Lecture 4

Graphs and Histograms

Exercises

① Modify example 25. of the tutorial to display three full periods of a sin-wave (and get rid of the ugly brown background color). Make the marker a full square and change the line color to yellow.

```
{
   //
   // To see the output of this macro, click  here.
   //
   gROOT->Reset();
   c1 = new TCanvas("c1","A Simple Graph Example",200,10,700,500);

   c1->SetFillColor(42);
   c1->SetGridx();
   c1->SetGridy();

   const Int_t n = 20;
   Float_t x[n], y[n];
   for (Int_t i=0;i<n;i++) {
     x[i] = i*0.1;
     y[i] = 10*sin(x[i]+0.2);
     printf(" i %i %f %f\n",i,x[i],y[i]);
   }
   gr = new TGraph(n,x,y);
   gr->SetFillColor(19);
   gr->SetLineColor(2);
   gr->SetLineWidth(4);
   gr->SetMarkerColor(4);
   gr->SetMarkerStyle(21);
   gr->SetTitle("a simple graph");
   gr->Draw("ACP");

   //Add axis titles.
   //A graph is drawn using the services of the TH1F histogram class.
   //The histogram is created by TGraph::Paint.
   //TGraph::Paint is called by TCanvas::Update. This function is called by default
   //when typing <CR> at the keyboard. In a macro, one must force TCanvas::Update.

   c1->Update();
   c1->GetFrame()->SetFillColor(21);
   c1->GetFrame()->SetBorderSize(12);
   gr->GetHistogram()->SetXTitle("X title");
   gr->GetHistogram()->SetYTitle("Y title");
   c1->Modified();
}
```

Exercises

① Experiment with the histogram drawing options, starting from example 24. of the tutorials.

Lecture 5

Ntuples and Trees

Why Should You Use a Tree?

In the Input/Output chapter, we saw how objects can be saved in ROOT files. In case you want to store large quantities of same-class objects, ROOT has designed the TTree and TNtuple classes specifically for that purpose. The TTree class is optimized to reduce disk space and enhance access speed. A TNtuple is a TTree that is limited to only hold floating-point numbers; a TTree on the other hand can hold all kind of data, such as objects or arrays in addition to all the simple types.

What is a Tree?

A Tree is like a large and wide table:

A Tree is an array of ‘entries’ or ‘events’, similar to a row of a table.

Within each entry, there are independent ‘branches’. Each branch can contain an object or sub-branches. This can be compared to a column of a table.

Within each branch, there are ‘leaves’, which hold the member-variables of complicated classes. These are the final values.

There are several Tree-like classes in ROOT:

Tree	‘array’ of TObjects
TNtuple	TTree with only Float_t
TNtupleD	TTree with only Double_t
THbookTree	Direct access to a HBook (Paw) file
TChain	collection of files containing TTree objects

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Making a Tree Object

A tree has a very simple constructor:

```
TTree(const char *name,const char *title, Int_t splitlevel = 99)
```

The Tree is created in the current directory

Use the various Branch functions to add branches to the Tree.

If the first character of ‘title’ is a "/", the function assumes a folder name. In this case, it creates automatically branches following the folder hierarchy. *splitlevel* may be used in this case to control the split level.

Example:

```
TTree* tree = new TTree("treeName","treeTitle");
```

Non-Object Branches

```
TBranch* Branch(const char *name, void *address, const char *leaflist,Int_t bufsize)
```

This constructor supports non-objects, *e.g.* C-style structs, or arrays of variables.

address is a pointer to the beginning of the data

leaflist is the list of variable *names*, separated by ":". Variable *types* are separated by "/"

Example:

```
ROOT [0] TTree* mytree = new TTree("mytree","Test Tree");
ROOT [1] Double_t values[5];
ROOT [2] TBranch *b = tree->Branch("val",values, "a/D:b:c:d:e")
```

Supported Simple Types

C	a character string terminated by the 0 character	B	an 8 bit signed integer (Char_t)
b	an 8 bit unsigned integer (UChar_t)	S	a 16 bit signed integer (Short_t)
s	a 16 bit unsigned integer (UShort_t)	I	a 32 bit signed integer (Int_t)
i	a 32 bit unsigned integer (UInt_t)	F	a 32 bit floating point (Float_t)
D	a 64 bit floating point (Double_t)	L	a 64 bit signed integer (Long64_t)
l	a 64 bit unsigned integer (ULong64_t)	O	a boolean (Bool_t)

Object Branches

The constructor:

```
TBranch* Branch(const char* name, const char* classname, void*** addobj, ···)
```

classname refers to the class of the object you want to store
addobj is the address of the pointer to the object you want to store
(poorly documented)

Example:

```
ROOT [0] TTree* mytree = new TTree("mytree","Test Tree");
ROOT [1] TH1D* h = new TH1D("h","h",10,0,1);
ROOT [2] TBranch *branch = tree->Branch("hBranch","TH1D",&h);
```

Filling a Tree

Extremely simple:

```
mytree->Fill();
```

This function loops over all the branches of the tree. For each branch, it copies the current values of the leaves to the branch buffer.

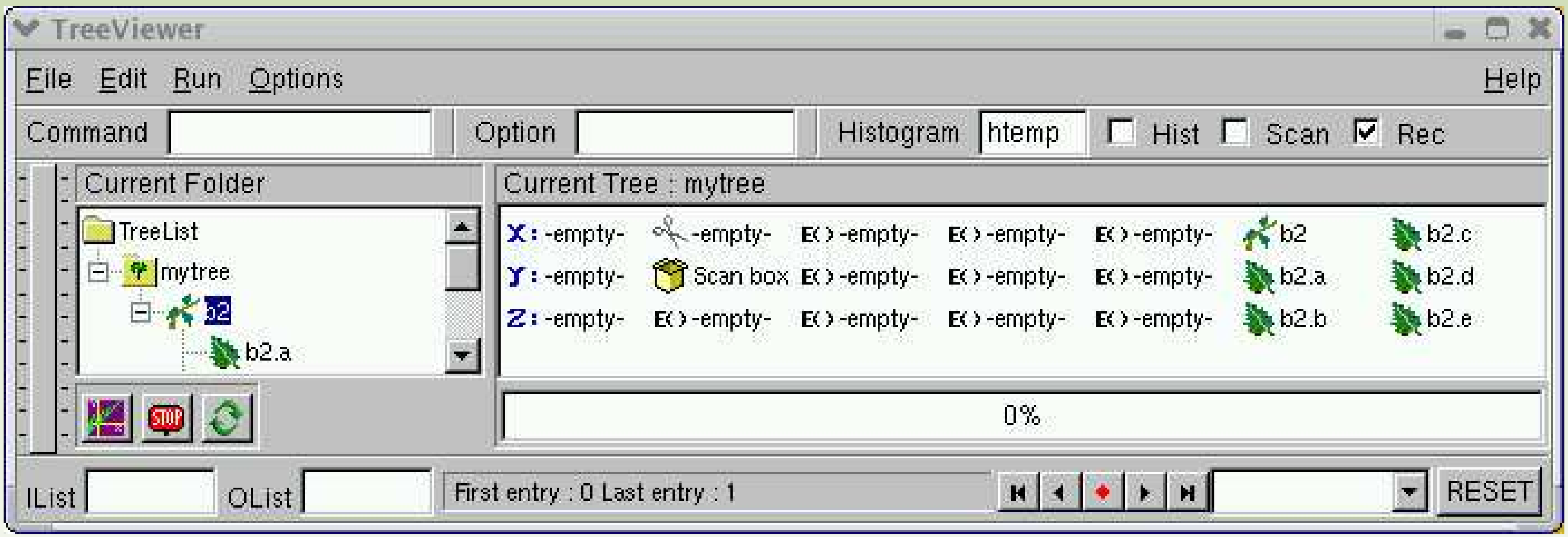
Example:

```
ROOT [0] TTree* mytree = new TTree("mytree","Test Tree");
ROOT [1] TH1D* h = new TH1D("h","h",10,0,1);
ROOT [2] Double_t values[5] = {0,0,0,0,0};
ROOT [3] TBranch *b1 = mytree->Branch("b1","TH1D",&h);
ROOT [4] TBranch *b2 = mytree->Branch("b2",values, "a/D:b:c:d:e");
ROOT [5] mytree->Fill();
ROOT [6] h->FillRandom("gaus");
ROOT [7] values[0] = 1; values[3] = -3.14;
ROOT [8] mytree->Fill();
```

Browsing the Tree

A graphical interface to play with a tree is started using:

```
mytree->StartViewer()
```



Tree on the Command Line

The contents of the tree can be drawn from the commandline:

```
Draw(const char *exp, const char *cut, Option_t *option, Long64_t nent, Long64_t first)
```

exp: expression describing what to draw, *e.g.* "y:x", or "sqrt(x/y*z*z)". For 2-D (or 3-D) plots, expressions are separated by a ":". Convention: $z : y : x$. Statement "x»histoname" will save to predefined histogram.

cut: expression describing some conditions, *e.g.* "z>0"

option: drawing option (see histograms)

Example:

```
ROOT [0] TTree* mytree = new TTree("mytree","Test Tree");
ROOT [1] Double_t values[3];
ROOT [2] TBranch *b2 = mytree->Branch("b2",values, "x/D:y:z");
ROOT [3] macroToFillTree();
ROOT [4] mytree->Draw("sqrt(z):x*y","z>0","surf4",1000,10);
```

Tree on the Command Line (Cont'd)

The structure of the Tree can be printed:

```
mytree->Print();
```

```
******************************************************************************
*Tree    :mytree    : TestTree                                               *
*Entries :        2 : Total =            1281 bytes  File  Size =          0 *
*        :          : Tree compression factor =   1.00                       *
******************************************************************************
*Br    0 :b2        : a/D:b:c:d:e
*Entries :        2 : Total  Size=       1001 bytes  One basket in memory    *
*Baskets :        0 : Basket Size=      32000 bytes  Compression=   1.00     *
*............................................................................*
```

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Tree on the Command Line (Cont'd)

You can get a list of (part of) the contents:

```
mytree->Scan("a:b");
```

```
************************************
*    Row   *          a *          b *
************************************
*        0 *          0 *          0 *
*        1 *          1 *          0 *
************************************
```

Tree on the Command Line (Cont'd)

You can also inspect the contents of a specific entry numerically:

```
mytree->Show(1);
```

```
======> EVENT:1
 a                    = 1
 b                    = 0
 c                    = 0
 d                    = -3.14
 e                    = 0
```

Reading a Tree from a Macro

Very similar to the filling method:

```
GetEntry(Long64_t entry = 0, Int_t getall = 0)
```

Of course, you have to tell the tree first, where to store the data:

```
SetBranchAddress(const char* bname, void** add)
```

Example:

```
ROOT [0] TFile* file = new TFile("test.root");
ROOT [1] TTree* mytree = (TTree*)file->Get("mytree");
ROOT [2] TH1D* h = 0;
ROOT [3] mytree->SetBranchAddress("b1",&h);
ROOT [4] mytree->GetEntry(0);
ROOT [5] h->Draw();
ROOT [6] mytree->GetEntry(1);
ROOT [7] h->Draw();
```

Some Very Helpful Tools

For large trees, with many branches and leaves, and complicated objects, reading a tree may become a lot of work. Work is simplified with

```
MakeClass(const char* classname = "0", Option_t* option)
MakeCode(const char* filename = "0")
```

Example:

```
ROOT [0] TTree* mytree = new TTree("mytree","Test Tree");
ROOT [1] Double_t values[3];
ROOT [2] TBranch *b = tree->Branch("val",values, "a/D:b:c");
ROOT [3] mytree->MakeCode("fastCode.cxx");
```

What the generated code looks like

```
{
   ... some stuff deleted here ....
   TTree *mytree = (TTree*)gDirectory->Get("mytree");

//Declaration of leaves types
   Double_t        b2_a;
   Double_t        b2_b;
   Double_t        b2_c;

   // Set branch addresses.
   mytree->SetBranchAddress("b2",&b2_a);
   mytree->SetBranchAddress("b2",&b2_b);
   mytree->SetBranchAddress("b2",&b2_c);

//     This is the loop skeleton
//       To read only selected branches, Insert statements like:
// mytree->SetBranchStatus("*",0);  // disable all branches
// TTreePlayer->SetBranchStatus("branchname",1);  // activate branchname

   Long64_t nentries = mytree->GetEntries();

   Int_t nbytes = 0;
//   for (Long64_t i=0; i<nentries;i++) {
//      nbytes += mytree->GetEntry(i);
//   }
}
```

Now an Ntuple is straightforward!

TNtuple is a derived class from a TTree. So it can do all the things a TTree can. The only difference is that it can only contain Float_t (TNtuple) or Double_t (TNtupleD) variables. Each variable behaves as a separate branch.

Constructor:

```
TNtuple(const char* name, const char* title, const char* varlist, Int_t bufsize = 32000)
```

Filling:

```
- Fill(Float_t x0, Float_t x1 = 0, Float_t x2 = 0, ..... , Float_t x14 = 0)
- Fill(const Float_t* x)
```

Example:

```
ROOT [0] TNtuple* nt = new TNtuple("ntName","ntTitle","a:b:c");
ROOT [1] nt->Fill(3.1415,2.7182818,1.41421);
ROOT [2] nt->Fill(1/3.1415,1/2.7182818,1/1.41421);
ROOT [3] nt->Draw("cos(a):ln(b):c*c","b>0&&c>0");
```

Exercises

1. Download the root-file on the website: http://kvir03.kvi.nl/rootcourse/. Inside you'll find a tree containing histograms and an array of Double_t's. Write a macro that draws the histograms of the third entry and prints the values of the array.
2. Download the ascii file from the root-course website and convert it into an Ntuple. Make a 2D histogram with the fourth value on the x-axis and the second on the y-axis. Plot it with a smooth surface and label the axes. Send me the postscript file of this plot (onderwater@kvi.nl).