Introduction to `grace` system

Y. Kurihara and T. Kaneko

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Contents:

1. Introduction

- Problem:
  - Too many processes in high energy collider physics
  - Too many Feynman graphs for a process with many final pariticles.

Example:

$- pp \Rightarrow W + 3jet$

31 processes

736 Tree Feynman Graphs

20915 One-loop Feynman Graphs

$- pp \Rightarrow W + 4jet$

96 processes

9716 Tree Feynman Graphs

414906 One-loop Feynman Graphs

(initial 1 generation, final 2 generations)

- Solution
  Automatize pertubative calculation on computers.
  - Generation of Feynman graphs
  - Generation of code for calculation
  - Without approximation
  - Generation of event generator

- Status of `grace`
  - Full automatic for tree processes: (2 $\Rightarrow$ 6, 7, 8, ...)
    - Electro-weak
    - SUSY (MSSM)
    - QCD with Parton shower/PDF

    This tutorial is for tree processes.

– Automatic code generation for 1-loop processes:
(2 $\Rightarrow$2, 3)

* Electro-weak
* SUSY (MSSM)

Calculation requires large CPU time for 2 $\Rightarrow$3, ...
Need to write many scripts to run jobs.

– Automatic generation NLO QCD processes

* Generation of Matrix Elements
* NLO parton shower
* Hadronization

In progress

– Event generators

  * grc4f
  * susy23
  * GR@PPA
  * Used in KORALW

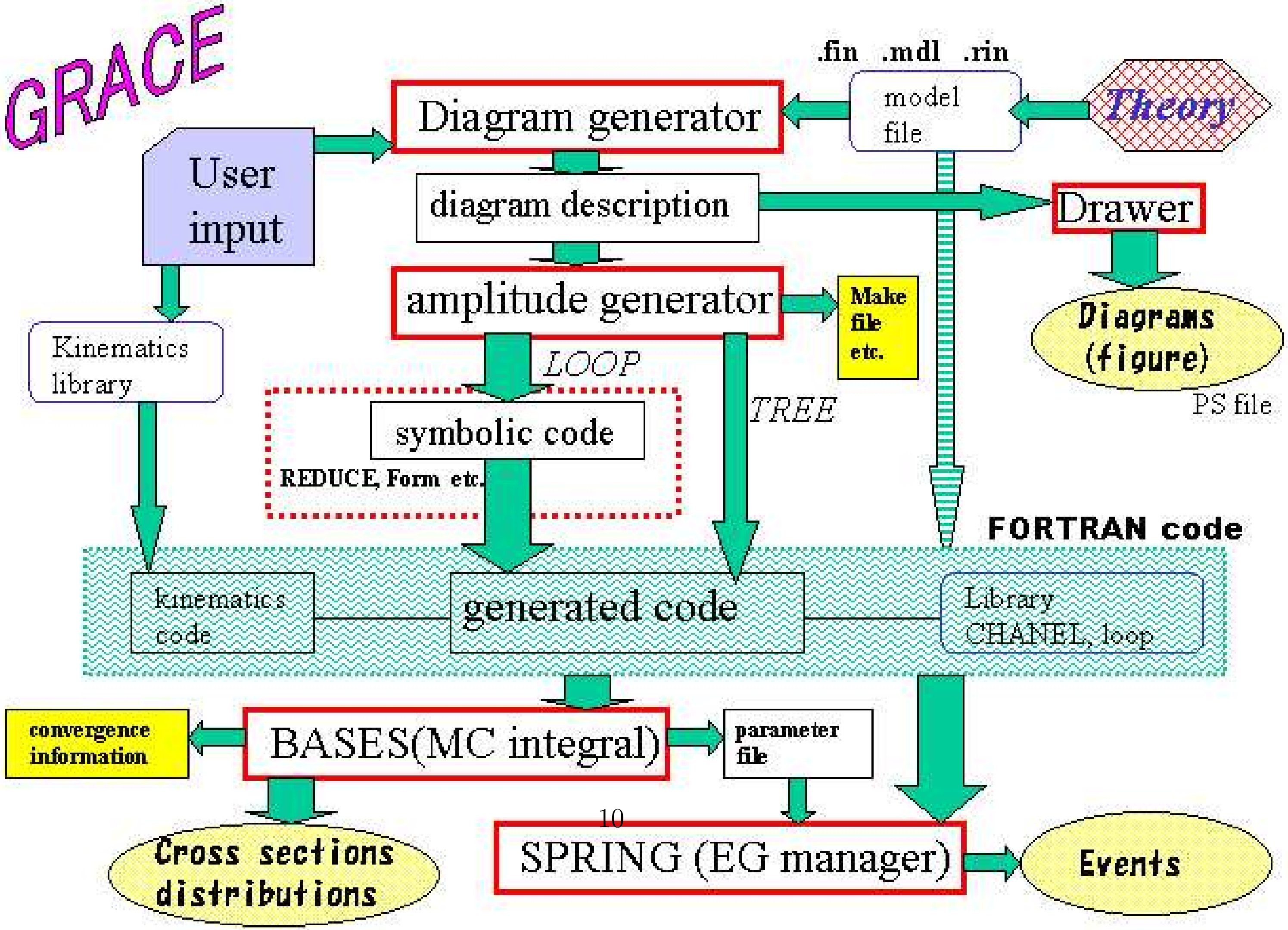
Joint to `grace` project!

2. Structure of grace

- input
  - in.prc : Description of processes
  - *.mdl : Description of the model
  - *.fin : Model dependent run-time routines
- output
  - *.f etc. : Generated code
  - Histograms : Value of cross section
  - Events : Generated events

For tree processes

1. Graph generation (`grc`: all order)
2. Graph drawing (`gracefig`, `grcdraw`)
3. Generation of Fortran code (`grcfort`)
4. Library of helicity amplitude (`chanel`)
5. Kinematics library (`dbkinem`)
6. Phase space integration (`bases`)
7. Event generation (`spring`)


GRACE
.fin .mdl .rin
Diagram generator
model file
Theory
User input
diagram description
Drawer
amplitude generator
Make file etc.
Diagrams (figure)
Kinematics library
LOOP
TREE
PS file
symbolic code
REDUCE, Form etc.
FORTRAN code
kinematics code
generated code
Library CHANEL, loop
convergence information
BASES(MC integral)
parameter file
Cross sections distributions
SPRING (EG manager)
Events

Confirmation of the results

- Gauge invariance at one phase space point.
  $\sim$ 15 digits in double precision
  $\sim$ 30 digits in quadruple precision

$\Rightarrow$ logical consistency of generated code.

$\Rightarrow$ correctness of small contributing terms.
$\Rightarrow$may give large contributions for different parameters or conditions.

$\Rightarrow$ check numerical stability.

4. Installation

1. System Requirement
   (a) ANSI C compiler
   (b) Fortran 77 compiler
   (c) Standard Unix commands
   (d) X Window system : optional for drawing graphs
   (e) Motif Toolkit or its clone (`OpenMotif`, `lesstif`) : optional for drawing graphs

2. Getting source code:

```
http://minami-home.kek.jp/
```

3. Expand source code:

```
tar xvzf grace.220.yyyy.mmdd.tgz
```

4. Configuration:

```
cd grace.2.2.0
./Config.sh
```

5. Compilation:

```
make
make install
```

6. Check system:

```
make test-install
```

for $e^+e^- \longrightarrow W^+W^-\gamma$ in SM:

```
tail testinst/sm/eewwa/fort/gauge.out
```

and for $e^+e^- \longrightarrow \gamma\tilde{\chi}_1^+\tilde{\chi}_1^-$ in MSSM:

```
tail testinst/mssm/asw1SW1/fort/gauge.out
```

4. Sample calculation

1. Add commands to search PATH

```
setenv PATH $PATH:$HOME/grace.2.2.0/bin
rehash
```

in "csh" or "tcsh", or

```
PATH=$PATH:$HOME/grace.2.2.0/bin
export PATH
```

in "sh" or "bash".

2. Preparation of input file

(a) Create working directory

```
cd
mkdir grcwork
cd grcwork
```

(b) Copy sample input file “`in.prc`”

```
cp ~/grace.2.2.0/testinst/sm/eewwa/input/in.prc .
```

(c) Edit input file "in.prc"

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Model="sm.mdl";
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Process;
  ELWK=3;
  Initial={electron, positron};
  Final  ={photon W-plus, W-minus};
  Expand=Yes;
  OPI=No;
  Kinem="2302";
Pend;
```

- `Model="sm.mdl";`
  Calculate in standard model
  Try to find in `grace.2.2.0/lib/model/sm.mdl`
- `ELWK=3;`
  The order of Electro-Weak coupling constants is 3
- `Initial={...}`
  Initial particles
- `Final={...}`
  Final particles
- `Kinem="2302";`
  Select kinematics : see `grace.2.2.0d/lib/dbkinem/doc`

(d) Names of particles

Try

```
grep Particle grace.2.2.0/lib/model/sm.mdl
```

For the standard model:

particle	anti-p.	type	charge	color
W-plus	W-minus	vector	1	1
Z	Z	vector	0	1
Photon	Photon	vector	0	1
Gluon	Gluon	vector	0	1

particle	anti-p.	type	charge	color
Higgs	Higgs	scalar	0	1
chi-plus	chi-minus	scalar	1	1
chi-3	chi-3	scalar	0	1

particle	anti-p.	type	charge	color
nu-e	nu-e-bar	fermion	0	1
nu-mu	nu-mu-bar	fermion	0	1
nu-tau	nu-tau-bar	fermion	0	1
electron	positron	fermion	-1	1
muon	anti-muon	fermion	-1	1
tau	anti-tau	fermion	-1	1

particle	anti-p.	type	charge	color
u	u-bar	fermion	2/3	3
c	c-bar	fermion	2/3	3
t	t-bar	fermion	2/3	3
d	d-bar	fermion	-1/3	3
s	s-bar	fermion	-1/3	3
b	b-bar	fermion	-1/3	3

particle	anti-p.	type	charge	color
c-plus	c-plus-bar	ghost	1	1
c-minus	c-minus-bar	ghost	-1	1
c-z	c-z-bar	ghost	0	1
c-a	c-a-bar	ghost	0	1
c-g	c-g-bar	ghost	0	8

3. Feynman graphs generation:

   `grc`

   This command reads "`in.prc`" and creates a file "out.grf".

   You can read "`out.grf`"

4. Draw Feynman graphs:

```
gracefig
```

or for creation of ps file:

```
gracefig -p
```

5. Fortran code generation

```
grcfort
```

The generated code is compiled by

```
make make integ make spring
```

or

```
make all
```

6. Gauge invariance check

```
./gauge
```

For the confirmation of the values of parameters: uncomment the line in "gauge.f"

```
CC call prmass
```

7. Integration over phase space

```
./integ
```

You should carefully examine the convergence behavior of of the integration. If the convergence is not so good, you must increase the number of sampling points or replace kinematics routines.

8. Event generation

```
./spring
```