle = particleTable->FindParticle("e-");
  particleGun->SetParticleDefinition(particle);
  particleGun->SetParticlePosition(G4ThreeVector(x,y,z));
  particleGun->SetParticleMomentumDirection(G4ThreeVector(x,y,z));
  particleGun->SetParticleEnergy(energy);
}
MyPrimaryGeneratorAction :: ~MyPrimaryGeneratorAction()  {}
void MyPrimaryGeneratorAction::GeneratePrimaries(G4Event* anEvent)
{  particleGun->GeneratePrimaryVertex(anEvent); }
```

Optional user action classes

- *Five virtual classes whose methods the user may override in order to gain control of the simulation at various stages*

- *Each method of each action class has an empty default implementation, allowing the user to inherit and implement desired classes and methods*

- *Objects of user action classes must be registered with G4RunManager*

Optional user action classes

G4UserRunAction

- BeginOfRunAction(const G4Run*)
  - example: book histograms
- EndOfRunAction(const G4Run*)
  - example: store histograms

G4UserEventAction

- BeginOfEventAction(const G4Event*)
  - example: event selection
- EndOfEventAction(const G4Event*)
  - example: analyse the event

G4UserTrackingAction

- PreUserTrackingAction(const G4Track*)
  - example: decide whether a trajectory should be stored or not
- PostUserTrackingAction(const G4Track*)

G4UserSteppingAction

- UserSteppingAction(const G4Step*)
  - example: kill, suspend, postpone the track

G4UserStackingAction

- PrepareNewEvent()
  - reset priority control
- ClassifyNewTrack(const G4Track*)
  - Invoked every time a new track is pushed
  - Classify a new track *(priority control)*

    Urgent, Waiting, PostponeToNextEvent, Kill
- NewStage()
  - invoked when the Urgent stack becomes empty
  - change the classification criteria
  - event filtering *(event abortion)*

Summary

- User classes
- Mandatory classes
- Optional action classes
- How to initialise the classes (mandatory and optional) in the main