1 Making BUGS Open

BUGS is a long running software project aiming to make modern MCMC techniques based on graphical models available to applied statisticians in an easy to use package. This talk will give an overview of the structure of OpenBUGS the open source version of the BUGS software and the tools used in its creation and maintenance. Interfacing BUGS to R will also be discussed in particular the possibilities for closer coupling than currently available in the BRugs package.

2 Adopt a module

Unique once in a life time opertunity. You can choose which OpenBUGS module you would like to care for. Adopt a module and you can take a precious piece of software home with you to read and play with! Hundreds of modules to choose from but many thousands of BUGS users. Hurry while stocks last!

3 Happy modules

Would an OpenBUGS module be happy with you? Some questions to ask yourself: what is a module? what is a class? what is an object? what is a factory object? what is an interface? what is the difference between client and extension interfaces? why are concrete classes hidden? what is metaprogramming? what do I do with blue diamonds? why are trap messages helpful? what is the Hollywood principle of programming? can I program in C?

4 Myth I

BUGS is one big scary monster

Reality

BUGS is lots of friendly little bits

5 Myth II

BUGS is writen in a strange complicated language

Reality

Component Pascal is a very simple powerful language

6 Myth III

BUGS uses strange developement tools

Reality

BlackBox tools are very simple to use (they are also free...)

7 Myth IV

Open source software must be developed in C/C++ using GNU tools

Reality

Open source software must be developed in C/C++ using GNU tools

8 Myth V

Software technology has not changed in the past 20 years

Reality

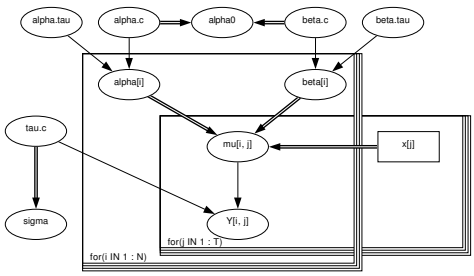
There is Microsoft, there is Linux, there is the Intel based PC (and the Mac...)

9 How BUGS works

Create lots of objects, wire them together and then get the objects to talk to each other.

Need a plan of how to do this

10 The plan



11 Bayesian graphical models

The type of plan BUGS understands is called a bayesian graphical model.

Bayesian graphical models describe conditional idependence assumptions

Give factorization of joint probability distribution

12 Graphs as (formal) language

```
model
{
   for( i in 1 : N ) {
      for( j in 1 : T ) {
         Y[i , j] ~ dnorm(mu[i , j],tau.c)
         mu[i , j] <- alpha[i] + beta[i] * (x[j] - xbar)
      }
      alpha[i] ~ dnorm(alpha.c,alpha.tau)
      beta[i] ~ dnorm(beta.c,beta.tau)
   }
   tau.c ~ dgamma(0.001,0.001)
   sigma <- 1 / sqrt(tau.c)
   alpha.c ~ dnorm(0.0,1.0E-6)
   alpha.tau ~ dgamma(0.001,0.001)
   beta.c ~ dnorm(0.0,1.0E-6)
```

13 Compilation

Turning description in one language into equivalent description in another language

Can add extra information

New description can be executable

14 An analogy

Science program writen in fortran

Compiled to assembly language

Assembly language - low level instruction that cause the CPU to do things

15 An analogy continued

Statistical model writen as a graph

Compiled into inference algorithm

Inference algorithm executed

16 Inference algorithms

Many possibilities

Want good natured algorithm not fussy about what it is asked to do.

MCMC simulation good choice

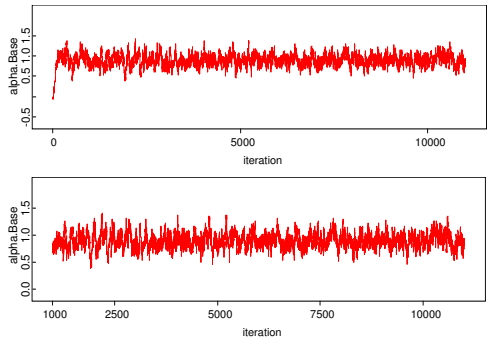
17 MCMC simulation

Generate lots of random numbers

After a bit calculate averages of these random numbers

Also can calculate quartiles, kernel densities etc.

18 MCMC simulation continued



	mean	sd	MC_error	val2.5pc	median	val97.5pc	start	sample
alpha.Base	0.8934	0.1388	0.006738	0.6265	0.8891	1.173	1001	10000

19 The BUGS software

BUGS has to do lots of tasks.

This does not make BUGS one big scary monster.

BUGS contains subsystems to perform specific tasks

Each subsystem consists of a number of modules

Each module is small and easy to understand

20 Tasks and subsystems

Describing graphical models
Doodle subsystem

Compiling graphical model
Bugs subsystem

Probability calculations
Graph subsystem

MCMC simulation
Updater subsystem

Summary statistics
Samples, Summary, Ranks, Deviance subsystems

21 Subsystems and modules I

Subsystems can consist of a small number of modules or a large number

Samples subsystem is small

SamplesMonitors SamplesIndex SamplesInterface
SamplesFormatted SamplesEmbed SamplesViews
SamplesPlots SamplesCmds SamplesCorrelat
SamplesDensity SamplesDiagnostics SamplesHistory
SamplesQuantiles SamplesTrace

22 Subsystems and modules contd

Graph subsystem is large

GraphRules GraphNodes GraphLogical GraphStochastic
GraphScalar GraphVector GraphUnivariate
GraphMultivariate GraphConjugateMV GraphChain
GraphConstant GraphCompile GraphStack GraphMixture
GraphFlat GraphGeneric GraphBlock
GraphCloglog GraphCut GraphEigenvals GraphGammap
GraphInprod GraphInverse GraphKepler GraphLog
GraphLogdet GraphLogit GraphProbit GraphProduct
GraphRanks GraphPValue GraphSumation GraphTable
GraphFunctional GraphODEmath GraphODElang
GraphPredictive GraphBern GraphBinomial GraphCat
GraphFounder GraphGeometric GraphGEV
GraphHypergeometric GraphMendelian GraphNegbin
GraphPoisson GraphRecessive GraphMultinom
GraphBeta GraphChisqr GraphDbexp GraphExp GraphF
GraphGamma GraphGengamma GraphLogistic
GraphLognorm GraphNormal GraphPareto
GraphPolygene GraphT GraphTrapezium GraphUniform
GraphWeibull GraphWeibullShifted GraphDirichlet
GraphMVNormal GraphMVT GraphRENormal
GraphStochtrend GraphWishart

23 Subsystems and modules II

BUGS consists of 15 subsystems

5 Windows only subsystems

BUGS consists of 263 modules

63 windows only modules

BUGS is a small system

24 Styles of modules in BUGS

Many different styles of module in BUGS both within and between subsystems.

Example the BugsNames modules contains 78 statements, the BugsInterpreter module contains 20 statements

In general modules either implement algorithms or they establish concepts

25 What is a module (in CP)

A module is a package of source code with a well defined interface

A module is a unit of compilation

A module is a unit of loading

A module knows what services it provides (syntaxticaly)

A module can make "use" of other modules

Under the "use" relation modules are arranged in a DAG

26 Languages other than CP

Weird languages have weird ideas (they just happened)

Header files

Include

Name spaces

Only classes

main{}

Dynamic link libraries

27 Software developement tools

These tools are never free

These tools are often very complex

These tools often do tasks that are not needed (or should not be needed)

Best to use commonly used tools (it's nice to be in a crowd)

28 Object orientated software I

Objects are the easy bit

Designing the classes is the hard bit

(Code) Inheritance is evil

Methods should not be extended

Composition is good

29 Object orientated software II

Large class hierarchies can be a nightmare

Multiple inheritance deepens that nightmare

Need tools that control the complexity of the hierarchy

Need IDL to describe software

30 IDL Interface Definition Language

```
DEFINITION GraphNodes;

   TYPE
      Factory = POINTER TO ABSTRACT RECORD
         (f: Factory) New (option: INTEGER): Node, NEW, ABSTRACT
      END;

      List = POINTER TO RECORD
         node-: Node;
         next-: List
      END;

      Node = POINTER TO ABSTRACT RECORD
         props-: SET;
         (node: Node) AddParent (VAR list: List), NEW;
         (node: Node) Check (): SET, NEW, ABSTRACT;
         (node: Node) Init, NEW, ABSTRACT;
         (node: Node) Parents (): List, NEW, ABSTRACT;
         (node: Node) Representative (): Node, NEW, ABSTRACT;
         (node: Node) Set (IN args: Args; OUT res: SET), NEW, ABSTRACT;
         (node: Node) SetProps (props: SET), NEW;
         (node: Node) Signature (OUT signature: ARRAY OF CHAR), NEW, ABSTRACT;
         (node: Node) Size (): INTEGER, NEW, ABSTRACT;
         (node: Node) Value (): REAL, NEW, ABSTRACT
      END;

      Vector = POINTER TO ARRAY OF Node;

      Args = ABSTRACT RECORD
         valid: BOOLEAN;
         (VAR args: Args) Init, NEW, ABSTRACT
      END;

   PROCEDURE SetFactory (f: Factory);

END GraphNodes.
```

31 More IDL

```
DEFINITION GraphLogical;
   IMPORT GraphNodes;

   TYPE
      List = POINTER TO RECORD
         node-: Node;
         next-: List
      END;

      Node = POINTER TO ABSTRACT RECORD (GraphNodes.Node)
         level-: INTEGER;
         parents-: List;
         (node: Node) AddToList (VAR list: List), NEW;
         (node: Node) CalculateLevel, NEW;
         (node: Node) ClassFunction (parent: GraphNodes.Node): INTEGER, NEW,
              ABSTRACT;
         (node: Node) ClearLevel, NEW;
         (node: Node) HandleMsg (msg: INTEGER), NEW, EMPTY;
         (node: Node) Init;
         (node: Node) Optimize (parent: GraphNodes.Node), NEW, EMPTY;
         (node: Node) StoreParents, NEW
      END;

      Vector = POINTER TO ARRAY OF Node;

      Args = RECORD (GraphNodes.Args)
         numConsts, numOps, numScalars, numVectors: INTEGER;
         consts: ARRAY 50 OF REAL;
         scalars: ARRAY 50 OF GraphNodes.Node;
         ops: ARRAY 100 OF INTEGER;
         vectors: ARRAY 10 OF GraphNodes.SubVector;
         (VAR args: Args) Init
      END;

   PROCEDURE Ancestors (node: GraphNodes.Node): List;
END GraphLogical.
```

32 Metaprogramming

Self awareness for software

Software can ask itself questions

Is there an item called FooBar?

What sort of item is FooBar?

Do this with item FooBar

33 Metaprogramming cont

Can ask if a module of given name is loaded and if so to return its metadata

Can ask to load a module of given name and return its metadata

Can ask a module's metadata if it contains an item with a given name and type

Modules metadata limited to what is in the modules inteface

34 Metaprogramming example

```
DEFINITION GraphT;

  IMPORT GraphNodes;

  VAR fact-: GraphNodes.Factory;

  PROCEDURE Install;

END GraphT.
```

Can ask to load module GraphT and return its metadata

Can ask metadata if there is a procedure called Install (with signiture no arguments)

Can ask to execute the Install procedure

35 Metaprogramming and BUGS

Used in many places

To support the BUGS language

To load sampling algorithms

To load data reading algorithms

To construct GUI interface

To implement scripting

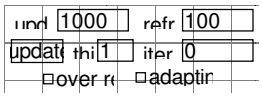
To interface to R

36 BUGS language support

Grammar file (snipet)

```
dbern     "GraphBern.Install"
dbeta     "GraphBeta.Install"
dbin      "GraphBinomial.Install"
dcat      "GraphCat.Install"
dchisqr   "GraphChisqr.Install"
ddexp     "GraphDbexp.Install"
dexp      "GraphExp.Install"
dnorm     "GraphNormal.Install"
dt        "GraphT.Install"
```

37 GUI and BUGS




```
Definition BugsCmds;

  TYPE
      UpdateDialog = POINTER TO RECORD
        iteration-, refresh, thin, updates: INTEGER;
        isAdapting-, overRelax: BOOLEAN
      END;

  VAR   updateDialog: UpdateDialog;

  PROCEDURE Update;

  PROCEDURE UpdateGuardWin (VAR par: Dialog.Par);
```

38 Scripting and BUGS

modelCheck(^0) --->

"BugsCmds.SetFilePath('^0'); BugsCmds.ParseGuard;
BugsCmds.ParseFile"

modelUpdate(^0) -->

"BugsCmds.updateDialog.updates := ^0;
BugsCmds.UpdateGuard; BugsCmds.Update"

samplesStats(^0) -->

"SamplesCmds.SetVariable('^0'); SamplesCmds.StatsGuard;
SamplesCmds.Stats"

39 R and BUGS makes BRugs

R has a nice paste function

R can talk to dynamic link libraries

Dynamic link library can use metaprogramming to talk to BUGS

Few technical problems: heap management most difficult

BRugs package up on CRAN thanks to Uwe and Sibyle

40 R and BUGS's Guts

New OpenBUGS module BugsRobjects to help R see and interact with OpenBUGS internal data structures

Can set node values

Can look at node values

Can program higher level algorithms in R

Can load data / inits from R objects (no need for textual representation)

41 Adopt a module (please)

BUGS has become OpenBUGS

Open source software needs active developers

OpenBUGS is small and friendly (just don't mention C)

You can make a difference -- take a module home today!