Introduction to ROOT

Asif Saddique

National Centre for Physics (NCP), Islamabad, Pakistan

ROOT Tree, A useful Tool for Data Analysis
Tutorial # 3

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Why Tree ?

Defining a tree in useful because:

- you can store complex types of data, i.e. objects can be stored in a tree.
- ROOT tree is extremely efficient write once, read many times.
- All the variable stay connected for all the entries. You can easily change selection criteria in a small macro.
- Trees allow fast direct and random access to any entry.
  - Trees have column-wise access. They can directly access to any event, any branch or any leaf even in the case of variable length structures.
  - Makes same members consecutive, e.g. for object with position in X, Y, Z, and energy E, all X are consecutive, then come Y, then Z, then E. A lot higher zip efficiency!
- Trees are Optimized for network access, and they are buffered to disk.

ROOT Tree

A tree (TTree) contains branches (TBranch) and leaves (TLeaf).

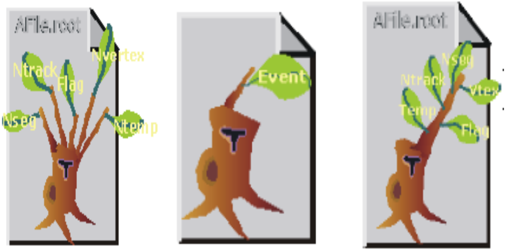
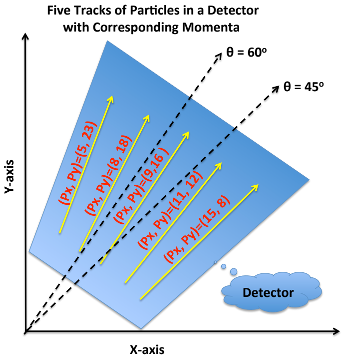


Figure : Examples of split, non-split trees and tree with a branch containing several leafs (leaves).

Wait !!! Before Tree, Get Concept of Cuts/Filters

In data analysis many variables are linked/dependent to/on each other.



Cuts/Filters	#Tracks
No Cut	5
$\theta < 60^o$	3
$P_x < 10$	3
$P_y > 10$	4
$\theta > 45^o$	3
$45^o < \theta < 60^o$	1
$\theta < 60^o$ && $P_x > 10$	2
$P_x < 9$ && $P_y > 16$	2
$P_x \leq 9$ && $P_y > 16$	2
$P_x \leq 9$ && $P_y \geq 16$	3
$P_x \leq 9$ && $P_y \geq 16$ && $\theta > 60^o$	2

Your supervisor gives you a task in the morning, and you store P_x in one hitso, and P_y in second hitso (after 5hr code running), for $\theta < 60^o$. In evening he says, no no its wrong, you need P_x and P_y histograms, for $\theta < 45^o$. WHAT!!!! I need another 5 hr to run the code again ....

BUT DON'T WORRY STAY TUNED

Writing a Tree

- A tree is defined as:

```
TTree *mytree = new TTree("ntuples","an example Tree");
```

- A branches in this tree can be defined as:

```
mytree→Branch("px",&px,"px/F");
```

Here, the branch variable "px" (a leaf) must be defined before setting up branch.

- Fill the tree in event loop.

```
for (Int_t evt=0; evt<1000; evt++) {
px = gRandom→Gaus(0,2);
mytree→Fill();
}
```

- After the event loop, any leaf histogram can drawn with any cut.

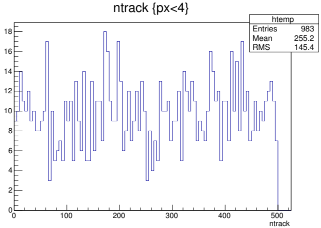
```
mytree→Draw("px","px>2");
```

But here binning is automatic, we look into this matter later.

Writing a Tree

Let's write several branches in a tree and put it into a root file.

```
void ATree_with_ThreeBranches()
{ // ***The code starts****
const Int_t kMaxTrack = 500;
// Defining branch variables
Int_t ntrack; Float_t px, py;
// Creating a root file to put the tree in
TFile file("mybranches.root","recreate");
// Creating a tree
TTree *mytree = new TTree("ntuples","an example Tree");
// Creating branches in the tree
mytree→Branch("ntrack",&ntrack,"ntrack/I");
mytree→Branch("px",&px,"px/F");
mytree→Branch("py",&py,"py/F");
for (Int_t evt=0; evt<1000; evt++)
{ // ***Event loop starts***
Int_t nt = gRandom→Rndm()*(kMaxTrack-1);
px = gRandom→Gaus(0,2);
py = gRandom→Gaus(1,2);
ntrack = nt;
mytree→Fill();
} // ***Event loop ends***
mytree→Draw("ntrack","px<4");
} // ***The code ends****
```



The above code defines a tree with three branches, and writes them into "**mybranches.root**", and draws the leaf histogram for "track" for "px<4" (so we started getting rewards !!!)

Writing a Tree (along with an ascii file)

```
void ATree_with_ThreeBranches()
{ // ***The code starts****
const Int_t kMaxTrack = 500;
// Defining branch variables
Int_t ntrack; Float_t px, py;
// Defining/opening an ascii file
ofstream outFile;
outFile.open(“myAscii.dat”);
// Creating a root file to put the tree in
TFile file(“mybranches.root”,“recreate”);
// Creating a tree
TTree *mytree = new TTree(”ntuples”,”an example Tree”);
// Creating branches in the tree
mytree→Branch(“ntrack”,&ntrack,“ntrack/I”);
mytree→Branch(“px”,&px,“px/F”);
mytree→Branch(“py”,&py,“py/F”);
for (Int_t evt=0; evt<1000; evt++)
{ // ***Event loop starts***
Int_t nt = gRandom→Rndm()*(kMaxTrack-1);
px = gRandom→Gaus(0,2);
py = gRandom→Gaus(1,2);
ntrack = nt;
mytree→Fill();
outFile≪ntrack≪“ ”≪px≪“ ”≪py≪endl;
} // ***Event loop ends***
outFile.close();
mytree→Draw(“ntrack”,“px<4”);
} // ***The code ends****
```

- Blue lines are added in the previous code to make an ascii file.
- The code generates “myAscii.dat” file, which contains three columns.

```
Asifs-MacBook-Pro:TreeExample asifsaddique$ more myAscii.dat
498 -0.869529 2.56359
115 -6.2526 -0.801752
369 0.0158244 0.178474
157 0.3833 -0.970132
```

- What a tree has to do with an ascii file ?? see later !!!
- Let’s worry about “**mybranches.root**” for now.

Browsing a Tree

We can check the created tree by TBrowser.

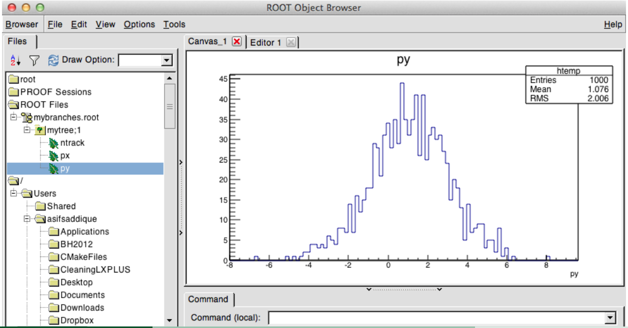
- First connect the root file to prompt:

```
$ root mybranches.root
```

  Alternatively, you can also load the root file in prompt.

- Then open TBrowser:

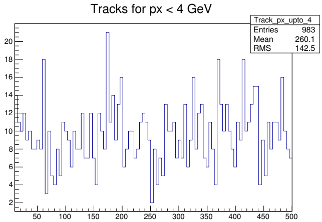
```
root[ ] new TBrowser
```



Reading a Tree and making Histograms

```
void ReadTreeMakeHisto() {
// Reading the root file
TFile *file = new TFile(“/PathToRootFile/mybranches.root”, “READ”);
// Go into the file
file→cd();
// Calling branches, and define bins you want
// Putting cuts/set-of-cuts on branches
mytree→Draw(“ntrack≫Track_px_upto_4(100,10,500)”,“px<4”);
mytree→Draw(“ntrack≫Track_py_upto_3(100,10,500)”,“py<3”);
mytree→Draw(“ntrack≫Track_px4_py3(100,10,500)”,”px<4 && py<3”);
// Defining Histograms and connecting them with tree branches
TH1F *Track_4x = (TH1F*)gDirectory → Get(“Track_px_upto_4”);
TH1F *Track_3y = (TH1F*)gDirectory → Get(“Track_py_upto_3”);
TH1F *Track_xy = (TH1F*)gDirectory → Get(“Track_px4_py3”);
// Drawing an example Histogram
Track_4x → Draw();
// Creating a root file to put histos obtained from tree
TFile hfile(”myHistofromTree.root”,”recreate”);
// Making a directory inside root file
hfile.mkdir(”Histo”);
// Going inside directory
hfile.cd(”Histo”);
// Writing histos inside directory
Track_4x → Write();
Track_3y → Write();
Track_xy → Write();
}
```

- The code generates “myHistofromTree.root” file, and also draws an example plot:

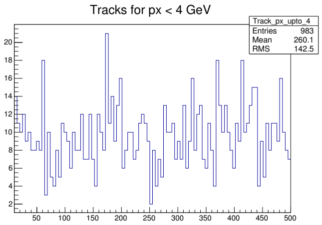


Please note statistics from the stat box.

A Tree can easily read an Ascii file

```
void Tree_Reading_Ascii()
{
// Defining root file to store tree
TFile *f = new TFile("basic.root","RECREATE");
// Defining tree to store data from ascii
TTree *T = new TTree("ntuples","data from ascii file");
// Extracting data from ascii to tree
Long64_t nlines = T→ReadFile("myAscii.dat","tracks:px:py");
// Printing total # of lines
printf(" found %lld points /n",nlines);
// Plot a column (tracks) by putting condition on the other (px).
// Also binning is re-defined for the tracks.
T → Draw("tracks≫Track_px_upto_4(100,10,500)","px<4");
// Putting Tree in root file
T → Write();
// Define Histogram taking input from tree and draw
TH1F *h1 = (TH1F*)gDirectory → Get("Track_px_upto_4");
h1→SetTitle("Tracks for px < 4 GeV");
h1→Draw();
}
```

- The code generates "basic.root" file with a tree "ntuples" containing three branches, "tracks","px" and "py". It also produces following plot:



The plot obtained from Ascii file through tree is obtained by using the same binning and selection criteria as used for the plot on previous slide. The stat box shows the same results. Hence a tree can efficiently read an ascii file.

Printing a Tree

- First load the root file in prompt:

  root[ ] TFile *file=new TFile("mybranches.root");

- Check if tree is there in the file:

  root[ ] file → ls()

- To print information from a tree:

  root[ ] mytree → Print()

  It will print the tree structure (sizes, branches, entries etc.) as following:

```
******************************************************************************
*Tree    :mytree    : an example Tree                                        *
*Entries :     1000 : Total =           13988 bytes  File  Size =      10207 *
*        :          : Tree compression factor =   1.26                       *
******************************************************************************
*Br    0 :ntrack    : ntrack/I                                               *
*Entries :     1000 : Total  Size=       4553 bytes  File Size  =       2012 *
*Baskets :        1 : Basket Size=      32000 bytes  Compression=   2.03     *
*............................................................................*
*Br    1 :px        : px/F                                                   *
*Entries :     1000 : Total  Size=       4533 bytes  File Size  =       3838 *
*Baskets :        1 : Basket Size=      32000 bytes  Compression=   1.06     *
*............................................................................*
*Br    2 :py        : py/F                                                   *
*Entries :     1000 : Total  Size=       4533 bytes  File Size  =       3816 *
*Baskets :        1 : Basket Size=      32000 bytes  Compression=   1.07     *
*............................................................................*
```

Scaning a Tree

- To scan information from a tree:

  root[ ] mytree $\rightarrow$ Scan()

  It will print the structure of each entry as following:

```
************************************************
*    Row   *   ntrack *        px *        py *
************************************************
*        0 *      498 * -0.869528 * 2.5635924 *
*        1 *      115 * -6.252603 * -0.801751 *
*        2 *      369 * 0.0158244 * 0.1784736 *
*        3 *      157 * 0.3833004 * -0.970132 *
*        4 *       84 * -3.569256 * -0.147238 *
*        5 *       15 * -2.776595 * 2.5347931 *
*        6 *      289 * 1.1594425 * 0.2357311 *
*        7 *      248 * -1.631610 * 0.1861021 *
*        8 *       58 * 2.3306736 * 0.0915950 *
*        9 *      361 * -0.999278 * 0.6351276 *
*       10 *       49 * -0.485695 * 4.9937224 *
*       11 *       64 * 4.5208911 * 4.0810632 *
*       12 *       63 * -1.741184 * 4.0493841 *
*       13 *      145 * 1.1042200 * 0.7273818 *
*       14 *       70 * 3.2522122 * 0.7632834 *
*       15 *       22 * 0.0247242 * 1.0441280 *
*       16 *      369 * -2.643235 * 4.4886541 *
*       17 *      338 * -0.494545 * -1.360430 *
*       18 *      169 * 3.5270268 * -3.019523 *
*       19 *      184 * 0.6015881 * 1.9763412 *
*       20 *      414 * 0.4878255 * -1.184678 *
*       21 *      305 * -1.575853 * -4.160276 *
*       22 *       21 * -2.486564 * 0.5242354 *
*       23 *      219 * -1.307872 * 0.0622450 *
*       24 *      215 * -1.670127 * 0.6595612 *
Type <CR> to continue or q to quit ==>
```

Making a Class from a Tree

- First load the root file in prompt:

  root[ ] TFile *file=new TFile("mybranches.root");

- Cross check the tree name:

  root[ ] file → ls()

- Now make your Class:

  root[ ] mytree → MakeClass("MyCode");

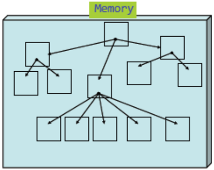
  It will show the output like following:

```
root [7] mytree->MakeClass("MyCode")
Info in <TTreePlayer::MakeClass>: Files: MyCode.h and MyCode.C generated from TTree: mytree
```

  Here **MyCode.C** contains the basic structure of code with an event loop, and **MyCode.h** tells you variable that you can access while building your code in the event loop (inside MyCode.C).
  Remember, Its good way to start your code.

Tree Memory

- Each node is the branch in Tree



Tree Memory

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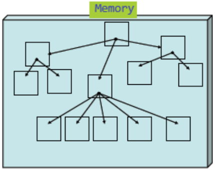

Tree Memory

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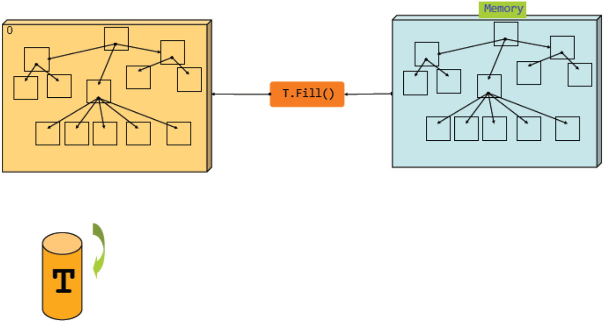

Tree Memory

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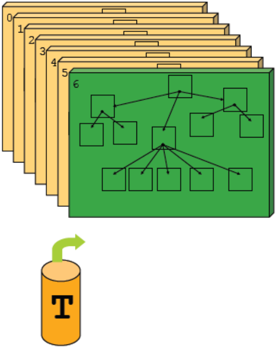

Tree Memory

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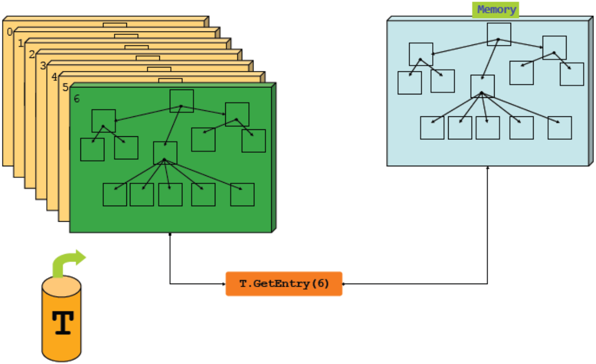
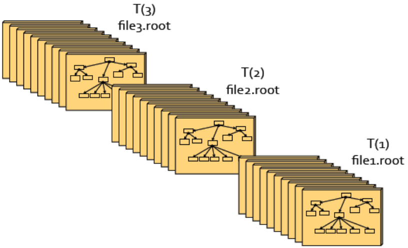


TChain

- If there are three root files, “file1.root”, “file2.root” and “file3.root”, which have the same tree ”T”. It possible to combine them by TChain:

```
TChain chain(“T”)
chain.Add(“file1.root”);
chain.Add(“file2.root”);
chain.Add(“file3.root”);
```

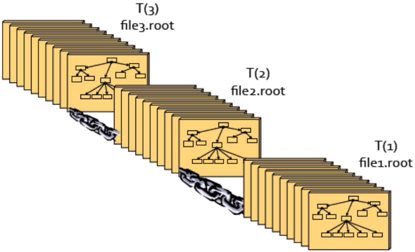


- TChain can be used like TTree.

TChain

- If there are three root files, “file1.root”, “file2.root” and “file3.root”, which have the same tree ”T”. It possible to combine them by TChain:

```
TChain chain(“T”)
chain.Add(“file1.root”);
chain.Add(“file2.root”);
chain.Add(“file3.root”);
```



- TChain can be used like TTree.

Making a Class from a Tree

For example, you have data files in root format and you want to analyze the data in those files. Take any data file and make a class from the tree to start your code.

Preview of “MyCode.C”

```
#define MyCode_cxx
#include "MyCode.h"
#include <TH2.h>
#include <TStyle.h>
#include <TCanvas.h>

void MyCode::Loop()
{
//   In a ROOT session, you can do:
//      Root > .L MyCode.C
//      Root > MyCode t
//      Root > t.GetEntry(12); // Fill t data members with entry number 12
//      Root > t.Show();       // Show values of entry 12
//      Root > t.Show(16);     // Read and show values of entry 16
//      Root > t.Loop();       // Loop on all entries
//

//     This is the loop skeleton where:
//    jentry is the global entry number in the chain
//    ientry is the entry number in the current Tree
//  Note that the argument to GetEntry must be:
//    jentry for TChain::GetEntry
//    ientry for TTree::GetEntry and TBranch::GetEntry
//
//       To read only selected branches, Insert statements like:
// METHOD1:
//    fChain->SetBranchStatus("*",0);  // disable all branches
//    fChain->SetBranchStatus("branchname",1);  // activate branchname
// METHOD2: replace line
//    fChain->GetEntry(jentry);       //read all branches
//by  b_branchname->GetEntry(ientry); //read only this branch
   if (fChain == 0) return;

   Long64_t nentries = fChain->GetEntriesFast();

   Long64_t nbytes = 0, nb = 0;
   for (Long64_t jentry=0; jentry<nentries;jentry++) {
      Long64_t ientry = LoadTree(jentry);
      if (ientry < 0) break;
      nb = fChain->GetEntry(jentry);   nbytes += nb;
      // if (Cut(ientry) < 0) continue;
   }
<de.Cline=1  col=1  totlin=43  bytval=0x23,1,CPP                    Top
```

Preview of “MyCode.h”

```
//////////////////////////////////////////////////////////
// This class has been automatically generated on
// Sun Nov 23 22:43:02 2014 by ROOT version 5.34/18
// from TTree mytree/an example Tree
// found on file: mybranches.root
//////////////////////////////////////////////////////////

#ifndef MyCode_h
#define MyCode_h

#include <TROOT.h>
#include <TChain.h>
#include <TFile.h>

// Header file for the classes stored in the TTree if any.

// Fixed size dimensions of array or collections stored in the TTree if an
y.

class MyCode {
public :
   TTree          *fChain;   //!pointer to the analyzed TTree or TChain
   Int_t           fCurrent; //!current Tree number in a TChain

   // Declaration of leaf types
   Int_t           ntrack;
   Float_t         px;
   Float_t         py;

   // List of branches
   TBranch        *b_ntrack;   //!
   TBranch        *b_px;   //!
   TBranch        *b_py;   //!

   MyCode(TTree *tree=0);
   virtual ~MyCode();
   virtual Int_t    Cut(Long64_t entry);
   virtual Int_t    GetEntry(Long64_t entry);
   virtual Long64_t LoadTree(Long64_t entry);
   virtual void     Init(TTree *tree);
   virtual void     Loop();
   virtual Bool_t   Notify();
<.hline=19  col=1  totlin=135  bytval=0x63,1,CPP                    Top
```

Let’s focus on **Method1** to read the tree and write some code in event loop.

Making a Class from a Tree→Building/Running Code

For example, you have data files in root format and you want to analyze the data in those files. Take any data file and make a class from the tree to start your code.

Preview of "MyCode.C"

```
#define MyCode_cxx
#include "MyCode.h"
#include <TH2.h>
#include <TStyle.h>
#include <TCanvas.h>

void MyCode::Loop()
{
// METHOD1:To Read Tree
      fChain->SetBranchStatus("*",0);  // disable all branches
      fChain->SetBranchStatus("ntrack",1); // activate branch
      fChain->SetBranchStatus("px",1); // activate branch
// Define HISTOs
TH1F * px_100trk = new TH1F("px_100trk","", 50,    0 ,5);
TH1F * px_200trk = new TH1F("px_200trk","", 50,    0 ,5);

   if (fChain == 0) return;
   Long64_t nentries = fChain->GetEntriesFast();

   Long64_t nbytes = 0, nb = 0;
   for (Long64_t jentry=0; jentry<nentries;jentry++) {
      Long64_t ientry = LoadTree(jentry);
      if (ientry < 0) break;
      nb = fChain->GetEntry(jentry);   nbytes += nb;
       if (ntrack < 2) continue; // Throw this Event
// FILLING HISTOs
       if(ntrack>=100){px_100trk->Fill(px);}
       if(ntrack>=200){px_200trk->Fill(px);}
}
TFile* file = new TFile("output_MyCode.root", "RECREATE");
file->cd();
// WRITING HISTOs
px_100trk->Write();
px_200trk->Write();

}
~
<  col=1  totlin=36  [+]bytval=0x0,1,CPP                    All
```

How to run the code "MyCode.C"

- Compile the code:

  root[ ] .L MyCode.C++;

  If there is no error, it will make **MyCode_C.so**

- Chain up all the input root files:

  root[ ] TChain* chain=new TChain("mytree");
  root[ ] chain→ Add("mybranches.root");

- Load the shared object (so):

  root[ ] gSystem→ Load("MyCode_C.so");

- Run the Loop:

  root[ ] MyCode run(chain);
  root[ ] run.Loop();

The code generates **output_myCode.root** file with two histograms.

Exercises

- Writing/Reading a Tree

Exercise#1 Make/write a tree into a ROOT File for 800 entries containing x, y, z and t branches as floats. Please use $\{x, y, z, t\} = \{$Gaus(0,1), Gaus(1,2),Gaus(1,3), Gaus(3,2)$\}$. Draw variable z for $x > 0$ and $t < 4$.

Exercise#2 Draw the variable z again with the same conditions but with the bin range from 0 to 3 having 30 bins.

Exercise#3 Make a four columns ascii file containing variables x, y, z and t. Also draw the same z plot (as in Exercise 2) from the ascii file through a ROOT tree and compare the entries, mean and RMS values.

- TChain/combing trees from different File

Exercise#4 Run the above code 3 times but each time change the name of output ROOT file, e.g. myfile1.root, myfile2.root and myfile3.root. Join all the files by TChain method and find total number of entries [Hint: by using chain→GetEntries()] after combining all the three files.

- MakeClass/Building and Running the code

Exercise#5 Make a class from the ROOT file obtained from Exercise#1. Obtain a histogram for variable "y" for the case of "t<3" in a ROOT file.

Thanks