Exercises for Lecture 8

Exercise 1)

Use ACLiC to compile the script you used for the exercises in the previous lecture. How much acceleration do you get?

Exercises for Lecture 8

The original macro

```
void doit(UInt_t rgNr = 1, Int_t nrEvents = 200000000)
{
  if (gRandom) delete gRandom;
  switch (rgNr) {
   case (2):
      gRandom = new TRandom2();
      break;
   case (3):
      gRandom = new TRandom3();
      break;
   default:
      gRandom = new TRandom();
      break;
   }
  TH1D * hist=new TH1D("hist","TRandom",500,-10,10);

  TStopwatch *st=new TStopwatch();

  st->Start();
  for (Int_t i=0; i<nrEvents; i++) hist->Fill(gRandom->Gaus(0,1));
  st->Stop();

  TF1* gs = new TF1("gs","gaus",-10,10);
  hist->Fit("gs");
  Double_t normchi2 = gs->GetChisquare()/gs->GetNDF();
  printf("%s : %.1fs %.2f mus/event %.4f\n",
       gRandom->GetName(), st->CpuTime(), 1e6*st->CpuTime()/nrEvents, normchi2);
}
```

Exercises for Lecture 8

ACLiC compatible

```
#include "TRandom.h"
#include "TRandom2.h"
#include "TRandom3.h"
#include "TH1D.h"
#include "TStopwatch.h"
#include "TF1.h"

void doit(UInt_t rgNr = 1, Int_t nrEvents = 200000000)
{
  if (gRandom) delete gRandom;
  switch (rgNr) {
   case (2):
      gRandom = new TRandom2();
      break;
   case (3):
      gRandom = new TRandom3();
      break;
   default:
      gRandom = new TRandom();
      break;
   }
  TH1D * hist=new TH1D("hist","TRandom",500,-10,10);

  TStopwatch *st=new TStopwatch();

  st->Start();
  for (Int_t i=0; i<nrEvents; i++) hist->Fill(gRandom->Gaus(0,1));
  st->Stop();

  TF1* gs = new TF1("gs","gaus",-10,10);
  hist->Fit("gs");
  Double_t normchi2 = gs->GetChisquare()/gs->GetNDF();
  printf("%s : %.1fs %.2f mus/event %.4f\n",
       gRandom->GetName(), st->CpuTime(), 1e6*st->CpuTime()/nrEvents, normchi2);
}
```

Exercises for Lecture 8

CINT-MACRO:

```
root[0] .L ex8_1.C
root[1] doit(1)
….
```

ACLiC:

```
root[0] .L ex8_1.C+
Info in <TUnixSystem::ACLiC>: creating shared library
    /Users/messchendorp/Documents/rootCourse/./lec8_1_C.so
root[1] doit(1)
….
```

Exercises for Lecture 8

CINT-MACRO (.L ex8_1.C):

Random : 469.7s ***2.35 μs/event*** 2.0890
Random2 : 543.7s ***2.72 μs/event*** 0.9439
Random3 : 494.7s ***2.47 μs/event*** 0.9839

ACLiC (.L ex8_1.C+):

Random : 147.6s ***0.74 μs/event*** 2.0890
Random2 : 209.9s ***1.05 μs/event*** 0.9439
Random3 : 152.5s ***0.76 μs/event*** 0.9839

~2.5-3.3 faster!!

Full compilation (./ex8_1.exe):

Random : 140.3s ***0.70 μs/event*** 2.0890
Random2 : 211.6s ***1.06 μs/event*** 0.9439
Random3 : 147.1s ***0.74 μs/event*** 0.9839

Similar speed as with ACLiC

Exercises for Lecture 8

Exercise 2)

Complete the script below. Determine the speed (μs/event) for each of the 5 methods to fill a histogram when you run it in CINT or ACLiC mode. Comment on the difference …

```
Double_t mygaus(Double_t* c, Double_t* par)
{
Double_t x = c[0];
return par[0]*exp(-0.5*(x-par[1])*(x-par[1])/par[2]/par[2]);
}

void compare()
{
TF1* gs1 = new TF1("gs1","gaus",-10,10); gs1->SetParameters(1,0,1);
TF1* gs2 = new TF1("gs2",mygaus,-10,10,3); gs2->SetParameters(1,0,1);

hist1->FillRandom(g1,nEvents); // method 1
hist2->FillRandom(g2,nEvents); // method 2
for(Int_t i=0;i<nEvents;i++) hist3->Fill(gRandom->Gaus(0,1); // method 3
for(Int_t i=0;i<nEvents;i++) hist4->Fill(gs1->GetRandom()); // method 4
for(Int_t i=0;i<nEvents;i++) hist5->Fill(gs2->GetRandom()); // method 5
}
```

Lecture 8, Exercise 2

```
#include "TH1D.h"
#include "TF1.h"
#include "TRandom3.h"
#include "TStopwatch.h"

Double_t mygaus(Double_t* c, Double_t *par)
{
  Double_t x=c[0];
  return par[0]*exp(-0.5*(x-par[1])*(x-par[1])/par[2]/par[2]);
}

void compare(Int_t nrEvents=1)
{
  if (gRandom) delete gRandom;
  gRandom=new TRandom3();

  TH1D *hist1=new TH1D("hist1","Method 1",500,-10,10);
  TH1D *hist2=new TH1D("hist2","Method 2",500,-10,10);
  TH1D *hist3=new TH1D("hist3","Method 3",500,-10,10);
  TH1D *hist4=new TH1D("hist4","Method 4",500,-10,10);
  TH1D *hist5=new TH1D("hist5","Method 5",500,-10,10);

  TF1* gs1 = new TF1("gs1","gaus",-10,10);   gs1->SetParameters(1,0,1);
  TF1* gs2 = new TF1("gs2",mygaus,-10,10,3); gs2->SetParameters(1,0,1);

  TStopwatch *st=new TStopwatch();

  st->Start(); hist1->FillRandom("gs1",nrEvents); st->Stop();
  printf("Method 1 : %.1fs %.2f mus/event\n",st->CpuTime(), 1e6*st->CpuTime()/nrEvents);

  st->Start(); hist2->FillRandom("gs2",nrEvents); st->Stop();
  printf("Method 2 : %.1fs %.2f mus/event\n",st->CpuTime(), 1e6*st->CpuTime()/nrEvents);

  st->Start(); for (Int_t i=0; i<nrEvents; i++) hist3->Fill(gRandom->Gaus(0,1)); st->Stop();
  printf("Method 3 : %.1fs %.2f mus/event\n",st->CpuTime(), 1e6*st->CpuTime()/nrEvents);

  st->Start(); for (Int_t i=0; i<nrEvents; i++) hist4->Fill(gs1->GetRandom());st->Stop();
  printf("Method 4 : %.1fs %.2f mus/event\n",st->CpuTime(), 1e6*st->CpuTime()/nrEvents);

  st->Start(); for (Int_t i=0; i<nrEvents; i++) hist5->Fill(gs2->GetRandom());st->Stop();
  printf("Method 5 : %.1fs %.2f mus/event\n",st->CpuTime(), 1e6*st->CpuTime()/nrEvents);
}
```

Exercises for Lecture 8

100mln events

CINT-MACRO (.L ex8_2.C):

Method 1 (FillRandom, "gaus")	***0.66 μs/event***
Method 2 (FillRandom, "mygaus")	***0.66 μs/event***
Method 3 (Loop, Fill, Gaus(0,1))	***2.42 μs/event***
Method 4 (Loop, Fill, "gaus")	***1.91 μs/event***
Method 5 (Loop, Fill, "mygaus")	***1.89 μs/event***

ACLiC (.L ex8_2.C+):

Method 1 (FillRandom, "gaus")	***0.67 μs/event***
Method 2 (FillRandom, "mygaus")	***0.64 μs/event***
Method 3 (Loop, Fill, Gaus(0,1))	***0.75 μs/event***
Method 4 (Loop, Fill, "gaus")	***0.69 μs/event***
Method 5 (Loop, Fill, "mygaus")	***0.67 μs/event***

Conclusions from Exercises 8

1) The use of pre-defined or user-defined functions does not matter in performance.

2) Using macros with for-loops in CINT cause a significant drop in performance. Avoid making a "lot of calls" in a CINT macro.

3) Compiled code with ACLiC gives similar performance in all cases, independent of using a "lot of calls" or not in your macro.

4) The performance of a CINT macro is similar to ACLiC code if you minimize the number of calls in the macro.

ROOT Lecture 9

Networking and Threads

Why networking in a ROOT analysis?

1) Performance

   Divide the analysis work/tasks among several computers.

2) Monitoring and Control

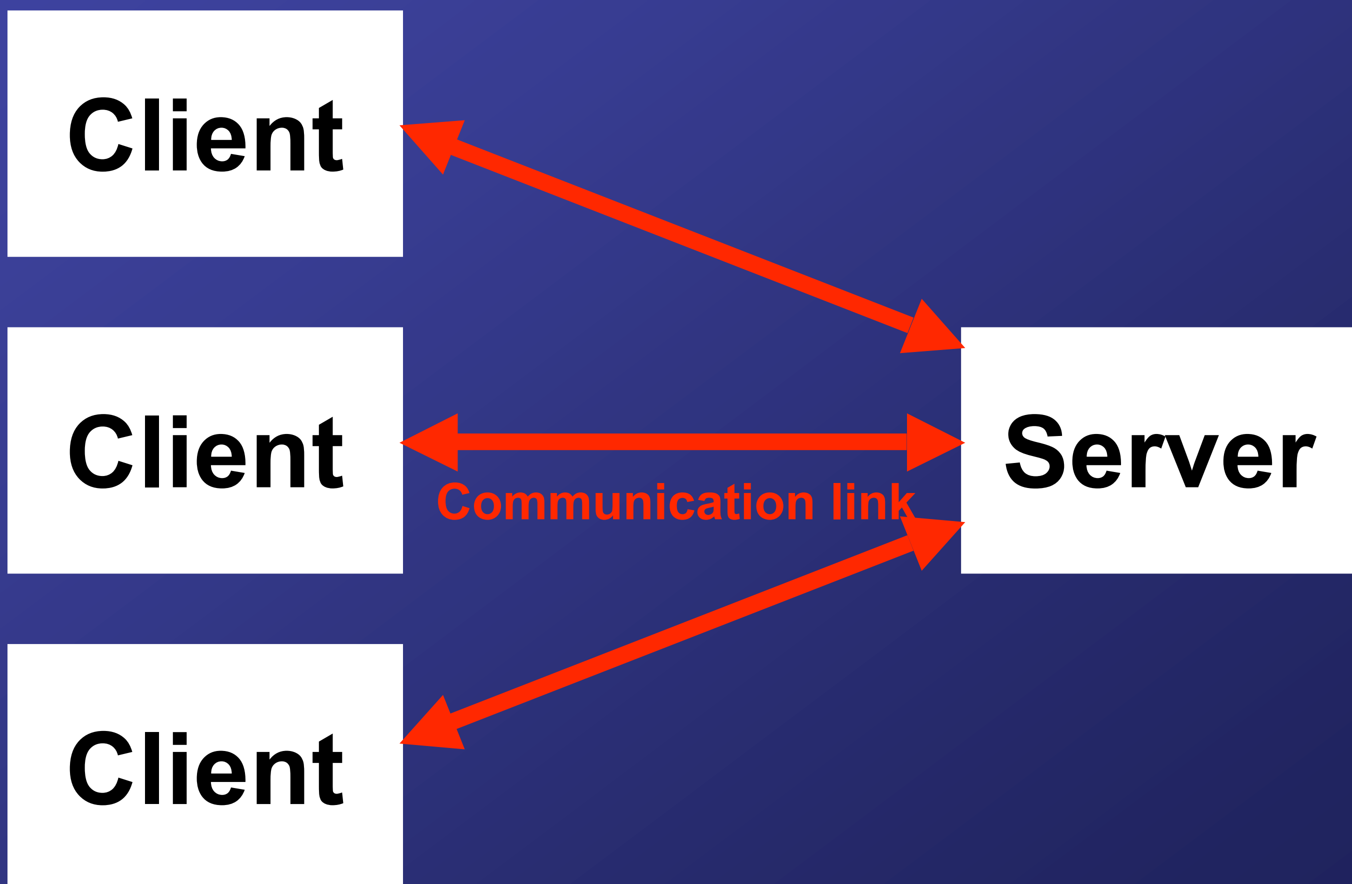
   Monitor results and change parameters on-the-fly.

3) Flexibility

   Run your certain parts of the analysis anywhere you like.

A TCP/IP network: the basics

TCP/IP: Transmission Control Protocol/Internet Protocol.
A standard network protocol which allows to setup a reliable full-duplex communication link between two or more computers.



Some TCP/IP examples in Unix

Client	Server	Description
telnet	in.telnetd	Terminal emulation
ssh	sshd	Secure Shell
ftp	in.ftpd	File Transport Protocol
http browsers	httpd	Hyper Text Transport Protocol (WWW)
TNetFile	rootd	ROOT file access via internet

Accessing a ROOT file via internet

Class TNetFile : public TFile;

TNetFile(*"root://kvir03.kvi.nl/rootcourse/myrootfile.root","..."*)

Server address running "rootd"

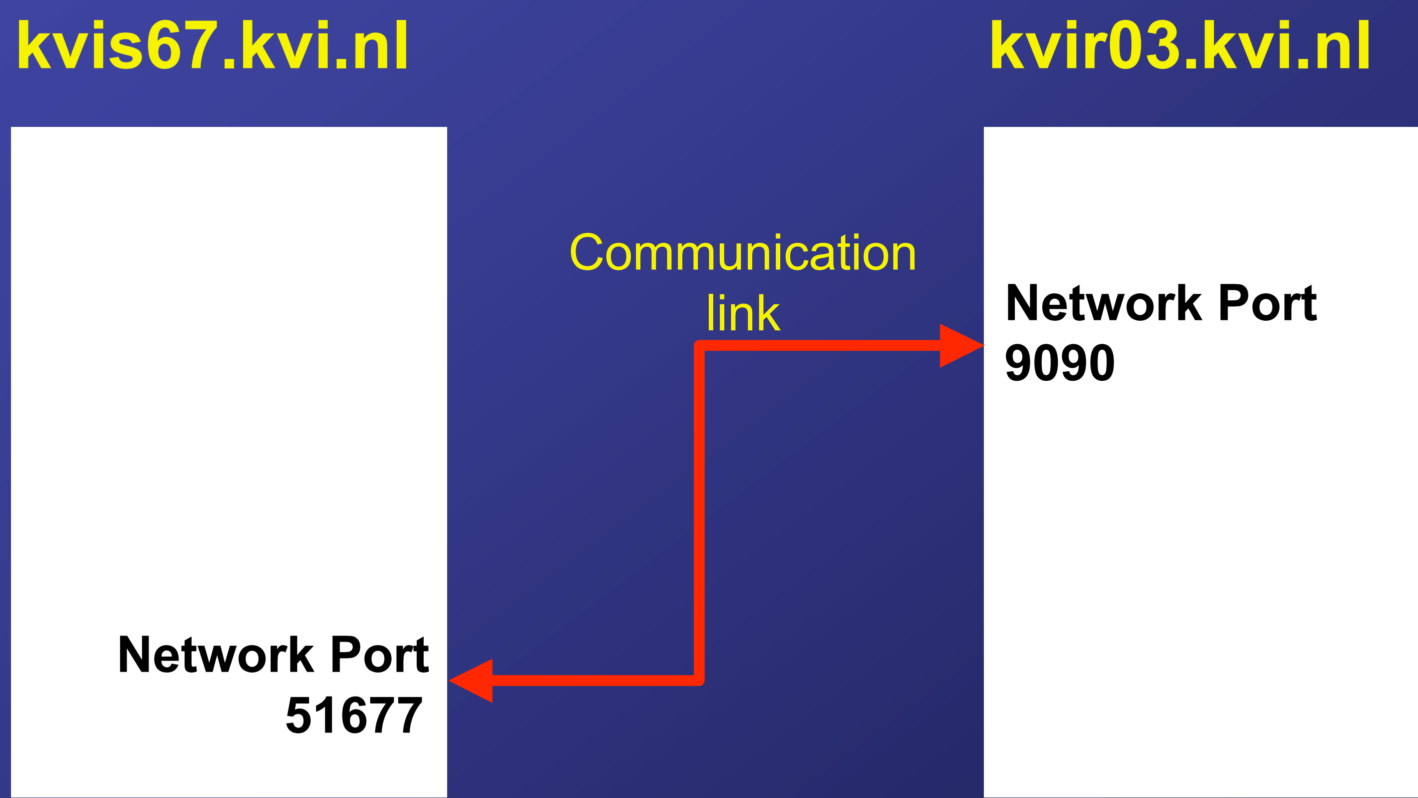
Some remarks:

1) **"rootd" has to run on server: $(ROOTSYS)/bin/rootd**

2) **Connecting to a "rootd" requires the remote user id and password.**

Building your own client-server application

A TCP connection:



Building your own client-server application

Port numbers: 16-bit "phone-number"

0-1023: **well-known ports**. Controlled by Internet Assigned Numbers Authority (IANA). Example: port 80 = Web server. Never use these numbers for your server!!

1024-49151: **registered ports**. Not controlled by IANA. Check before using a number in this range. Example: port 1094 = rootd.

49152-65535: **dynamic or private ports**. Not listed by IANA. Dynamical ports generated by client applications always use numbers in this range.

http://www.iana.org/assignments/port-numbers

Building your own client-server application

A TCP connection: Socket object

Client:

Local IP-addr:	kvis67.kvi.nl
Local port no:	51677
Remote IP-addr:	kvir03.kvi.nl
Remote port no:	9090

Client Socket

Server:

Local IP-addr:	kvir03.kvi.nl
Local port no:	9090
Remote IP-addr:	kvis67.kvi.nl
Remote port no:	51677

Server Socket

A TCP connection is uniquely defined by a 4-tuple, i.e. addresses (IP-address+portnr) of both endpoints. These numbers are called a *socket*-pair.

Building your own client-server application

Setting up a TCP connection

Server "listen socket": it waits for client connection

Server
Local: kvir03.kvi.nl/9090
Remote: */*

listenSocket

```
TServerSocket *listenSocket = new TServerSocket(9090)
TSocket       *srvSocket    = listenSocket->Accept()
                     /* waits for connection before
                        returning "connection" socket */
```

Building your own client-server application

Setting up a TCP connection

Client rings the server

Server "listen socket": it receives a client connection

Client
Local: kvis67.kvi.nl/ 51677
Remote: kvir03.kvi.nl/9090

Server
Local: kvir03.kvi.nl/9090
Remote: */*

listenSocket

TSocket *clntSocket=new TSocket("kvir03.kvi.nl",9090)
/* returns socket if connection established */

Building your own client-server application

Setting up a TCP connection

**TSocket *clntSocket =
new TSocket("kvir03.kvi.nl",9090)**

Client
Local: kvis67.kvi.nl/ 51677
Remote: kvir03.kvi.nl/9090

clntSocket

**TServerSocket *listenSocket =
new TServerSocket(9090)**

Server
Local: kvir03.kvi.nl/9090
Remote: */*

**TSocket *srvSocket =
listenSocket->Accept()**

Local: kvir03.kvi.nl/9090
Remote: kvis67.kvi.nl/51677

srvSocket

Client establishes connection:
"connection" sockets created

Building your own client-server application

Communication between client and server (byte-stream)

Client —str→ **Server**

```
clntSocket->Send("Hello server")
```

```
Char_t str[32];
srvSocket->Recv(str,32)
```

Note:

1) **Recv()** "blocks" till data available
2) **Send()** does not block by default

Building your own client-server application

Communication between client and server (byte-stream)

Client ← str ← **Server**

```
Char_t str[32];
clntSocket->Recv(str,32)
```

```
srvSocket->Send("Hello client")
```

TCP/IP is a fully duplex protocol

Building your own client-server application

Closing connection between client and server

Client → empty message → **Server**

```
clntSocket->Close()
```

```
Int_t nrBytes=srvSocket->Recv(str,32);
if (nrBytes==0) /* Client closes conn. */
{
  srvSocket->Close();
}
```

Sending ROOT-type messages via TCP

```
class TMessage : public TBuffer ;

TMessage(UInt_t what=kMESS_ANY)
```

kMESS_ANY	generic message type
kMESS_STRING	string message type
kMESS_OBJECT	object message type
kMESS_CINT	cint command follows
kMESS_ZIP	compress message
kMESS_ACK	message has to be acknowledged before “Send(..)” returns

Example: (create message which will contain a compressed object)

```
TMessage *m=new TMessage(kMESS_OBJECT|kMESS_ZIP)
```

Sending ROOT objects via TCP

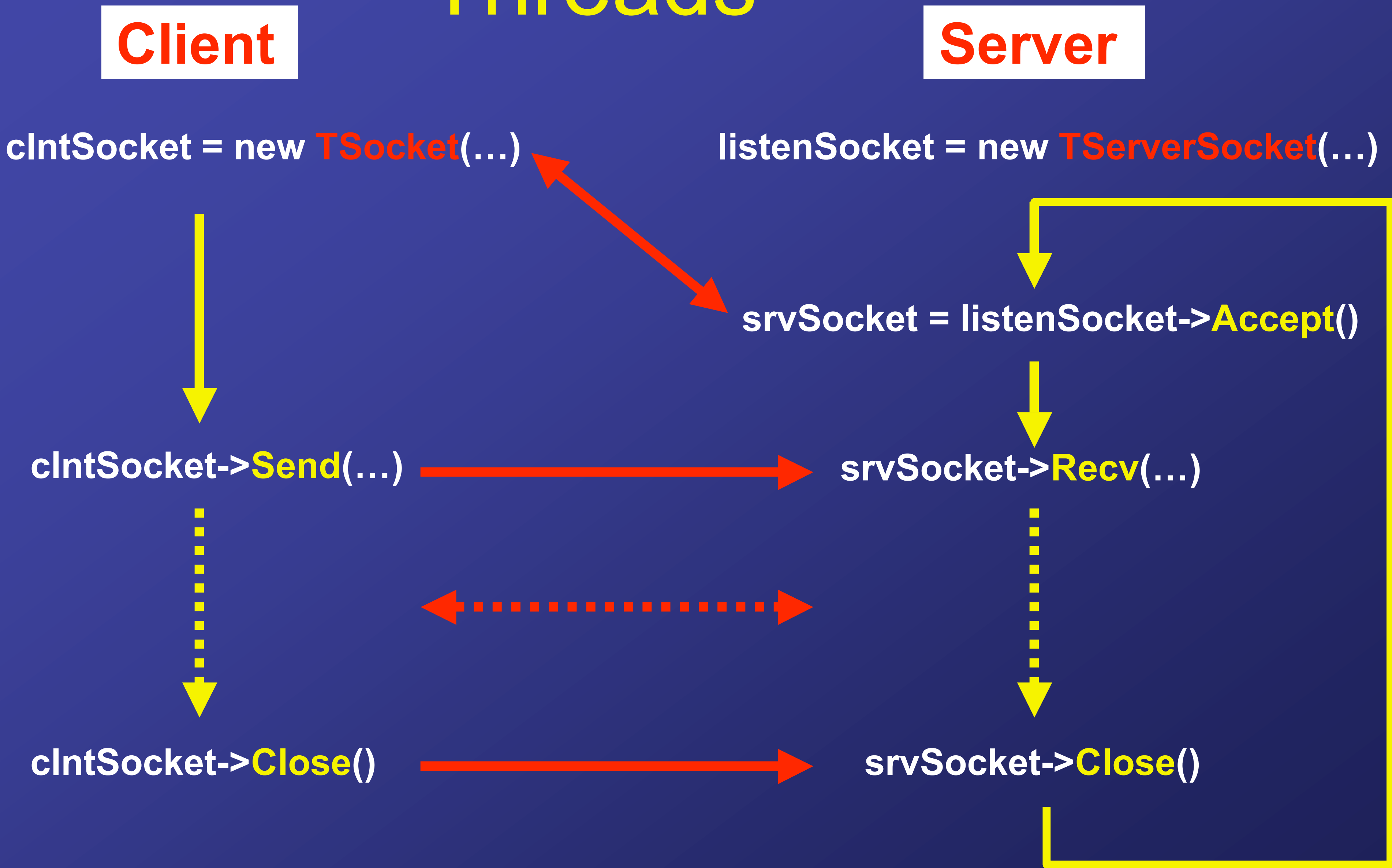
The sender…WriteObject

```
TH1D *his = new TH1D(…);
…
TMessage mess(kMESS_OBJECT);
mess.WriteObject(his);
socket->Send(mess);
```

The receiver…ReadObject

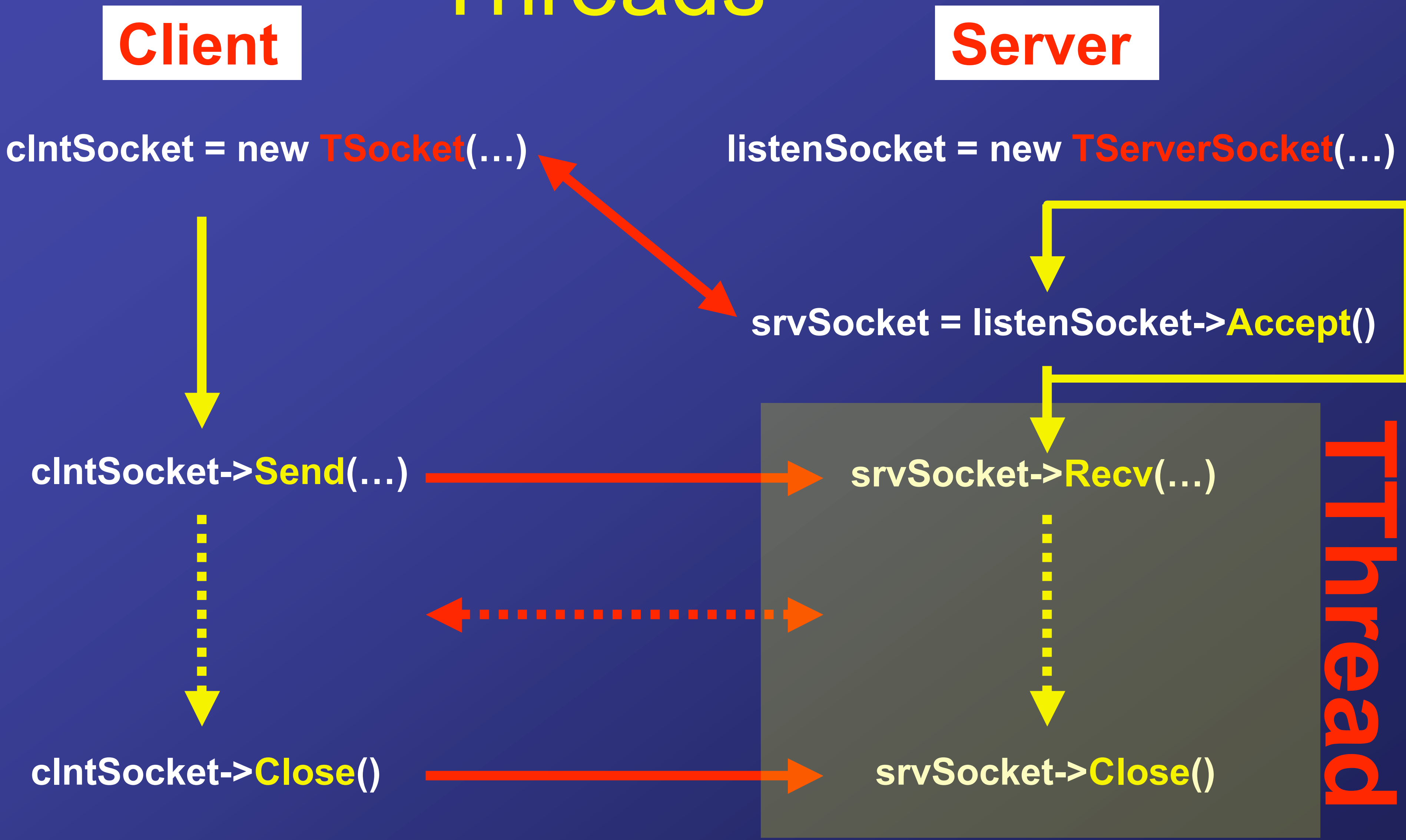
```
TMessage *mess;
socket->Recv(mess);
TH1D *his = (TH1D *)mess->ReadObject(mess->GetClass());
…
```

Threads



Only one client can connect to server !!!

Threads



Create detached process which handles communication with client in parallel : TThread

Threads

UNIX:

```
[messchendorp@KVIS67 messchendorp] xterm &
[1] 23238
[messchendorp@KVIS67 messchendorp] ps ax | grep xterm
23241 std  S      0:00.17 xterm
```

ROOT:

```
class TThread : public TNamed ;

TThread( const char name, void *process_name,
            void *process_arguments=0,
            Epriority priority=kNormalPriority )
```

Threads, a server example

```
void runServer()
{
 TServerSocket *listenSocket = new TServerSocket(…);

 while (1)
 {
  TSocket *sock = listenSocket->Accept();
  TThread *thread = new TThread(“clntThread”, handleRequest, sock);
  thread->Run(); /* Runs thread as detached process */
  TThread::Ps(); /* Similar to Unix “ps” */
 }
}

void *handleRequest(void *arg) {
  TSocket *sock = (TSocket *) arg;
  Int_t nrBytes=sock->Recv(…);
  …
  sock->Close();
  (TThread::Self())->Delete();
}
```

Main server process

Create listen socket

Loop for-ever

Wait for client

Create, start thread,
… wait for next client

Thread sub-process

Communicate with client

Delete thread when finished with client

Threads and Treats

1) Parallelism and Performance

   Threads could increase performance due to parallel processing. Not only on multi CPU computers!

2) Sharing process resources

   Threads share the same resources (globally defined variables), which allows an easy “communication” between the different threads.

Threads and Threats

1) <u>Sharing process resources</u>

Threads share the same resources, which might lead to *race* problems!

A thread producer could modify shared data at the same time a thread consumer reads it! The read data array might not be complete or corrupted…

Threads and Threats

Solution…put a lock on it!
TThread::Lock() and TThread::UnLock()

```
void FillArray()  {
TThread::Lock();
  …/ * manipulate array */
TThread::UnLock();
}

void ReadArray() {
TThread::Lock();
  …/* read array */
TThread::UnLock();
}
```

Rare cases for which a lock doesn't solve the problem

Threads and Threats

1) <u>Sharing process resources</u>

   Threads share the same resources, which might lead to *race* problems!

2) <u>ROOT CINT</u>

   Threads do not work with CINT! So use ACLiC or compile your code.

3) <u>Thread-compatible ROOT</u>

   Your ROOT version might not been build with thread support. If so, recompile!

Exercise for Lecture 9

Write a fully-functional client-server program. The functionality of the server and a client are given in the next slides. A template of the server and client code can be found on *http://kvir03.kvi.nl/rootcourse*

A client-server program

The Server

Main Server:

1) Starts DAQ Thread
2) Wait for Client connections and create Client Thread

DAQ Thread:

Fills continuously a 1D histogram with random numbers

Client Thread:

On request sends 1D histogram to client

A client-server program

The Server

Create global data “his”

```
TH1D his(“his”,””,5000,-4,4);
```

Main server code

```
void exampleServer(UInt_t portNumber=9090) {
```

Create DAQ Thread

```
  TThread *daqThread=new TThread("daqThread", handleDAQ);
  daqThread->Run();
```

Create listen socket

```
  TServerSocket *listenSocket = new TServerSocket(portNumber);
```

Loop for-ever

```
  while (1) {
    cout << "Waiting for connection..." << endl;
```

Accept a client connection

```
    TSocket *srvSocket = listenSocket->Accept();
```

Create Client Thread on connection

```
    TThread *clntThread = new TThread("clntThread",
                                      handleClnt, (void *) srvSocket);
    clntThread->Run();
  }
}
```

The Thread code for DAQ

```
void handleDAQ(void *arg)
{ …}
```

The Thread code for dealing with Client

```
void handleClnt(void *arg)
{…}
```

A client-server program

A Client

Client's functionalities:

openConnection(serverName, portNumber):

- **Connects to server (server creates Client Thread)**

closeConnection():

- **Closes communication with server (server terminates Client Thread)**

drawHisto():

- **Obtain the histogram from server (server sends TH1 object to client)**
- **Plot it**

A client-server program

The Client

Create global objects

```
TSocket  *sock=NULL;
```

Connect to server

```
void openConnection(Char_t *host="localhost",
                    UInt_t portnumber=9090)
{
  sock = new TSocket(host, portnumber);
}
```

Disconnect from server by closing socket

```
void closeConnection()
{
  sock->Close();
}
```

Draw histogram via TCPIP

```
void drawHisto()
{
  ....
}
```