Title: Tutorial 2A: O(N) bootstrap equations. Bootstrapping O(N) islands with the cutting surface algorith

Speakers: Ning Su

Collection: Mini-Course of Numerical Conformal Bootstrap

Date: April 25, 2023 - 1:30 PM

URL: https://pirsa.org/23040140

autoboot_demo.nb * - Wolfram Mathematica 11.1

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load autoboot

```
Quit[];

GetFileDirectory[] := If[$InputFileName === "", NotebookDirectory[], DirectoryName@$InputFileName];
AppendTo[$Path, GetFileDirectory[]];
<< "group.m"
SetDirectory[GetFileDirectory[]];
```

Ising

```
z2 = getGroup[2, 1];
setGroup[z2];
setOps[{op[eps, z2[id]], op[sig, rep[2]]}];
format[eq = bootAll[]]
```

$$\text{eqn}\left[\left\{\beta^2_{\text{sig,sig,eps},1}\, F^{\{\text{eps,sig,eps,sig}\}}_{\text{sig}} + \sum_{\text{op}\in\text{rep}[2]-}\left[\beta^2_{\text{eps,sig,op},1}\, F^{\{\text{eps,sig,eps,sig}\}}\right] + \sum_{\text{op}\in\text{rep}[2]+}\left[\beta^2_{\text{eps,sig,op},1}\, F^{\{\text{eps,sig,eps,sig}\}}\right],\right.$$

$$\left.\{\text{eps,eps,sig,sig}\} \qquad \{\text{eps,eps,sig,sig}\} \qquad \{\text{eps,sig,sig,eps}\}\right.$$

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Ising

```
z2 = getGroup[2, 1];
setGroup[z2];
setOps[{op[eps, z2[id]], op[sig, rep[2]]}];
format[eq = bootAll[]]
```

$$\text{eqn}\Big[\Big\{\beta^2_{\text{sig,sig,eps,1}}\,F^{\{\text{eps,sig,eps,sig}\}}_{\text{sig}} + \sum_{\text{op}\in\text{rep}[2]^-}\Big[\beta^2_{\text{eps,sig,op,1}}\,F^{\{\text{eps,sig,eps,sig}\}}\Big] + \sum_{\text{op}\in\text{rep}[2]^+}\Big[\beta^2_{\text{eps,sig,op,1}}\,F^{\{\text{eps,sig,eps,sig}\}}\Big],$$

$$H^{\{\text{eps,eps,sig,sig}\}}_{0} + \beta_{\text{eps,eps,eps,1}}\,\beta_{\text{sig,sig,eps,1}}\,H^{\{\text{eps,eps,sig,sig}\}}_{\text{eps}} - \beta^2_{\text{sig,sig,eps,1}}\,H^{\{\text{eps,sig,sig,eps}\}}_{\text{sig}} +$$

$$\sum_{\text{op}\in\text{rep}[2]^-}\Big[\beta^2_{\text{eps,sig,op,1}}\,H^{\{\text{eps,sig,sig,eps}\}}\Big] + \sum_{\text{op}\in\text{rep}[1]^+}\Big[\beta_{\text{eps,eps,op,1}}\,\beta_{\text{sig,sig,op,1}}\,H^{\{\text{eps,eps,sig,sig}\}}\Big] -$$

$$\sum_{\text{op}\in\text{rep}[2]^+}\Big[\beta^2_{\text{eps,sig,op,1}}\,H^{\{\text{eps,sig,sig,eps}\}}\Big],\ F^{\{\text{eps,eps,sig,sig}\}}_{0} + \beta_{\text{eps,eps,eps,1}}\,\beta_{\text{sig,sig,eps,1}}\,F^{\{\text{eps,eps,sig,sig}\}}_{\text{eps}} +$$

$$\beta^2_{\text{sig,sig,eps,1}}\,F^{\{\text{eps,sig,sig,eps}\}}_{\text{sig}} - \sum_{\text{op}\in\text{rep}[2]^-}\Big[\beta^2_{\text{eps,sig,op,1}}\,F^{\{\text{eps,sig,sig,eps}\}}\Big] +$$

$$\sum_{\text{op}\in\text{rep}[1]^+}\Big[\beta_{\text{eps,eps,op,1}}\,\beta_{\text{sig,sig,op,1}}\,F^{\{\text{eps,eps,sig,sig}\}}\Big] + \sum_{\text{op}\in\text{rep}[2]^+}\Big[\beta^2_{\text{eps,sig,op,1}}\,F^{\{\text{eps,sig,sig,eps}\}}\Big],$$

$$F^{\{\text{sig,sig,sig,sig}\}}_{0} + \beta^2_{\text{sig,sig,eps,1}}\,F^{\{\text{sig,sig,sig,sig}\}}_{\text{eps}} + \sum_{\text{op}\in\text{rep}[1]^+}\Big[\beta^2_{\text{sig,sig,op,1}}\,F^{\{\text{sig,sig,sig,sig}\}}\Big],$$

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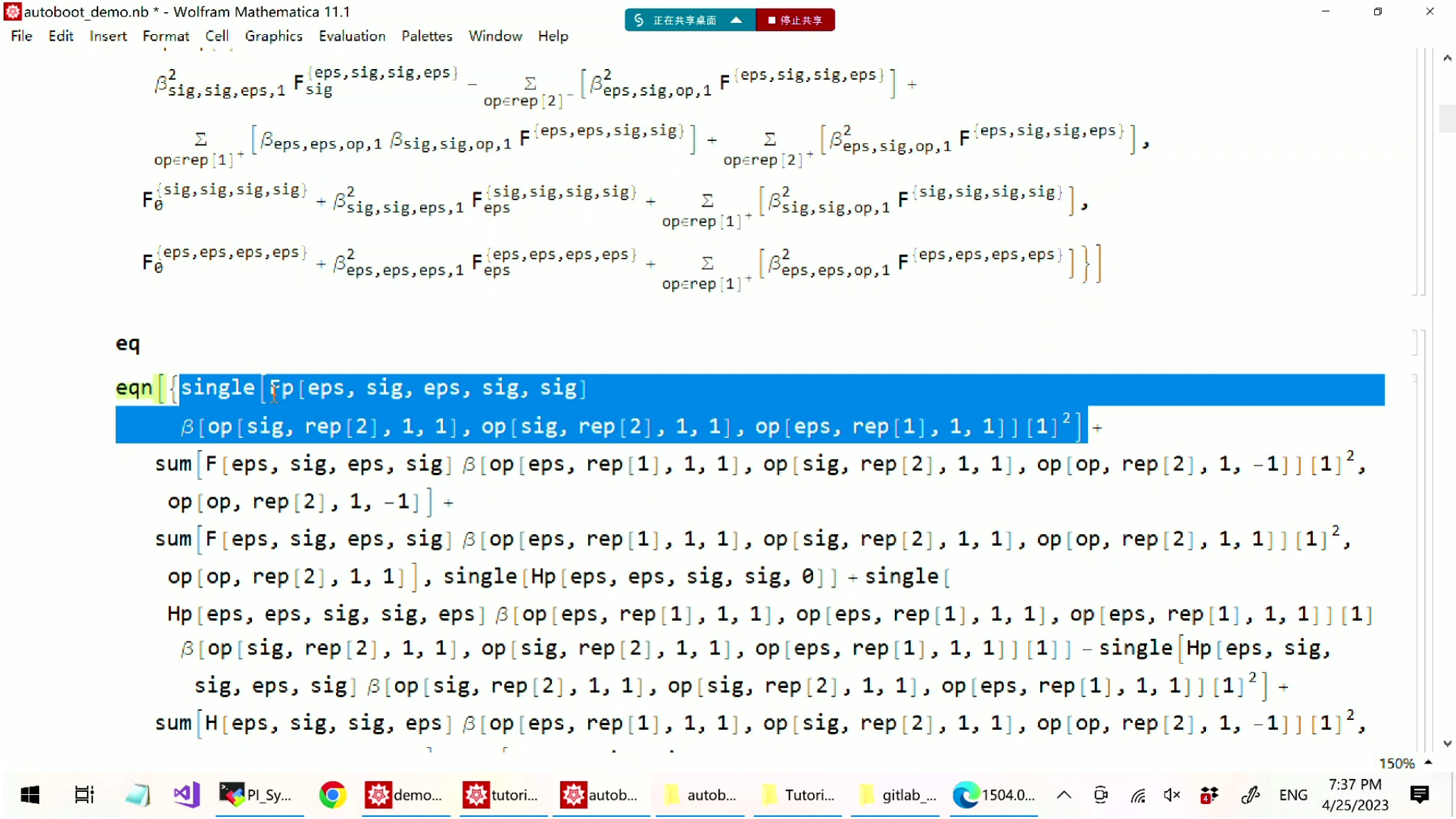
autoboot_demo.nb * - Wolfram Mathematica 11.1
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File Edit Insert Format Cell Graphics Evaluation Palettes Window Help
eq
eqn[{single[Fp[eps, sig, eps, sig, sig]
β[op[sig, rep[2], 1, 1], op[sig, rep[2], 1, 1], op[eps, rep[1], 1, 1]][1]^2] +
sum[F[eps, sig, eps, sig] β[op[eps, rep[1], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[2], 1, -1]][1]^2,
op[op, rep[2], 1, -1]] +
sum[F[eps, sig, eps, sig] β[op[eps, rep[1], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[2], 1, 1]][1]^2,
op[op, rep[2], 1, 1]], single[Hp[eps, eps, sig, sig, 0]] + single[
Hp[eps, eps, sig, sig, eps] β[op[eps, rep[1], 1, 1], op[eps, rep[1], 1, 1], op[eps, rep[1], 1, 1]][1]
β[op[sig, rep[2], 1, 1], op[sig, rep[2], 1, 1], op[eps, rep[1], 1, 1]][1]] - single[Hp[eps, sig,
sig, eps, sig] β[op[sig, rep[2], 1, 1], op[sig, rep[2], 1, 1], op[eps, rep[1], 1, 1]][1]^2] +
sum[H[eps, sig, sig, eps] β[op[eps, rep[1], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[2], 1, -1]][1]^2,
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```
GetFileDirectory[]:=If[$InputFileName==="",NotebookDirectory[],DirectoryName@$InputFileName];
SetDirectory@GetFileDirectory[];

Get["AutoEqu.m"];
```

Ising

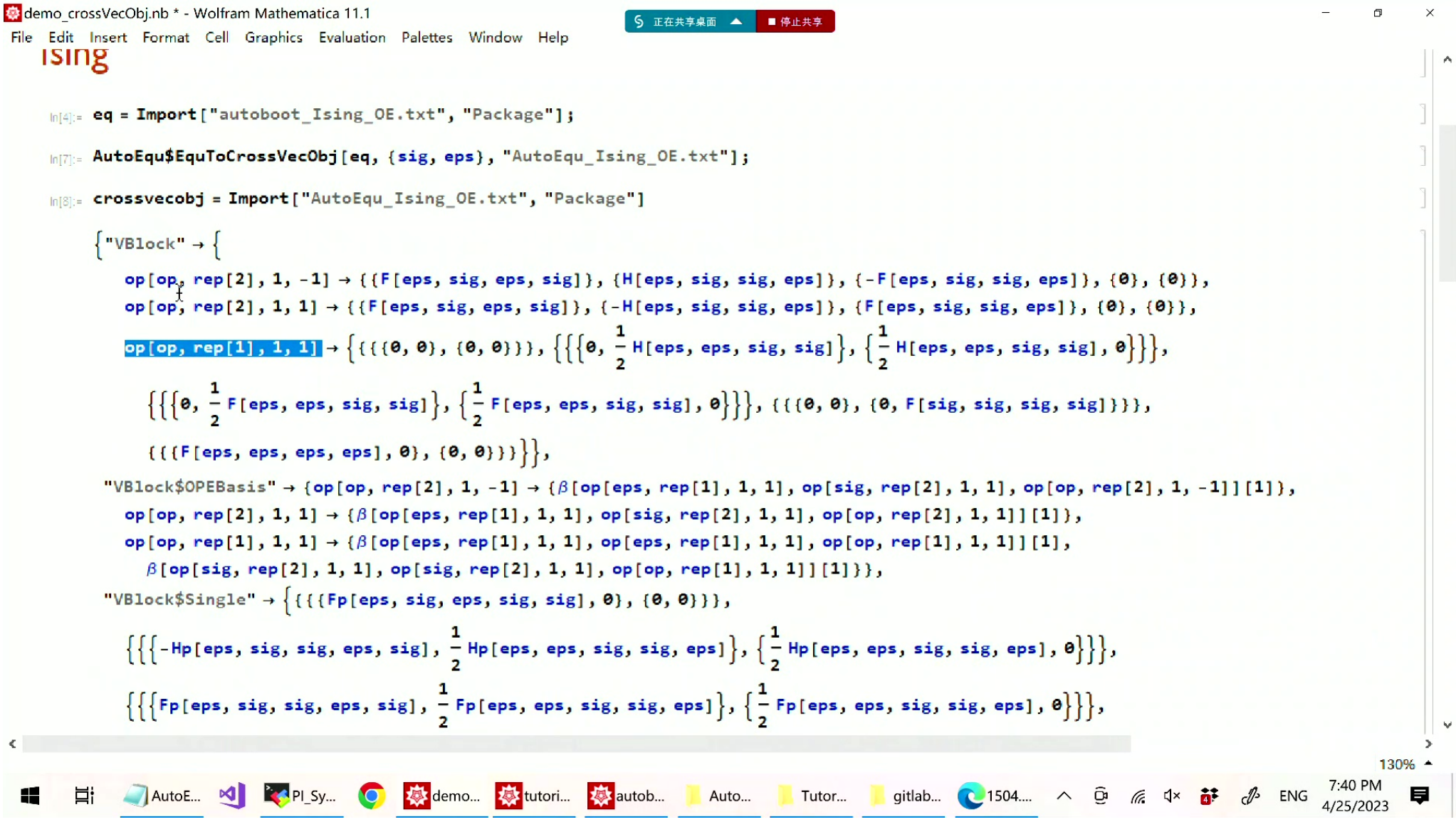
```
eq = Import["autoboot_Ising_OE.txt", "Package"];

AutoEqu$EquToCrossVecObj[eq, {sig, eps}, "AutoEqu_Ising_OE.txt"];

crossvecobj = Import["AutoEqu_Ising_OE.txt", "Package"]
```

```
{VBlock → {op[op, rep[2], 1, -1] → {{F[eps, sig, eps, sig]}, {H[eps, sig, sig, eps]}, {-F[eps, sig, sig, eps]}, {0}, {0}},
   op[op, rep[2], 1, 1] → {{F[eps, sig, eps, sig]}, {-H[eps, sig, sig, eps]}, {F[eps, sig, sig, eps]}, {0}, {0}},
   op[op, rep[1], 1, 1] → {{{0, 0}, {0, 0}}}, {{{0, -1/2 H[eps, eps, sig, sig]}, {1/2 H[eps, eps, sig, sig], 0}}},
    {{{0, -1/2 F[eps, eps, sig, sig]}, {1/2 F[eps, eps, sig, sig], 0}}}, {{{0, 0}, {0, F[sig, sig, sig, sig]}}}, {{{F[eps, eps, eps, eps], 0}, {0, 0}}}}},
 VBlock$OPEBasis → {op[op, rep[2], 1, -1] → {β[op[eps, rep[1], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[2], 1, -1]][1]},
   op[op, rep[2], 1, 1] → {β[op[eps, rep[1], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[2], 1, 1]][1]}, op[op, rep[1], 1, 1] →
    {β[op[eps, rep[1], 1, 1], op[eps, rep[1], 1, 1], op[op, rep[1], 1, 1]][1], β[op[sig, rep[2], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[1], 1, 1]][1]}},
 VBlock$Single → {{{Fp[eps, sig, eps, sig, sig], 0}, {0, 0}}}, {{{-Hp[eps, sig, sig, eps, sig], -1/2 Hp[eps, eps, sig, sig, eps]}, {1/2 Hp[eps, eps, sig, sig, eps], 0}}},
   {{{Fp[eps, sig, sig, eps, sig], -1/2 Fp[eps, eps, sig, sig, eps]}, {1/2 Fp[eps, eps, sig, sig, eps], 0}}},
   {{{Fp[sig, sig, sig, sig, eps], 0}, {0, 0}}}, {{{0, 0}, {0, Fp[eps, eps, eps, eps, eps]}}}}, VBlock$Single$OPEBasis →
  {β[op[sig, rep[2], 1, 1], op[sig, rep[2], 1, 1], op[eps, rep[1], 1, 1]][1], β[op[eps, rep[1], 1, 1], op[eps, rep[1], 1, 1], op[eps, rep[1], 1, 1]][1]},
 VBlock$Deriv → {{odd}, {even}, {odd}, {odd}, {odd}},
```

100%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Ising
In[4]:= eq = Import["autoboot_Ising_OE.txt", "Package"];
In[7]:= AutoEqu$EquToCrossVecObj[eq, {sig, eps}, "AutoEqu_Ising_OE.txt"];
In[8]:= crossvecobj = Import["AutoEqu_Ising_OE.txt", "Package"]
{"VBlock" → {
op[op, rep[2], 1, -1] → {{F[eps, sig, eps, sig]}, {H[eps, sig, sig, eps]}, {-F[eps, sig, sig, eps]}, {0}, {0}},
op[op, rep[2], 1, 1] → {{F[eps, sig, eps, sig]}, {-H[eps, sig, sig, eps]}, {F[eps, sig, sig, eps]}, {0}, {0}},
op[op, rep[1], 1, 1] → {{{{0, 0}, {0, 0}}}, {{{0, 1/2 H[eps, eps, sig, sig]}, {1/2 H[eps, eps, sig, sig], 0}}},
{{{0, 1/2 F[eps, eps, sig, sig]}, {1/2 F[eps, eps, sig, sig], 0}}}, {{{0, 0}, {0, F[sig, sig, sig, sig]}}},
{{{F[eps, eps, eps, eps], 0}, {0, 0}}}}},
"VBlock$OPEBasis" → {op[op, rep[2], 1, -1] → {β[op[eps, rep[1], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[2], 1, -1]][1]},
op[op, rep[2], 1, 1] → {β[op[eps, rep[1], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[2], 1, 1]][1]},
op[op, rep[1], 1, 1] → {β[op[eps, rep[1], 1, 1], op[eps, rep[1], 1, 1], op[op, rep[1], 1, 1]][1],
β[op[sig, rep[2], 1, 1], op[sig, rep[2], 1, 1], op[op, rep[1], 1, 1]][1]}},
"VBlock$Single" → {{{{Fp[eps, sig, eps, sig, sig], 0}, {0, 0}}},
{{{-Hp[eps, sig, sig, eps, sig], 1/2 Hp[eps, eps, sig, sig, eps]}, {1/2 Hp[eps, eps, sig, sig, eps], 0}}},
{{{Fp[eps, sig, sig, eps, sig], 1/2 Fp[eps, eps, sig, sig, eps]}, {1/2 Fp[eps, eps, sig, sig, eps], 0}}},
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$$V_\theta = V_{\text{even}}(\Delta = \Delta_\epsilon, l = 0) + V_{\text{odd}}(\Delta = \Delta_\sigma, l = 0) \otimes \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

Crossing vectors

Channel name :

rep[1] : Z_2 even
rep[2] : Z_2 odd

```
crossvecobj=LoadExpression["AutoEqu_Ising_OE.txt"];
```

```
ObjGet[crossvecobj, "VBlock"]
```

$$\{op[op, rep[2], 1, -1] \to \{\{F[eps, sig, eps, sig]\}, \{H[eps, sig, sig, eps]\}, \{-F[eps, sig, sig, eps]\}, \{0\}, \{0\}\},$$
$$op[op, rep[2], 1, 1] \to \{\{F[eps, sig, eps, sig]\}, \{-H[eps, sig, sig, eps]\}, \{F[eps, sig, sig, eps]\}, \{0\}, \{0\}\},$$
$$op[op, rep[1], 1, 1] \to \left\{\{\{\{0, 0\}, \{0, 0\}\}\}, \left\{\left\{\left\{0, \frac{1}{2} H[eps, eps, sig, sig]\right\}\right\}, \left\{\left\{\frac{1}{2} H[eps, eps, sig, sig], 0\right\}\right\}\right\},\right.$$
$$\left.\left\{\left\{\left\{0, \frac{1}{2} F[eps, eps, sig, sig]\right\}\right\}, \left\{\left\{\frac{1}{2} F[eps, eps, sig, sig], 0\right\}\right\}\right\},\right.$$
$$\left.\{\{\{0, 0\}, \{0, F[sig, sig, sig, sig]\}\}\}, \{\{\{F[eps, eps, eps, eps], 0\}, \{0, 0\}\}\}\right\}$$

```
ObjGet[crossvecobj, "VBlock", op[op, rep[1], 1, 1]] // MatrixForm
```

$$\begin{pmatrix} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ 0 \qquad \frac{1}{2} H[eps, eps, sig, sig] \end{pmatrix}$$

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$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$

Crossing vectors

Channel name :

rep[1] : Z_2 even
rep[2] : Z_2 odd

In[9]:=
```
crossvecobj=LoadExpression["AutoEqu_Ising_OE.txt"];
```

In[17]:=
```
ObjGet[crossvecobj, "VBlock"]
```

Out[17]=
```
{op[op, rep[2], 1, -1] → {{F[eps, sig, eps, sig]}, {H[eps, sig, sig, eps]}, {-F[eps, sig, sig, eps]}, {0}, {0}},
 op[op, rep[2], 1, 1] → {{F[eps, sig, eps, sig]}, {-H[eps, sig, sig, eps]}, {F[eps, sig, sig, eps]}, {0}, {0}},
 op[op, rep[1], 1, 1] → {{{{0, 0}, {0, 0}}}, {{{0, 1/2 H[eps, eps, sig, sig]}}, {{1/2 H[eps, eps, sig, sig], 0}}},
   {{{0, 1/2 F[eps, eps, sig, sig]}}, {{1/2 F[eps, eps, sig, sig], 0}}},
   {{{0, 0}, {0, F[sig, sig, sig, sig]}}}, {{{F[eps, eps, eps, eps], 0}, {0, 0}}}}}
```

```
ObjGet[crossvecobj, "VBlock", op[op, rep[1], 1, 1]] // MatrixForm
```

$$\begin{pmatrix} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} & \\ 0 & \frac{1}{2} H[\text{eps}, \text{eps}, \text{sig}, \text{sig}] \\ \vdots & \end{pmatrix}$$

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{"item1"->content1, "item2"->content2, ...}
where content could be a object or a list of objects.

This functionality is similar to Mathematica Association but inequivalent.
Note : the prototype version of simpleboot was develop in Mathematica 8, which don't have Associations. ObjGet, ObjSet was designed to organize structured data in simpleboot and used in many places. Now it's hard to switch to Association.

ObjSet
ObjSet[obj,item]=value : set a value for certain item in the object

ObjGet
ObjGet[obj,item1, item2, ...] : get a value for inside the object. It works recursively. item could be n;;m if the corresponding data is a list of object.

Example:

```
In[19]:= obj1 = {"A" -> {{"α" -> {1, 2}, "β" -> {4, 5}}, {"α" -> {2, 7}, "β" -> {8, 9}}, {"α" -> {x, y}, "β" -> {10, 11}}}, "B" -> 2};

In[20]:= ObjGet[obj1, "A"]

Out[20]= {{α → {1, 2}, β → {4, 5}}, {α → {2, 7}, β → {8, 9}}, {α → {x, y}, β → {10, 11}}}

In[21]:= ObjGet[obj1, "A", 2 ;; 3]

Out[21]= {{α → {2, 7}, β → {8, 9}}, {α → {x, y}, β → {10, 11}}}

ObjGet[obj1, "A", 2 ;; 3]
ObjGet[obj1, "A", 2 ;; 3, "α"]
ObjGet[obj1, "A", 2 ;; 3, "α", 1 ;; 2]
```

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To use full functionality, simpleboot need automatic SSH login and SLURM cluster.

Automatic SSH login : SSH can be configured to passwordless login based RSA keys. See .

If automatic SSH login is not available, or SLURM cluster is not available, one can still operate simpleboot manually in a linux system with Mathematica. This section contains information for those scenarios.

Simpleboot in manual SSH mode

Simpleboot on non-SLURM cluster

Simpleboot without cluster

Control the cluster

Input : bootstrap condition

$$V_{\text{even}} = \left(\begin{pmatrix} F^{11,11}_{-,\Delta,l} & 0 \\ 0 & 0 \end{pmatrix}, \begin{pmatrix} 0 & 0 \\ 0 & F^{22,22}_{-,\Delta,l} \end{pmatrix}, \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}, \ldots, \ldots, 1, 11\,22 \right), \quad V_{\text{odd}} = \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, F^{12,12}_{-,\Delta,l}, \ldots, 21\,12 \right)$$

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rep[2] : $\mathcal{L}_2$ odd

In[9]:=
```
crossvecobj=LoadExpression["AutoEqu_Ising_OE.txt"];
```

In[27]:=
```
ObjGet[crossvecobj, "VBlock", op[op, rep[1], 1, 1]] // MatrixForm
```

Out[27]//MatrixForm=

$$\begin{pmatrix} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & \frac{1}{2} H[\text{eps}, \text{eps}, \text{sig}, \text{sig}] \\ \frac{1}{2} H[\text{eps}, \text{eps}, \text{sig}, \text{sig}] & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & \frac{1}{2} F[\text{eps}, \text{eps}, \text{sig}, \text{sig}] \\ \frac{1}{2} F[\text{eps}, \text{eps}, \text{sig}, \text{sig}] & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & F[\text{sig}, \text{sig}, \text{sig}, \text{sig}] \end{pmatrix} \\ \begin{pmatrix} F[\text{eps}, \text{eps}, \text{eps}, \text{eps}] & 0 \\ 0 & 0 \end{pmatrix} \end{pmatrix}$$

```
ObjGet[crossvecobj, "VBlock", op[op, rep[1], 1, 1]] // MatrixForm
```

$$\begin{pmatrix} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & \frac{1}{2} H[\text{eps}, \text{eps}, \text{sig}, \text{sig}] \\ \frac{1}{2} H[\text{eps}, \text{eps}, \text{sig}, \text{sig}] & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & \frac{1}{2} F[\text{eps}, \text{eps}, \text{sig}, \text{sig}] \\ \frac{1}{2} F[\text{eps}, \text{eps}, \text{sig}, \text{sig}] & 0 \end{pmatrix} \end{pmatrix}$$

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Gaps

Format :

GapConfiguration is a List of element in one of the following format:

{channel,gap,spins} // this means demand $\alpha \cdot V_{\text{channel}} \geq 0$ for $\Delta >$ gap and L in spins. spins can be a integer or set of integers.

{channel,IndividualOperator[Δ0],spin} // this means demand $\alpha \cdot (V_{\text{channel},\Delta 0,\text{spin}}) \geq 0$

{channel,IndividualOperator[Δ0,ope_List],spin} // this means demand $\alpha \cdot (\text{ope}.V_{\text{channel},\Delta 0,\text{spin}}.\text{ope}) \geq 0$

{channel,IntervalPositivity[Δmin,Δmax],spin} // this means demand $\alpha \cdot V_{\text{channel},\Delta,\text{spin}} \geq 0$ for $\Delta\text{min} < \Delta < \Delta\text{max}$

In[12]:=
```
Clear@GapConfiguration;
GapConfiguration[dim_,lset_]:={
{op[op, rep[2], 1, 1],3,0}, (* α.V_odd>0 for Δ>3 and L=0 *)
{op[op, rep[1], 1, 1],3,0}, (* α.V_even>0 for Δ>3 and L=0 *)

{op[op, rep[1], 1, 1],Δunitary[dim, /],Select[lset, EvenQ[#] && # > 0 & ]},  (* α.V_even>0 for Δ>Δ_unitary and L=2, 4, ... *)
{op[op, rep[2], 1, -1],Δunitary[dim, /],Select[lset, OddQ ]},               (* α.V_odd>0 for Δ>Δ_unitary and L=1, 3, ... *)
{op[op, rep[2], 1, 1],Δunitary[dim, /],Select[lset, EvenQ[#] && # > 0 & ]}  (* α.V_odd>0 for Δ>Δ_unitary and L=2, 4, ... *)
};
```

/ : place holder for spin

SDP template

normalization:

$\alpha \cdot (V_{\text{identity}}) = 1$ with $V_{\text{identity}} = (1 \quad 1) \cdot V_{\text{even}}(\Delta = 0, / = 0) \cdot \begin{pmatrix} 1 \\ 1 \end{pmatrix}$

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Input:
externalOperatorList: the values of the external operators. The order should match with "VBlock$External"
userDefinedVariables: user-defined variable in the template. Format : {"variable1"→value1, "variable2"→value2, ...}
paramFilename: SDP filename. Automatic : AutoCB3$GenerateSDP will choose a proper name automatically.

Output:
SDP filename

Delaunay Search

```
SSH$UploadCurrentNotebook[] (* save and upload current notebook as package (.m) to the cluster *)
```

```
SSH$UploadFile["AutoEqu_Ising_OE.txt"]
```

```
initpts = {{0.5181489, 1.412625}} ~ Join ~ GeneratePointsInRectangular[{0.515, 0.523}, {1.38, 1.45}, 3, 3] // SetPrec;
initpts // ListPlot
```

... N: Requested precision 16 is smaller than $MinPrecision. Using $MinPrecision instead.

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```
In[4]:= eq = Import["autoboot_Ising_OE.txt", "Package"];

In[7]:= AutoEqu$EquToCrossVecObj[eq, {sig, eps}, "AutoEqu_Ising_OE.txt"];

In[8]:= crossvecobj = Import["AutoEqu_Ising_OE.txt", "Package"]
```

O(3)

v,s,t

```
eq = Import["autoboot_O3_VST.txt", "Package"];

crossvecobj = AutoEqu$EquToCrossVecObj[eq, {v, s, t}, "AutoEqu_O3_VST.txt"];

ObjGet[crossvecobj, "VBlock"][[All, 1]]
```

```
{op[op, v[1, -1], 1, -1], op[op, v[1, -1], 1, 1], op[op, v[2, 1], 1, 1], op[op, v[2, -1], 1, -1],
 op[op, v[2, -1], 1, 1], op[op, v[3, -1], 1, -1], op[op, v[3, -1], 1, 1], op[op, v[2, 1], 1, -1],
 op[op, v[1, 1], 1, -1], op[op, v[3, 1], 1, -1], op[op, v[4, 1], 1, 1], op[op, v[0, 1], 1, 1]}
```

```
AutoEqu$GenerateGapTemplate[ObjGet[crossvecobj, "VBlock"][[All, 1]]]
```

v,s,t,t4

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O(3) : vst

In[10]:=
```
o3 = getO[3];
setGroup[o3];
```

VS

```
setOps[{op[s, o3[id]], op[v, v[1, -1]]}];

format[eq = bootAll[]]
```

$$\text{eqn}\left[\left\{\beta^2_{v,v,s,1}\,F_v^{\{s,v,s,v\}} + \sum_{op\in v[1,-1]^-}\left[\beta^2_{s,v,op,1}\,F^{\{s,v,s,v\}}\right] + \sum_{op\in v[1,-1]^+}\left[\beta^2_{s,v,op,1}\,F^{\{s,v,s,v\}}\right],\right.$$

$$H_0^{\{s,s,v,v\}} + \frac{\beta_{s,s,s,1}\,\beta_{v,v,s,1}\,H_s^{\{s,s,v,v\}}}{\sqrt{3}} - \frac{1}{3}\,\beta^2_{v,v,s,1}\,H_v^{\{s,v,v,s\}} + \frac{1}{3}\sum_{op\in v[1,-1]^-}\left[\beta^2_{s,v,op,1}\,H^{\{s,v,v,s\}}\right] +$$

$$\frac{\sum_{op\in v[0,1]^+}\left[\beta_{s,s,op,1}\,\beta_{v,v,op,1}\,H^{\{s,s,v,v\}}\right]}{\sqrt{3}} - \frac{1}{3}\sum_{op\in v[1,-1]^+}\left[\beta^2_{s,v,op,1}\,H^{\{s,v,v,s\}}\right],$$

$$\sum_{op\in v[1,1]^-}\left[\beta^2_{v,v,op,1}\,F^{\{v,v,v,v\}}\right] + \frac{3}{5}\sum_{op\in v[2,1]^+}\left[\beta^2_{v,v,op,1}\,F^{\{v,v,v,v\}}\right],$$

$$F^{\{v,v,v,v\}} \quad \frac{1}{\quad} \quad \beta^2 \qquad F^{\{v,v,v,v\}} \quad \frac{1}{\quad} \quad \left[\beta^2 \qquad F^{\{v,v,v,v\}}\right] \quad 2 \quad \left[\beta^2 \qquad F^{\{v,v,v,v\}}\right]$$

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$$\beta[\text{op}[\text{eps}, \text{rep}[1], 1, 1], \text{op}[\text{eps}, \text{rep}[1], 1, 1], \text{op}[\text{eps}, \text{rep}[1], 1, 1]][1]^4] +$$
$$\text{sum}[F[\text{eps}, \text{eps}, \text{eps}, \text{eps}]\, \beta[\text{op}[\text{eps}, \text{rep}[1], 1, 1], \text{op}[\text{eps}, \text{rep}[1], 1, 1], \text{op}[\text{op}, \text{rep}[1], 1, 1]][1]^2,$$
$$\text{op}[\text{op}, \text{rep}[1], 1, 1]]\}]$$

In[9]:=
```
Export["../autoboot_Ising_OE.txt", eq, "Package"];
```

O(3) : vst

In[5]:=
```
o3 = getO[3];
setGroup[o3];
```

vs

```
setOps[{op[s, o3[id]], op[v, v[1, -1]]}];
```

```
format[eq = bootAll[]]
```

$$\text{eqn}\Big[\Big\{\beta^2_{v,v,s,1}\, F_v^{\{s,v,s,v\}} + \sum_{\text{op}\in v[1,-1]^-}\Big[\beta^2_{s,v,\text{op},1}\, F^{\{s,v,s,v\}}\Big] + \sum_{\text{op}\in v[1,-1]^+}\Big[\beta^2_{s,v,\text{op},1}\, F^{\{s,v,s,v\}}\Big],$$
$$H_0^{\{s,s,v,v\}} + \frac{\beta_{s,s,s,1}\,\beta_{v,v,s,1}\, H_s^{\{s,s,v,v\}}}{\sqrt{3}} - \frac{1}{3}\,\beta^2_{v,v,s,1}\, H_v^{\{s,v,v,s\}} + \frac{1}{3}\sum_{\text{op}\in v[1,-1]^-}\Big[\beta^2_{s,v,\text{op},1}\, H^{\{s,v,v,s\}}\Big] +$$

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$$F_0^{\{s,s,v,v\}} + \frac{\beta_{s,s,s,1}\,\beta_{v,v,s,1}\,F_s^{\{s,s,v,v\}}}{\sqrt{3}} + \frac{1}{3}\,\beta_{v,v,s,1}^2\,F_v^{\{s,v,v,s\}} - \frac{1}{3}\sum_{op\in v[1,-1]^-}\left[\beta_{s,v,op,1}^2\,F^{\{s,v,v,s\}}\right] + \frac{\sum_{op\in v[0,1]^+}\left[\beta_{s,s,op,1}\,\beta_{v,v,op,1}\,F^{\{s,s,v,v\}}\right]}{\sqrt{3}} + \frac{1}{3}\sum_{op\in v[1,-1]^+}\left[\beta_{s,v,op,1}^2\,F^{\{s,v,v,s\}}\right],$$

$$H_0^{\{v,v,v,v\}} + \frac{1}{3}\,\beta_{v,v,s,1}^2\,H_s^{\{v,v,v,v\}} + \frac{1}{6}\sum_{op\in v[1,1]^-}\left[\beta_{v,v,op,1}^2\,H^{\{v,v,v,v\}}\right] + \frac{1}{3}\sum_{op\in v[0,1]^+}\left[\beta_{v,v,op,1}^2\,H^{\{v,v,v,v\}}\right] - \frac{1}{6}\sum_{op\in v[2,1]^+}\left[\beta_{v,v,op,1}^2\,H^{\{v,v,v,v\}}\right],\ F_0^{\{s,s,s,s\}} + \beta_{s,s,s,1}^2\,F_s^{\{s,s,s,s\}} + \sum_{op\in v[0,1]^+}\left[\beta_{s,s,op,1}^2\,F^{\{s,s,s,s\}}\right]\Big\}\Big]$$

In[9]:
```
Export["../autoboot_03_VS.txt", eq, "Package"];
```

vst

```
setOps[{op[s, o3[id]], op[v, v[1, -1]], op[t, v[2, 1]]}];
format[eq = bootAll[]]
```

$$\text{eqn}\Big[\Big\{\beta_{v,v,s,1}^2\,F_v^{\{s,v,s,v\}} + \sum_{op\in v[1,-1]^-}\left[\beta_{s,v,op,1}^2\,F^{\{s,v,s,v\}}\right] + \sum_{op\in v[1,-1]^+}\left[\beta_{s,v,op,1}^2\,F^{\{s,v,s,v\}}\right],$$

$$\beta_{v,t,v,1}\,\beta_{v,v,s,1}\,F_v^{\{s,v,t,v\}} - \sum_{op\in v[1,-1]^-}\left[\beta_{s,v,op,1}\,\beta_{v,t,op,1}\,F^{\{s,v,t,v\}}\right] + \sum_{op\in v[1,-1]^+}\left[\beta_{s,v,op,1}\,\beta_{v,t,op,1}\,F^{\{s,v,t,v\}}\right],$$

$$\beta_{t,t,s,1}\,\beta_{t,t,t,1}\,F_t^{\{s,t,t,t\}} + \sum\left[\beta_{s,t,op,1}\,\beta_{t,t,op,1}\,F^{\{s,t,t,t\}}\right],$$

$$\beta_{v,t,v,1}\, F_t^{\{\cdots\}} + \frac{1}{3}\sum_{op\in v[1,1]^-}\left[\beta_{v,v,op,1}\, F^{\{\cdots\}}\right] + \sum_{op\in v[2,1]^+}\left[\beta_{v,v,op,1}\, F^{\{\cdots\}}\right],$$

$$F_0^{\{v,v,v,v\}} + \frac{1}{3}\beta_{v,v,s,1}^2 F_s^{\{v,v,v,v\}} - \frac{2}{9}\sum_{op\in v[1,1]^-}\left[\beta_{v,v,op,1}^2 F^{\{v,v,v,v\}}\right] + \frac{1}{3}\sum_{op\in v[0,1]^+}\left[\beta_{v,v,op,1}^2 F^{\{v,v,v,v\}}\right],$$

$$F_0^{\{s,s,t,t\}} + \frac{\beta_{s,s,s,1}\,\beta_{t,t,s,1}\, F_s^{\{s,s,t,t\}}}{\sqrt{5}} + \frac{1}{5}\beta_{t,t,s,1}^2 F_t^{\{s,t,t,s\}} - \frac{1}{5}\sum_{op\in v[2,1]^-}\left[\beta_{s,t,op,1}^2 F^{\{s,t,t,s\}}\right] +$$

$$\frac{\sum_{op\in v[0,1]^+}\left[\beta_{s,s,op,1}\,\beta_{t,t,op,1}\, F^{\{s,s,t,t\}}\right]}{\sqrt{5}} + \frac{1}{5}\sum_{op\in v[2,1]^+}\left[\beta_{s,t,op,1}^2 F^{\{s,t,t,s\}}\right],$$

$$H_0^{\{v,v,v,v\}} + \frac{1}{3}\beta_{v,v,s,1}^2 H_s^{\{v,v,v,v\}} - \frac{1}{6}\beta_{v,t,v,1}^2 H_t^{\{v,v,v,v\}} + \frac{1}{6}\sum_{op\in v[1,1]^-}\left[\beta_{v,v,op,1}^2 H^{\{v,v,v,v\}}\right] +$$

$$\frac{1}{3}\sum_{op\in v[0,1]^+}\left[\beta_{v,v,op,1}^2 H^{\{v,v,v,v\}}\right] - \frac{1}{6}\sum_{op\in v[2,1]^+}\left[\beta_{v,v,op,1}^2 H^{\{v,v,v,v\}}\right],$$

$$F_0^{\{s,s,s,s\}} + \beta_{s,s,s,1}^2 F_s^{\{s,s,s,s\}} + \sum_{op\in v[0,1]^+}\left[\beta_{s,s,op,1}^2 F^{\{s,s,s,s\}}\right]\Big\}\Big]$$

```
Export["../autoboot_03_VST.txt", eq, "Package"];
```

vstt4

```
setOps[{op[s, o3[id]], op[v, v[1, -1]], op[t, v[2, 1]], op[t4, v[4, 1]]}];
format[eq = bootAll[]]
```

demo_crossVecObj.nb - Wolfram Mathematica 11.1

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Ising

In[4]:=
```
eq = Import["autoboot_Ising_OE.txt", "Package"];
```

In[7]:=
```
AutoEqu$EquToCrossVecObj[eq, {sig, eps}, "AutoEqu_Ising_OE.txt"];
```

In[8]:=
```
crossvecobj = Import["AutoEqu_Ising_OE.txt", "Package"]
```

O(3)

v,s,t

```
eq = Import["autoboot_O3_VST.txt", "Package"];

crossvecobj = AutoEqu$EquToCrossVecObj[eq, {v, s, t}, "AutoEqu_O3_VST.txt"];

ObjGet[crossvecobj, "VBlock"][[All, 1]]
```

```
{op[op, v[1, -1], 1, -1], op[op, v[1, -1], 1, 1], op[op, v[2, 1], 1, 1], op[op, v[2, -1], 1, -1],
 op[op, v[2, -1], 1, 1], op[op, v[3, -1], 1, -1], op[op, v[3, -1], 1, 1], op[op, v[2, 1], 1, -1],
 op[op, v[1, 1], 1, -1], op[op, v[3, 1], 1, -1], op[op, v[4, 1], 1, 1], op[op, v[0, 1], 1, 1]}
```

```
AutoEqu$GenerateGapTemplate[ObjGet[crossvecobj, "VBlock"][[All, 1]]]
```

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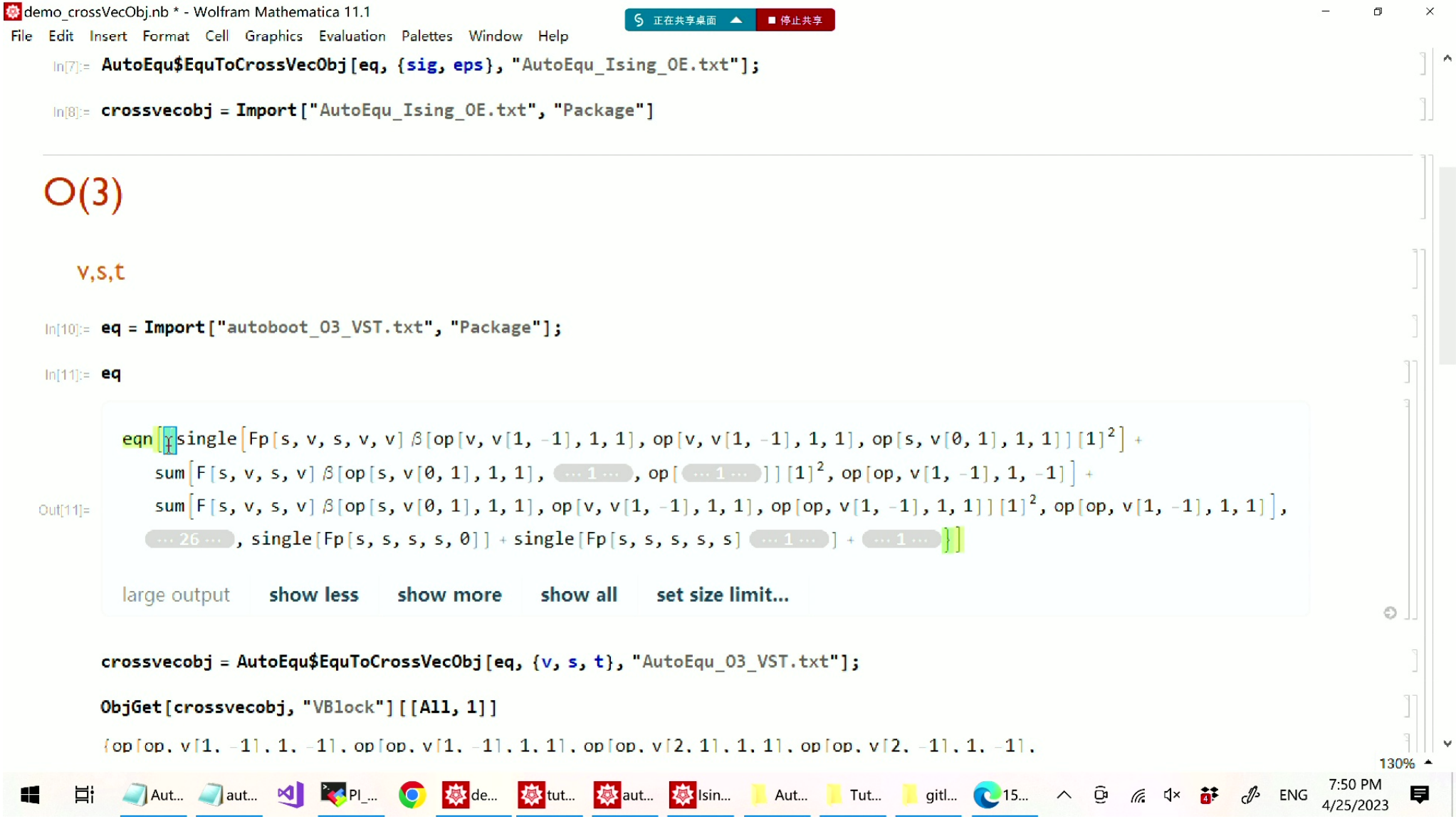
demo_crossVecObj.nb * - Wolfram Mathematica 11.1
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File Edit Insert Format Cell Graphics Evaluation Palettes Window Help
In[7]:= AutoEqu$EquToCrossVecObj[eq, {sig, eps}, "AutoEqu_Ising_OE.txt"];
In[8]:= crossvecobj = Import["AutoEqu_Ising_OE.txt", "Package"]
O(3)
V,S,t
In[10]:= eq = Import["autoboot_O3_VST.txt", "Package"];
In[11]:= eq
Out[11]= eqn[{single[Fp[s, v, s, v, v] β[op[v, v[1, -1], 1, 1], op[v, v[1, -1], 1, 1], op[s, v[0, 1], 1, 1]][1]^2] + sum[F[s, v, s, v] β[op[s, v[0, 1], 1, 1], ... 1 ..., op[... 1 ...]][1]^2, op[op, v[1, -1], 1, -1]] + sum[F[s, v, s, v] β[op[s, v[0, 1], 1, 1], op[v, v[1, -1], 1, 1], op[op, v[1, -1], 1, 1]][1]^2, op[op, v[1, -1], 1, 1]], ... 26 ..., single[Fp[s, s, s, s, 0]] + single[Fp[s, s, s, s, s] ... 1 ...] + ... 1 ...}]
large output show less show more show all set size limit...
crossvecobj = AutoEqu$EquToCrossVecObj[eq, {v, s, t}, "AutoEqu_O3_VST.txt"];
ObjGet[crossvecobj, "VBlock"][[All, 1]]
{op[op, v[1, -1], 1, -1], op[op, v[1, -1], 1, 1], op[op, v[2, 1], 1, 1], op[op, v[2, -1], 1, -1],
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```
In[7]:= AutoEqu$EquToCrossVecObj[eq, {sig, eps}, "AutoEqu_Ising_OE.txt"];

In[8]:= crossvecobj = Import["AutoEqu_Ising_OE.txt", "Package"]
```

O(3)

v,s,t

```
In[10]:= eq = Import["autoboot_O3_VST.txt", "Package"];

         crossvecobj = AutoEqu$EquToCrossVecObj[eq, {v, s, t}, "AutoEqu_O3_VST.txt"];

         ObjGet[crossvecobj, "VBlock"][[All, 1]]

         {op[op, v[1, -1], 1, -1], op[op, v[1, -1], 1, 1], op[op, v[2, 1], 1, 1], op[op, v[2, -1], 1, -1],
          op[op, v[2, -1], 1, 1], op[op, v[3, -1], 1, -1], op[op, v[3, -1], 1, 1], op[op, v[2, 1], 1, -1],
          op[op, v[1, 1], 1, -1], op[op, v[3, 1], 1, -1], op[op, v[4, 1], 1, 1], op[op, v[0, 1], 1, 1]}

         AutoEqu$GenerateGapTemplate[ObjGet[crossvecobj, "VBlock"][[All, 1]]]
```

v,s,t,t4

```
         eq = Import["autoboot_O3_VSTT4.txt", "Package"];

         crossvecobj = AutoEqu$EquToCrossVecObj[eq, {v, s, t, t4}, "AutoEqu_O3_VSTT4.txt"];
```

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demo_crossVecObj.nb * - Wolfram Mathematica 11.1

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In[12]:= `crossvecobj = AutoEqu$EquToCrossVecObj[eq, {v, s, t}, "AutoEqu_O3_VST.txt"];`

In[13]:= `crossvecobj`

Out[13]=

$$\{\text{VBlock} \to \{\text{op}[\text{op}, v[1,-1], 1, -1] \to \{\{\{F[s,v,s,v],0\},\{0,0\}\}\}, \{\{\{0,-\tfrac{1}{2}F[s,v,t,v]\},\{-\tfrac{1}{2}F[s,v,t,v],0\}\}\}, \{\{\{0,0\},\{0,0\}\}\},$$
$$\{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,F[v,t,v,t]\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,H[v,t,v,t]\}\}\}, \{\{\{0,0\},\{0,0\}\}\},$$
$$\{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,-\tfrac{1}{2}\sqrt{\tfrac{5}{3}}H[s,v,v,t]\},\{-\tfrac{1}{2}\sqrt{\tfrac{5}{3}}H[s,v,v,t],0\}\}\}, \{\{\{\tfrac{1}{3}H[s,v,v,s],0\},\{0,0\}\}\},$$
$$\{\{\{0,\tfrac{1}{2}\sqrt{\tfrac{5}{3}}F[s,v,v,t]\},\{\tfrac{1}{2}\sqrt{\tfrac{5}{3}}F[s,v,v,t],0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,-F[v,t,t,v]\}\}\},$$
$$\{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\},$$
$$\{\{\{0,0\},\{0,-H[v,t,t,v]\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{-\tfrac{1}{3}F[s,v,v,s],0\},\{0,0\}\}\},$$
$$\{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}\},$$
$$\text{op}[\text{op}, v[1,-1], 1, 1] \to \{\{\{F[s,v,s,v],0\},\{0,0\}\}\}, \{\{\{0,\tfrac{1}{2}F[s,v,t,v]\},\{\tfrac{1}{2}F[s,v,t,v],0\}\}\},$$
$$\{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,F[v,t,v,t]\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,H[v,t,v,t]\}\}\},$$
$$\{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,0\},\{0,0\}\}\}, \{\{\{0,-\tfrac{1}{2}\sqrt{\tfrac{5}{3}}H[s,v,v,t]\},\{-\tfrac{1}{2}\sqrt{\tfrac{5}{3}}H[s,v,v,t],0\}\}\},$$

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$$\frac{}{\sqrt{5}} + \frac{}{5} \sum_{op \in v[2,1]^+} \left[\beta^{s,t,op,1} \right],$$

$$H_0^{\{v,v,v,v\}} + \frac{1}{3} \beta^2_{v,v,s,1} H_s^{\{v,v,v,v\}} - \frac{1}{6} \beta^2_{v,t,v,1} H_t^{\{v,v,v,v\}} + \frac{1}{6} \sum_{op \in v[1,1]^-} \left[\beta^2_{v,v,op,1} H^{\{v,v,v,v\}} \right] +$$

$$\frac{1}{3} \sum_{op \in v[0,1]^+} \left[\beta^2_{v,v,op,1} H^{\{v,v,v,v\}} \right] - \frac{1}{6} \sum_{op \in v[2,1]^+} \left[\beta^2_{v,v,op,1} H^{\{v,v,v,v\}} \right],$$

$$F_0^{\{s,s,s,s\}} + \beta^2_{s,s,s,1} F_s^{\{s,s,s,s\}} + \sum_{op \in v[0,1]^+} \left[\beta^2_{s,s,op,1} F^{\{s,s,s,s\}} \right] \Big\} \Big]$$

```
Export["../autoboot_O3_VST.txt", eq, "Package"];
```

vstt4

```
setOps[{op[s, o3[id]], op[v, v[1, -1]], op[t, v[2, 1]], op[t4, v[4, 1]]}];
format[eq = bootAll[]]
```

$$\text{eqn}\left[\left\{ \beta^2_{v,v,s,1} F_v^{\{s,v,s,v\}} + \sum_{op \in v[1,-1]^-} \left[\beta^2_{s,v,op,1} F^{\{s,v,s,v\}} \right] + \sum_{op \in v[1,-1]^+} \left[\beta^2_{s,v,op,1} F^{\{s,v,s,v\}} \right], \right.$$

$$\beta_{t4,t4,s,1} \beta_{t4,t4,t,1} F_{t4}^{\{s,t4,t,t4\}} - \sum_{op \in v[4,1]^-} \left[\beta_{s,t4,op,1} \beta_{t4,t,op,1} F^{\{s,t4,t,t4\}} \right] +$$

$$\sum_{op \in v[4,1]^+} \left[\beta_{s,t4,op,1} \beta_{t4,t,op,1} F^{\{s,t4,t,t4\}} \right], \quad \cdots 78 \cdots, \quad H_0^{\{v,v,v,v\}} + \frac{1}{3} \beta^2_{v,v,s,1} H_s^{\{v,v,v,v\}} - \frac{1}{6} \beta^2_{v,t,v,1} H_t^{\{v,v,v,v\}} +$$

$$1 \quad \left[\beta^2 \quad \right]^{\{v,v,v,v\}} \quad 1 \quad \left[\beta^2 \quad \right]^{\{v,v,v,v\}} \quad 1 \quad \left[\beta^2 \quad \right]^{\{v,v,v,v\}}$$

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$$F_{\emptyset}^{\{s,s,s,s\}} + \beta_{s,s,s,1}^2 F_s^{\{s,s,s,s\}} + \sum_{op \in v[\emptyset,1]^+} \left[\beta_{s,s,op,1}^2 F^{\{s,s,s,s\}}\right]\Big\}\Big]$$

```
Export["../autoboot_O3_VST.txt", eq, "Package"];
```

vstt4

```
setOps[{op[s, o3[id]], op[v, v[1, -1]], op[t, v[2, 1]], op[t4, v[4, 1]]}];
format[eq = bootAll[]]
```

$$\text{eqn}\Big[\Big\{\beta_{v,v,s,1}^2 F_v^{\{s,v,s,v\}} + \sum_{op \in v[1,-1]^-} \left[\beta_{s,v,op,1}^2 F^{\{s,v,s,v\}}\right] + \sum_{op \in v[1,-1]^+} \left[\beta_{s,v,op,1}^2 F^{\{s,v,s,v\}}\right],$$

$$\beta_{t4,t4,s,1}\,\beta_{t4,t4,t,1} F_{t4}^{\{s,t4,t,t4\}} - \sum_{op \in v[4,1]^-} \left[\beta_{s,t4,op,1}\,\beta_{t4,t,op,1} F^{\{s,t4,t,t4\}}\right] +$$

$$\sum_{op \in v[4,1]^+} \left[\beta_{s,t4,op,1}\,\beta_{t4,t,op,1} F^{\{s,t4,t,t4\}}\right], \quad \cdots 78 \cdots, \quad H_{\emptyset}^{\{v,v,v,v\}} + \frac{1}{3}\beta_{v,v,s,1}^2 H_s^{\{v,v,v,v\}} - \frac{1}{6}\beta_{v,t,v,1}^2 H_t^{\{v,v,v,v\}} +$$

$$\frac{1}{6}\sum_{op \in v[1,1]^-} \left[\beta_{v,v,op,1}^2 H^{\{v,v,v,v\}}\right] + \frac{1}{3}\sum_{op \in v[\emptyset,1]^+} \left[\beta_{v,v,op,1}^2 H^{\{v,v,v,v\}}\right] - \frac{1}{6}\sum_{op \in v[2,1]^+} \left[\beta_{v,v,op,1}^2 H^{\{v,v,v,v\}}\right],$$

$$F_{\emptyset}^{\{s,s,s,s\}} + \beta_{s,s,s,1}^2 F_s^{\{s,s,s,s\}} + \sum_{op \in v[\emptyset,1]^+} \left[\beta_{s,s,op,1}^2 F^{\{s,s,s,s\}}\right]\Big\}\Big]$$

large output | show less | show more | show all | set size limit...

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```
ObjGet[crossvecobj, "VBlock", op[op, rep[1], 1, 1]] // MatrixForm
```

$$\begin{pmatrix} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & \frac{1}{2} H[\text{eps}, \text{eps}, \text{sig}, \text{sig}] \\ \frac{1}{2} H[\text{eps}, \text{eps}, \text{sig}, \text{sig}] & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & \frac{1}{2} F[\text{eps}, \text{eps}, \text{sig}, \text{sig}] \\ \frac{1}{2} F[\text{eps}, \text{eps}, \text{sig}, \text{sig}] & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & F[\text{sig}, \text{sig}, \text{sig}, \text{sig}] \end{pmatrix} \\ \begin{pmatrix} F[\text{eps}, \text{eps}, \text{eps}, \text{eps}] & 0 \\ 0 & 0 \end{pmatrix} \end{pmatrix}$$

```
ObjGet[crossvecobj, "VBlock", op[op, rep[2], 1, 1]] // MatrixForm
```

$$\begin{pmatrix} F[\text{eps}, \text{sig}, \text{eps}, \text{sig}] \\ -H[\text{eps}, \text{sig}, \text{sig}, \text{eps}] \\ F[\text{eps}, \text{sig}, \text{sig}, \text{eps}] \\ 0 \\ 0 \end{pmatrix}$$

```
ObjGet[crossvecobj, "VBlock", op[op, rep[2], 1, -1]] // MatrixForm
```

$$\begin{pmatrix} F[\text{eps}, \text{sig}, \text{eps}, \text{sig}] \\ H[\text{eps}, \text{sig}, \text{sig}, \text{eps}] \\ -F[\text{eps}, \text{sig}, \text{sig}, \text{eps}] \\ 0 \\ 0 \end{pmatrix}$$

Block specifications

120%

Aut... aut... Pl_... de... tut... aut... Isin... Aut... Tut... gitl... 15... ENG 7:51 PM 4/25/2023

AutoCB3$Init[crossvecobj,blockconfobj] : this function tells simpleboot about the crossing vectors and block specs.

Gaps

Format :

GapConfiguration is a List of element in one of the following format:
{channel,gap,spins} // this means demand $\alpha \cdot V_{\text{channel}} \geq 0$ for $\Delta >$ gap and L in spins. spins can be a integer or set of integers.
{channel,IndividualOperator[Δ0],spin} // this means demand $\alpha \cdot (V_{\text{channel},\Delta 0,\text{spin}}) \geq 0$
{channel,IndividualOperator[Δ0,ope_List],spin} // this means demand $\alpha \cdot (\text{ope}.V_{\text{channel},\Delta 0,\text{spin}}.\text{ope}) \geq 0$
{channel,IntervalPositivity[Δmin,Δmax],spin} // this means demand $\alpha \cdot V_{\text{channel},\Delta,\text{spin}} \geq 0$ for $\Delta\text{min} < \Delta < \Delta\text{max}$

In[12]:=
```
Clear@GapConfiguration;
GapConfiguration[dim_,lset_]:={
{op[op, rep[2], 1, 1],3,0}, (* α.V_odd>0 for Δ>3 and L=0 *)
{op[op, rep[1], 1, 1],3,0}, (* α.V_even>0 for Δ>3 and L=0 *)

{op[op, rep[1], 1, 1],Δunitary[dim, /],Select[lset, EvenQ[#] && # > 0 & ]},  (* α.V_even>0 for Δ>Δ_unitary and L=2, 4, ... *)
{op[op, rep[2], 1, -1],Δunitary[dim, /],Select[lset, OddQ ]},               (* α.V_odd>0 for Δ>Δ_unitary and L=1, 3, ... *)
{op[op, rep[2], 1, 1],Δunitary[dim, /],Select[lset, EvenQ[#] && # > 0 & ]}  (* α.V_odd>0 for Δ>Δ_unitary and L=2, 4, ... *)
};
```

/ : place holder for spin

SDP template

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```
GetFileDirectory[]:=If[$InputFileName==="",NotebookDirectory[],DirectoryName@$InputFileName];
SetDirectory@GetFileDirectory[];


<<"Birdtrack.m";
```

SO(N) projector

SO(N) projector, VA mix

SO(N) projector, T A mixed

SO(N) projector, VT mix

SO(2) projector

randomized index

V S mix projector

125%

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SO(N) projector, T A mixed

SO(N) projector, VT mix

4 - index projector, symmetric, TTTT

```
(*pT$S1[i_,j_,k_,l_]:=Expand[pT[{i[[1]]},{i[[2]]},{t},{s}] pT[{j[[1]]},{j[[2]]},{s},{t}] pT[{k[[1]]},{k[[2]]},{t1},{s1}] pT[{l[[1]]},{

pT$S1[n_][i_,j_,k_,l_]:=Expand[pT[n][{i[[1]]},{i[[2]]},{j[[1]]},{j[[2]]}] pT[n][{k[[1]]},{k[[2]]},{l[[1]]},{l[[2]]}]]/((1/2) (-2+n+n^2))/

pT$S20[n_][i_,j_,k_,l_]:=Expand[pT[n][{i[[1]]},{i[[2]]},{a1[n]},{s[n]}] pT[n][{j[[1]]},{j[[2]]},{s[n]},{a2[n]}] pT[n][{b1[n]},{t[n]},{

pT$S84[n_][i_,j_,k_,l_]:=Expand[(pT[n][{i[[1]]},{i[[2]]},{a1[n]},{s1[n]}] pT[n][{j[[1]]},{j[[2]]},{s2[n]},{a2[n]}] pT[n][{b1[n]},{t1[n

pT$S105[n_][i_,j_,k_,l_]:=Expand[(pT[n][{i[[1]]},{i[[2]]},{a1[n]},{s1[n]}] pT[n][{j[[1]]},{j[[2]]},{s2[n]},{a2[n]}] pT[n][{b1[n]},{t1[

pT$A15[n_][i_,j_,k_,l_]:=Expand[pT[n][{i[[1]]},{i[[2]]},{a1[n]},{s[n]}] pT[n][{j[[1]]},{j[[2]]},{s[n]},{a2[n]}] pT[n][{b1[n]},{t[n]},{

pT$A175[n_][i_,j_,k_,l_]:=Module[{temp},temp[ia_,ja_,ka_,la_]:=Expand[pT[n][{ia[[1]]},{ia[[2]]},{a1[n]},{s1[n]}] pT[n][{ja[[1]]},{ja[[2
(temp[i,j,k,l]-temp[j,i,k,l]-2 pT$A15[n][i,j,k,l])/2];
pT$Slist={pT$S1,pT$S20,pT$S84,pT$S105};
```

125%

Au... au... PI_... de... tut... au... lsi... S... Au... Tu... git... 15... ENG 7:54 PM 4/25/2023

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```
pT$Slist={pT$S1,pT$S20,pT$S84,pT$S105};
pT$Alist={pT$A15,pT$A175};
pT$list={Sequence@@pT$Slist,Sequence@@pT$Alist};
```

Check symmetrization

```
Table[pT$Slist[[i]][n][ilist, jlist, klist, llist] - pT$Slist[[i]][n][jlist, ilist, klist, llist] // FullSimplify,
 {i, 1, Length@pT$Slist}]
Table[pT$Alist[[i]][n][ilist, jlist, klist, llist] + pT$Alist[[i]][n][jlist, ilist, klist, llist] // FullSimplify,
 {i, 1, Length@pT$Alist}]
```

```
{0, 0, 0, 0}
```

```
{0, 0}
```

Check orthorgonality

```
Table[
  contract[pT$list[[i]][n], pT$list[[j]][n]] // Simplifyδ
  ------------------------------------------------------ // FullSimplify,
  pT$list[[j]][n][ilist, jlist, mlist, nlist] // Simplifyδ
  {i, 1, Length@pT$list}, {j, 1, Length@pT$list}] // MatrixForm
```

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

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```
 {i, 1, Length@pT$Alist}]
```

```
{0, 0, 0, 0}
```

```
{0, 0}
```

Check orthorgonality

```
Table[
  contract[pT$list[[i]][n], pT$list[[j]][n]] // Simplifyδ
  ------------------------------------------------------ // FullSimplify,
  pT$list[[j]][n][ilist, jlist, mlist, nlist] // Simplifyδ
  {i, 1, Length@pT$list}, {j, 1, Length@pT$list}] // MatrixForm
```

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

Check dimension

```
ilist = GenerateUniqueIndexList[m, 6];
jlist = GenerateUniqueIndexList[m, 6];
klist = GenerateUniqueIndexList[m, 6];
llist = GenerateUniqueIndexList[m, 6];
```

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```
ilist = GenerateUniqueIndexList[m, 6];
jlist = GenerateUniqueIndexList[m, 6];
klist = GenerateUniqueIndexList[m, 6];
llist = GenerateUniqueIndexList[m, 6];
mlist = GenerateUniqueIndexList[m, 6];
nlist = GenerateUniqueIndexList[m, 6];

Table[trace2[pT$list[[i]][m]], {i, 1, Length@pT$list}] // FullSimplify
Table[trace2[pT$Slist[[i]][m]], {i, 1, Length@pT$Slist}] /. m → 6 // FullSimplify
Table[trace2[pT$Alist[[i]][m]], {i, 1, Length@pT$Alist}] /. m → 6 // FullSimplify
```

$$\left\{1, \frac{1}{2}\left(-2+m+m^2\right), \frac{1}{12} m \left(-6-7 m+m^3\right), \frac{1}{24}(-1+m) m (1+m)(6+m), \frac{1}{2}(-1+m) m, \frac{1}{8}(-2+m)(-1+m)(1+m)(4+m)\right\}$$

```
{1, 20, 84, 105}

{15, 175}
```

3 - index projector, symmetric x vector

```
pVT$6[n_][i_,j_,k_,l_]:= Expand[pT[n][{i[[1]]},{i[[2]]},{s[n]},{j[[1]]}] pT[n][{s[n]},{l[[1]]},{k[[1]]},{k[[2]]}]] / ((-2+n+n^2)/(2 n)) //.cond1

pVT$64[n_][i_,j_,k_,l_]:= Expand[pT[n][{i[[1]]},{i[[2]]},{s[n]},{a1[n]}] pT[n][{s[n]},{a2[n]},{k[[1]]},{k[[2]]}] pA[n][{a1[n]},{j[[1]

pVT$50[n_][i_,j_,k_,l_]:= Expand[pT[n][{i[[1]]},{i[[2]]},{s[n]},{a1[n]}] pT[n][{s[n]},{a2[n]},{k[[1]]},{k[[2]]}] pT[n][{a1[n]},{j[[1]
```

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Au... au... PI_... de... tut... au... Isi... S... Au... Tu... git... 15... ENG 7:54 PM 4/25/2023

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```
we can construct singlet ϵijklmnAijAklAmn . Such term is invariant under SO(6) but not O(6). Therefore unless
 we want to do SO(6), we shouldn't identify A15 and S15.
*)
Clear[ON$VT$Projectors$SG$PPP];
ON$VT$Projectors$SG$PPP[ngroup_] := {
   Projector@Characters["TTTT"] → {
     "S" → pT$S1[ngroup],
     "T" → pT$S20[ngroup],
     "S84" → pT$S84[ngroup],
     "S105" → pT$S105[ngroup],
     "A" → pT$A15[ngroup],
     "175" → pT$A175[ngroup]
    },
   Projector@Characters["TVTV"] → {
     "V" → pVT$6[ngroup],
     "64" → pVT$64[ngroup],
     "50" → pVT$50[ngroup]
    },
   Projector@Characters["VVTT"] → {
     "S" → pVVTT$S1[ngroup],
     "T" → pVVTT$S20[ngroup],
     "A" → pVVTT$A15[ngroup]
    },
   Projector@Characters["VVVV"] → {
     "S" → pS1[ngroup],
```

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```
IndexType[ A ] → {ngroup, ngroup},

"RepDim" → {
  "S" → 1,
  "T" → 1/2 (-2 + ngroup + ngroup^2),
  "S84" → 1/12 ngroup (-6 - 7 ngroup + ngroup^3),  (* B4 : {2,2} *)
  "S105" → 1/24 (-1 + ngroup) ngroup (1 + ngroup) (6 + ngroup),  (* T4 : {4} *)
  "A" → 1/2 (-1 + ngroup) ngroup,
  "V" → ngroup,
  "64" → 1/3 ngroup (-4 + ngroup^2),  (* H3 : {2,1} *)
  "50" → 1/6 (-1 + ngroup) ngroup (4 + ngroup),  (* T3 : {3} *)
  "45" → 1/8 (-3 + ngroup) (-1 + ngroup) ngroup (2 + ngroup),  (* Y2,1,1 : {2,1,1} *)
  "175" → 1/8 (-2 + ngroup) (-1 + ngroup) (1 + ngroup) (4 + ngroup),  (* H4 : {3,1} *)
  "10" → 1/6 (-2 + ngroup) (-1 + ngroup) ngroup,  (* A3 : {1,1,1} *)
  "S15" → 1/24 (-3 + ngroup) (-2 + ngroup) (-1 + ngroup) ngroup  (* A4 : {1,1,1,1} *)
```

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```
    "A" → pTATA$15[ngroup],
    "T" → pTATA$20[ngroup],
    "175" → pTATA$175[ngroup]
   },

  Projector@Characters["TAVV"] → {
    "A" → pTAVV$15[ngroup],
    "T" → pTAVV$20[ngroup]
   },

  Projector@Characters["TVAV"] → {
    "V" → pTVAV$6[ngroup],
    "64" → pTVAV$64[ngroup]
   },

  Projector@Characters["SSSS"] → {
    "S" → pSSSS$S[ngroup]
   },
  Projector@Characters["VVSS"] → {
    "S" → pVVSS$S[ngroup]
   },
  Projector@Characters["SVVS"] → {
    "V" → pSVVS$V[ngroup]
   },

  IndexType["S"] → {},
```

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randomized index

V S mix projector

prod group final version

Produce crossing equations

O(5)

In[150]:=
```
<< "AutoEqu.m";

O5projCN = AutoEqu$Projector$PPP2CN[ON$VT$Projectors$SG$PPP[5]];

ObjGet[O5projCN, "RepDim"]

{S → 1, T → 14, S84 → 35, S105 → 55, A → 10, V → 5, 64 → 35, 50 → 30, 45 → 35, 175 → 81, 10 → 10, S15 → 5}

eq = AutoEqu$GenerateEqu[O5projCN, {op["v", "V"], op["s", "S"], op["t", "T"]}, "S",
  Characters /@ {"vvvv", "ssvv", "vsvs", "stvv", "vsvt", "ttvv", "vtvt", "ssss", "sstt", "tsts", "tstt", "tttt"}]

AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O5_VST.txt"]
```

O(4), O(3)

125%

SOn_projectorV1_prodgroup.nb * - Wolfram Mathematica 11.1

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prod group final version

Produce crossing equations

O(5)

In[150]:=
```
<< "AutoEqu.m";
```

In[151]:=
```
O5projCN = AutoEqu$Projector$PPP2CN[ON$VT$Projectors$SG$PPP[5]];
```

In[152]:=
```
ObjGet[O5projCN, "RepDim"]
```

Out[152]=
```
{S → 1, T → 14, S84 → 35, S105 → 55, A → 10, V → 5, 64 → 35, 50 → 30, 45 → 35, 175 → 81, 10 → 10, S15 → 5}
```

```
eq = AutoEqu$GenerateEqu[O5projCN, {op["v", "V"], op["s", "S"], op["t", "T"]}, "S",
  Characters /@ {"vvvv", "ssvv", "vsvs", "stvv", "vsvt", "ttvv", "vtvt", "ssss", "sstt", "tsts", "tstt", "tttt"}]
AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O5_VST.txt"]
```

O(6)×O(2)

vt

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["t", "T,S"]}, "S,S",
   Characters /@ {"vvvv", "ttvv", "tvtv", "tttt"}];
```

125%

SOn_projectorV1_prodgroup.nb * - Wolfram Mathematica 11.1

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Produce crossing equations

O(5)

In[150]:= `<< "AutoEqu.m";`

In[151]:= `O5projCN = AutoEqu$Projector$PPP2CN[ON$VT$Projectors$SG$PPP[5]];`

In[152]:= `ObjGet[O5projCN, "RepDim"]`

Out[152]= $\{S \to 1, T \to 14, S84 \to 35, S105 \to 55, A \to 10, V \to 5, 64 \to 35, 50 \to 30, 45 \to 35, 175 \to 81, 10 \to 10, S15 \to 5\}$

In[153]:= `O5projCN`

Out[153]=

$$\left\{\text{Projector}[\{T, T, T, T\}] \to \left\{S \to \left(1\ \text{pT\$S1}[5][\#\#\#1]\ \&\right), T \to \left(\frac{\text{pT\$S20}[5][\#\#\#1]}{\sqrt{14}}\ \&\right),\right.\right.$$

$$S84 \to \left(\frac{\text{pT\$S84}[5][\#\#\#1]}{\sqrt{35}}\ \&\right), S105 \to \left(\frac{\text{pT\$S105}[5][\#\#\#1]}{\sqrt{55}}\ \&\right), A \to \left(\frac{\text{pT\$A15}[5][\#\#\#1]}{\sqrt{10}}\ \&\right), 175 \to \left(\frac{1}{9}\ \text{pT\$A175}[5][\#\#\#1]\ \&\right)\Big\},$$

$$\text{Projector}[\{T, V, T, V\}] \to \left\{V \to \left(\frac{\text{pVT\$6}[5][\#\#\#1]}{\sqrt{5}}\ \&\right), 64 \to \left(\frac{\text{pVT\$64}[5][\#\#\#1]}{\sqrt{35}}\ \&\right), 50 \to \left(\frac{\text{pVT\$50}[5][\#\#\#1]}{\sqrt{30}}\ \&\right)\right\},$$

$$\text{Projector}[\{V, V, T, T\}] \to \left\{S \to \left(1\ \text{pVVTT\$S1}[5][\#\#\#1]\ \&\right), T \to \left(\frac{\text{pVVTT\$S20}[5][\#\#\#1]}{\sqrt{14}}\ \&\right), A \to \left(\frac{\text{pVVTT\$A15}[5][\#\#\#1]}{\sqrt{10}}\ \&\right)\right\},$$

$$\text{Projector}[\{V, V, V, V\}] \to \left\{S \to \left(1\ \text{pS1}[5][\#\#\#1]\ \&\right), A \to \left(\frac{\text{pA15}[5][\#\#\#1]}{\sqrt{10}}\ \&\right), T \to \left(\frac{\text{pT20}[5][\#\#\#1]}{\sqrt{14}}\ \&\right)\right\},$$

$$\text{Projector}[\{A, A, A, A\}] \to \left\{S \to \left(1\ \text{pA\$S1}[5][\#\#\#1]\ \&\right), T \to \left(\frac{\text{pA\$S20}[5][\#\#\#1]}{\sqrt{14}}\ \&\right),\right.$$

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```
In[150]:= << "AutoEqu.m";

In[151]:= O5projCN = AutoEqu$Projector$PPP2CN[ON$VT$Projectors$SG$PPP[5]];

In[152]:= ObjGet[O5projCN, "RepDim"]
Out[152]= {S → 1, T → 14, S84 → 35, S105 → 55, A → 10, V → 5, 64 → 35, 50 → 30, 45 → 35, 175 → 81, 10 → 10, S15 → 5}

In[154]:= eq = AutoEqu$GenerateEqu[O5projCN, {op["v", "V"], op["s", "S"], op["t", "T"]}, "S",
            Characters /@ {"vvvv", "ssvv", "vsvs", "stvv", "vsvt", "ttvv", "vtvt", "ssss", "sstt", "tsts", "tstt", "tttt"}]
          Warning: AutoEqu only support δ tensor structure. For
            other tensor structures (say Q_ijkl in cubic), AutoEqu$MMatrixFromProjs has to be modified.
          2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same
            term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.

          AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O5_VST.txt"]
```

O(6)×O(2)

vt

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["t", "T,S"]}, "S,S",
    Characters /@ {"vvvv", "ttvv", "tvtv", "tttt"}];
Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.
Warning: AutoEqu only support δ tensor structure. For
  other tensor structures (say Q_ijkl in cubic), AutoEqu$MMatrixFromProjs has to be modified.
2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same
```

125%

SOn_projectorV1_prodgroup.nb (Running...) - Wolfram Mathematica 11.1

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O(5)

In[150]:=
```
<< "AutoEqu.m";
```

In[151]:=
```
O5projCN = AutoEqu$Projector$PPP2CN[ON$VT$Projectors$SG$PPP[5]];
```

In[152]:=
```
ObjGet[O5projCN, "RepDim"]
```

Out[152]=
```
{S → 1, T → 14, S84 → 35, S105 → 55, A → 10, V → 5, 64 → 35, 50 → 30, 45 → 35, 175 → 81, 10 → 10, S15 → 5}
```

In[154]:=
```
eq = AutoEqu$GenerateEqu[O5projCN, {op["v", "V"], op["s", "S"], op["t", "T"]}, "S",
  Characters /@ {"vvvv", "ssvv", "vsvs", "stvv", "vsvt", "ttvv", "vtvt", "ssss", "sstt", "tsts", "tstt", "tttt"}]
```

```
Warning: AutoEqu only support δ tensor structure. For
  other tensor structures (say Q_ijkl in cubic), AutoEqu$MMatrixFromProjs has to be modified.
2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same
  term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.
```

```
AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O5_VST.txt"]
```

O(6)×O(2)

vt

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["t", "T,S"]}, "S,S",
   Characters /@ {"vvvv", "ttvv", "tvtv", "tttt"}];
```

```
Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.
```

125%

Au... au... PI_... de... tut... au... lsi... S... Au... Tu... git... 15... ENG 7:59 PM 4/25/2023

AutoEqu_O5_VST.txt - 记事本

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文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)

```
{"VBlock" -> Sp[op, "S", 1, 1] ->
    {{{{F["v", "v", "v", "v"], 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{H["v", "v", "v", "v"], 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, -F["s", "s", "v", "v"]/2, 0}, {-F["s", "s", "v", "v"]/2, 0, 0},
       {0, 0, 0}}}, {{{0, -H["s", "s", "v", "v"]/2, 0},
       {-H["s", "s", "v", "v"]/2, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, -F["t", "t", "v", "v"]/2}, {0, 0, 0},
       {-F["t", "t", "v", "v"]/2, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, -H["t", "t", "v", "v"]/2}, {0, 0, 0},
       {-H["t", "t", "v", "v"]/2, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, F["s", "s", "s", "s"], 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, -F["s", "s", "t", "t"]/2},
       {0, -F["s", "s", "t", "t"]/2, 0}}},
     {{{0, 0, 0}, {0, 0, -H["s", "s", "t", "t"]/2},
       {0, -H["s", "s", "t", "t"]/2, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, F["t", "t", "t", "t"]}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
     {{{0, 0, 0}, {0, 0, 0}, {0, 0, 0}}},
```

第 1 行，第 1 列　100%　Windows (CRLF)　UTF-8

SOn_projectorV1_prodgroup.nb (Running...) - Wolfram Mathematica 11.1

正在共享桌面 ■ 停止共享

File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

```
Warning: AutoEqu only support δ tensor structure. For
  other tensor structures (say Q_ijkl in cubic), AutoEqu$MMatrixFromProjs has to be modified.
2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same
  term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.

AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O5_VST.txt"]
```

O(6)×O(2)

vt

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["t", "T,S"]}, "S,S",
   Characters /@ {"vvvv", "ttvv", "tvtv", "tttt"}];
```

```
Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.
Warning: AutoEqu only support δ tensor structure. For
  other tensor structures (say Q_ijkl in cubic), AutoEqu$MMatrixFromProjs has to be modified.
2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same
  term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.

AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O6O2_vt.txt"]
```

vm

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["m", "T,T"]}, "S,S",
  Characters /@ {"vvvv", "mmvv", "mvmv", "mmmm"}]
```

```
Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.
```

125%

SOn_projectorV1_prodgroup.nb (Running...) - Wolfram Mathematica 11.1

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In[154]:=
```
eq = AutoEqu$GenerateEqu[O5projCN, {op["v", "V"], op["s", "S"], op["t", "T"]}, "S",
  Characters /@ {"vvvv", "ssvv", "vsvs", "stvv", "vsvt", "ttvv", "vtvt", "ssss", "sstt", "tsts", "tstt", "tttt"}]
```

Warning: AutoEqu only support δ tensor structure. For other tensor structures (say Q_{ijkl} in cubic), AutoEqu$MMatrixFromProjs has to be modified.

2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.

```
AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O5_VST.txt"]
```

O(6)×O(2)

vt

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["t", "T,S"]}, "S,S",
   Characters /@ {"vvvv", "ttvv", "tvtv", "tttt"}];
```

Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.

Warning: AutoEqu only support δ tensor structure. For other tensor structures (say Q_{ijkl} in cubic), AutoEqu$MMatrixFromProjs has to be modified.

2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.

```
AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O6O2_vt.txt"]
```

vm

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["m", "T,T"]}, "S,S",
```

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SOn_projectorV1_prodgroup.nb (Running...) - Wolfram Mathematica 11.1

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```
AutoEqu$EquToCrossVecObj[eq, {"v", "t"}, "AutoEqu_O6O2_vt.txt"]
```

vm

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["m", "T,T"]}, "S,S",
  Characters /@ {"vvvv", "mmvv", "mvmv", "mmmm"}]
```

```
Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.

Warning: AutoEqu only support δ tensor structure. For
  other tensor structures (say Q_ijkl in cubic), AutoEqu$MMatrixFromProjs has to be modified.

2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same
  term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.
```

{ ··· 1 ··· }

large output | show less | show more | show all | set size limit...

tm

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["t", "T,S"], op["m", "T,T"]}, "S,S",
  Characters /@ {"tttt", "mmtt", "mtmt", "mmmm"}]
```

```
Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.

Warning: AutoEqu only support δ tensor structure. For
  other tensor structures (say Q_ijkl in cubic), AutoEqu$MMatrixFromProjs has to be modified.
```

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SOn_projectorV1_prodgroup.nb * - Wolfram Mathematica 11.1

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other tensor structures (say Q_{ijkl} in cubic), AutoEqu$MMatrixFromProjs has to be modified.

2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.

```
{single[Fp[t, t, t, t, 0]] -
  1/2 Sqrt[7] sum[F[t, t, t, t] β[op[t, T,S, 1, 1], op[t, T,S, 1, 1], op[op, 175,S, 1, -1]][1]^2, op[op, 175,S, 1, -1]] -
  1/2 Sqrt[3/5] sum[F[t, t, t, t] β[ ··· 1 ··· ][1]^2, op[op, A,S, 1, -1]] +
  sum[F[t, t, t, t] β[op[t, T,S, 1, 1], op[t, T,S, 1, 1], op[op, S,S, 1, 1]][1]^2, op[op, S,S, 1, 1]],
 ··· 1 ···, ··· 38 ···, ··· 1 ···, ··· 11 ··· + sum[ ··· 1 ··· ]}
```

large output | show less | show more | show all | set size limit...

ytm

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["t", "T,S"], op["m", "T,T"]},
  "S,S", Characters /@ {"vvvv", "ttvv", "tvtv", "mtvv", "vmvt", "mmvv", "mvmv", "tttt", "mmtt", "mtmt", "mmmm"}]
```

Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.

Warning: AutoEqu only support δ tensor structure. For other tensor structures (say Q_{ijkl} in cubic), AutoEqu$MMatrixFromProjs has to be modified.

2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.

125%

Au... au... PI_... de... tut... au... lsi... S... Au... Tu... git... 15... ENG 8:02 PM 4/25/2023

SOn_projectorV1_prodgroup.nb - Wolfram Mathematica 11.1

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```
In[152]:= ObjGet[O5projCN, "RepDim"]
Out[152]= {S → 1, T → 14, S84 → 35, S105 → 55, A → 10, V → 5, 64 → 35, 50 → 30, 45 → 35, 175 → 81, 10 → 10, S15 → 5}

In[154]:= eq = AutoEqu$GenerateEqu[O5projCN, {op["v", "V"], op["s", "S"], op["t", "T"]}, "S",
    Characters /@ {"vvvv", "ssvv", "vsvs", "stvv", "vsvt", "ttvv", "vtvt", "ssss", "sstt", "tsts", "tstt", "tttt"}]
  AutoEqu$EquToCrossVecObj[eq, {"v", "s", "t"}, "AutoEqu_O5_VST.txt"]
```

O(6)×O(2)

vt

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["t", "T,S"]}, "S,S",
   Characters /@ {"vvvv", "ttvv", "tvtv", "tttt"}];
```

Warning: Projectors must be in canonical convention! Otherwise ProdMMatrix is not correct.

Warning: AutoEqu only support δ tensor structure. For
other tensor structures (say Q_{ijkl} in cubic), AutoEqu$MMatrixFromProjs has to be modified.

2020/07/03 : simple cases involves ϵ is also supported. But there might be issue when both ϵ δ appear in same
term. For more general cases involves ϵ, AutoEqu$MMatrix, AutoEqu$MMatrixFromProjs need to be carefully tested.

```
AutoEqu$EquToCrossVecObj[eq, {"v", "t"}, "AutoEqu_O6O2_vt.txt"]
```

vm

```
equ = AutoEqu$GenerateEqu$ProdGroup[{O6projCN, O2projCN}, {op["v", "V,V"], op["m", "T,T"]}, "S,S",
  Characters /@ {"vvvv", "mmvv", "mvmv", "mmmm"}]
```

125%

IsingOE_OPEscan.nb - Wolfram Mathematica 11.1

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*** show command to load Ising from autoboot

```
(* data for crossing vectors. see ArXiv:1406.4858 *)

crossvecobj={"VBlock"→{

op[op,"E",1,1]→{{{F[sig,sig,sig,sig],0},{0,0}},{{0,0},{0,F[eps,eps,eps,eps]}},{{0,0},{0,0}},{{0,1/2 F[sig,sig,eps,eps]},{1/2 F[sig,sig,eps,eps],0}},{{0,1/2 H[sig,sig,eps,eps]},{1/2 H[sig,sig,eps,eps],0}}}, (* crossing vector V_even for Z_2 even, spin even channel *)

op[op,"O",1,1]→{{0},{0},{F[sig,eps,sig,eps]},{F[eps,sig,sig,eps]},{-H[eps,sig,sig,eps]}}, (* crossing vector V_odd for Z_2 odd, spin even channel *)

op[op,"O",1,-1]→{{0},{0},{F[sig,eps,sig,eps]}} (* crossing vector V_odd for Z_2 odd, spin odd channel *)
```

120%

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Block specifications

```
(* conformal block specifications : spacetime dimension, derivative order, pole keeping order, r_ order, spins *)
blockconfobj={"dim"→3,"Λmax"→11,"κ"→12,"rN"→48,"lset"→Range[0,20]~Join~{49,52}};
```

```
dim = 3;
Lambda = 27;
AutoCB3$BlockSetting["DSD"][dim,Lambda] (* some presetting in simpleboot *)
```

```
{dim → 3, Λmax → 27, κ → 20, rN → 80, lset → {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11,
   12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 29, 30, 33, 34, 37, 38, 41, 42, 45, 46, 49, 50}}
```

Initialize simpleboot

```
(* tell simpleboot about the crossing vectors and block specs *)
AutoCB3$Init[crossvecobj,blockconfobj];
```

AutoCB3$Init[crossvecobj,blockconfobj] : this function tells simpleboot about the crossing vectors and block specs.

Gaps

Format :

GapConfiguration is a List of element in one of the following format:

{channel,gap,spins} // this means demand $\alpha \cdot V_{\text{channel}} \geq 0$ for $\Delta >$ gap and l in spins ... spins can be a integer or set of integers

120%

A... a... PI... d... tu... a... Is... S... Is... T... T... gi... 1... ENG 8:03 PM 4/25/2023

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```
Clear@GapConfiguration;
GapConfiguration[dim_,lset_]:={
{op[op, "O", 1, 1],3,0}, (* α.V_odd>0 for Δ>3 and L=0 *)
{op[op, "E", 1, 1],3,0}, (* α.V_even>0 for Δ>3 and L=0 *)

{op[op, "E", 1, 1],Δunitary[dim, /],Select[lset, EvenQ[#] && # > 0 & ]},  (* α.V_even>0 for Δ>Δ_unitary and L=2, 4, ... *)
{op[op, "O", 1, -1],Δunitary[dim, /],Select[lset, OddQ ]},                (* α.V_odd>0 for Δ>Δ_unitary and L=1, 3, ... *)
{op[op, "O", 1, 1],Δunitary[dim, /],Select[lset, EvenQ[#] && # > 0 & ]}   (* α.V_odd>0 for Δ>Δ_unitary and L=2, 4, ... *)
};
```

/ : place holder for spin

SDP template

normalization:

$\alpha \cdot (V_{\text{identity}}) = 1$ with $V_{\text{identity}} = (1 \quad 1) \cdot V_{\text{even}}(\Delta = 0,\ / = 0) \cdot \begin{pmatrix} 1 \\ 1 \end{pmatrix}$

positivity condition:

$\alpha \cdot V_{\text{even}}(\Delta, /) \geq 0$ for $\Delta \geq 3,\ / = 0$

$\alpha \cdot V_{\text{odd}}(\Delta, /) \geq 0$ for $\Delta \geq 3,\ / = 0$

$\alpha \cdot V_{\text{even}}(\Delta, /) \geq 0$ for $\Delta \geq \Delta_{\text{unitary}},\ / = 2, 4, 6, \ldots$

$\alpha \cdot V_{\text{odd}}(\Delta, /) \geq 0$ for $\Delta \geq \Delta_{\text{unitary}},\ / = 1, 2, 3, 4, \ldots$

$\alpha . V_\theta \geq 0$ where $V_\theta = V_{\text{even}}(\Delta = \Delta_\epsilon, / = 0) + V_{\text{odd}}(\Delta = \Delta_\sigma, / = 0) \otimes \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$

120%

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```
Clear@SDPTemplate$IsingOE$MainPart;
SDPTemplate$IsingOE$MainPart[]:=Module[
{BC$normalization,BC$objective,BC$condition,sdp,V$theta},

BC$normalization=AutoCB3$Vector[CrossVec["identity"]];  (* α.V_identity=1 *)
BC$objective=AutoCB3$Vector[CrossVec["zero"]];
BC$condition=AutoCB3$Condition[GapConfiguration];  (* the rest positivity conditions *)

sdp=SDPData[BC$objective,BC$normalization,BC$condition];

sdp
];

SDPTemplate$IsingOE$ThetaPart[]:=Module[
{BC$normalization,BC$objective,BC$condition,sdp,V$theta},

V$theta=MapAt[{OPE$sse,OPE$eee}.#.{OPE$sse,OPE$eee}&,CrossVec["V$theta"],{All,1}];

BC$normalization=AutoCB3$Vector[CrossVec["identity"]];
BC$objective=AutoCB3$Vector[CrossVec["zero"]];
BC$condition=AutoCB3$Condition[1,V$theta,0,{0}];

sdp=SDPData[BC$objective,BC$normalization,BC$condition];

sdp
];
```

120%

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```
BC$condition=AutoCB3$Condition[GapConfiguration];  (* the rest positivity conditions *)

sdp=SDPData[BC$objective,BC$normalization,BC$condition];

sdp
];

SDPTemplate$IsingOE$ThetaPart[]:=Module[
{BC$normalization,BC$objective,BC$condition,sdp,V$theta},

V$theta=MapAt[{OPE$sse,OPE$eee}.#.{OPE$sse,OPE$eee}&,CrossVec["V$theta"],{All,1}];

BC$normalization=AutoCB3$Vector[CrossVec["identity"]];
BC$objective=AutoCB3$Vector[CrossVec["zero"]];
BC$condition=AutoCB3$Condition[1,V$theta,0,{0}];

sdp=SDPData[BC$objective,BC$normalization,BC$condition];

sdp
];
```

In[21]:=
```
1;
```

```
⎛                    ⎛Fp[sig, sig, sig, sig, eps]  0⎞ ⎞
⎜                    ⎜                              ⎟ ⎟
⎜                    ⎝0                             0⎠ ⎟
⎜⎛0  0                                                ⎞ ⎟
⎜⎝0  Fp[eps, eps, eps, eps, eps]                      ⎠ ⎟
⎜⎛Fp[sig, eps, sig, eps, sig]  0                      ⎞ ⎟
```

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In[23]:=
```
CrossVec["V$theta"] // MatrixForm
```

Out[23]//MatrixForm=

$$\begin{pmatrix} \begin{pmatrix} \text{CBPoly\$Hold[Fixed, FS[sig, sig, sig, sig], } \ell\text{, m, n, ExtOp\$eps]} & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & \text{CBPoly\$Hold[Fixed, FS[eps, eps, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} \end{pmatrix} \\ \begin{pmatrix} \text{CBPoly\$Hold[Fixed, F[sig, eps, sig, eps], } \ell\text{, m, n, ExtOp\$sig]} & 0 \\ 0 & 0 \end{pmatrix} \end{pmatrix}$$

$$\begin{pmatrix} \text{CBPoly\$Hold[Fixed, F[eps, sig, sig, eps], } \ell\text{, m, n, ExtOp\$sig]} & \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} \\ \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} & 0 \end{pmatrix}$$

$$\begin{pmatrix} -\text{CBPoly\$Hold[Fixed, F[eps, sig, sig, eps], } \ell\text{, m, n, ExtOp\$sig]} & \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} \\ \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} & 0 \end{pmatrix}$$

```
"VBlock$Single" → ( ( Fp[sig, sig, sig, sig, eps]   0 )
                  (          0                     0 )
                  ( 0                      0        )
                  ( 0   Fp[eps, eps, eps, eps, eps] )
                  ( Fp[sig, eps, sig, eps, sig]   0 )
                  (          0                    0 )
                  (  Fp[eps, sig, sig, eps, sig]    1/2 Fp[sig, sig, eps, eps, eps] )
                  ( 1/2 Fp[sig, sig, eps, eps, eps]                0                 )
                  ( -Hp[eps, sig, sig, eps, sig]    1/2 Hp[sig, sig, eps, eps, eps] )
                  ( 1/2 Hp[sig, sig, eps, eps, eps]                0                 ) )
```

```
CrossVec["V$theta"] // MatrixForm
```

120%

IsingOE_OPEscan.nb - Wolfram Mathematica 11.1

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```
{BC$normalization,BC$objective,BC$condition,sdp,V$theta},

V$theta=MapAt[{OPE$sse,OPE$eee}.#.{OPE$sse,OPE$eee}&,CrossVec["V$theta"],{All,1}];

BC$normalization=AutoCB3$Vector[CrossVec["identity"]];
BC$objective=AutoCB3$Vector[CrossVec["zero"]];
BC$condition=AutoCB3$Condition[1,V$theta,0,{0}];

sdp=SDPData[BC$objective,BC$normalization,BC$condition];

sdp
];
```

In[23]:= `CrossVec["V$theta"] // MatrixForm`

Out[23]//MatrixForm=

$$\begin{pmatrix} \begin{pmatrix} \text{CBPoly\$Hold[Fixed, FS[sig, sig, sig, sig], } \ell\text{, m, n, ExtOp\$eps]} & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & \text{CBPoly\$Hold[Fixed, FS[eps, eps, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} \end{pmatrix} \\ \begin{pmatrix} \text{CBPoly\$Hold[Fixed, F[sig, eps, sig, eps], } \ell\text{, m, n, ExtOp\$sig]} & 0 \\ 0 & 0 \end{pmatrix} \end{pmatrix}$$

$$\begin{pmatrix} \text{CBPoly\$Hold[Fixed, F[eps, sig, sig, eps], } \ell\text{, m, n, ExtOp\$sig]} & \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} \\ \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} & 0 \end{pmatrix}$$

$$\begin{pmatrix} -\text{CBPoly\$Hold[Fixed, F[eps, sig, sig, eps], } \ell\text{, m, n, ExtOp\$sig]} & \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} \\ \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], } \ell\text{, m, n, ExtOp\$eps]} & 0 \end{pmatrix}$$

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8:06 PM 4/25/2023

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```
sdp
];

SDPTemplate$IsingOE$ThetaPart[]:=Module[
{BC$normalization,BC$objective,BC$condition,sdp,V$theta},

V$theta=MapAt[{OPE$sse,OPE$eee}.#.{OPE$sse,OPE$eee}&,CrossVec["V$theta"],{All,1}];

BC$normalization=AutoCB3$Vector[CrossVec["identity"]];
BC$objective=AutoCB3$Vector[CrossVec["zero"]];
BC$condition=AutoCB3$Condition[1,V$theta,0,{0}];

sdp=SDPData[BC$objective,BC$normalization,BC$condition];

sdp
];
```

```
MapAt[{OPE$sse, OPE$eee}.#.{OPE$sse, OPE$eee} &, CrossVec["V$theta"], {All, 1}]
```

In[23]:=
```
CrossVec["V$theta"] // MatrixForm
```

Out[23]//MatrixForm=

$$\begin{pmatrix} \begin{pmatrix} \text{CBPoly\$Hold[Fixed, FS[sig, sig, sig, sig], \ell, m, n, ExtOp\$eps]} & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & \text{CBPoly\$Hold[Fixed, FS[eps, eps, eps, eps], \ell, m, n, ExtOp\$eps]} \end{pmatrix} \\ \begin{pmatrix} \text{CBPoly\$Hold[Fixed, F[sig, eps, sig, eps], \ell, m, n, ExtOp\$sig]} & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} \text{CBPoly\$Hold[Fixed, F[eps, sig, sig, eps], \ell, m, n, ExtOp\$sig]} & \frac{1}{2}\,\text{CBPoly\$Hold[Fixed, FS[sig, sig, eps, eps], \ell, m, n, ExtOp\$eps]} \end{pmatrix} \end{pmatrix}$$

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```
rossVec["identity"]];
Vec["zero"]];
V$theta,0,{0}];

lization,BC$condition];
```

In[25]:=
```
MapAt[{OPE$sse, OPE$eee}.#.{OPE$sse, OPE$eee} &, CrossVec["V$theta"], {All, 1}] // MatrixForm
```

$$\begin{pmatrix} \text{OPE\$sse}^2\ \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{sig}, \text{sig}], \ell, m, n, \text{ExtOp\$eps}] \\ \text{OPE\$eee}^2\ \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{eps}, \text{eps}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] \\ \text{OPE\$sse}^2\ \text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{sig}, \text{eps}, \text{sig}, \text{eps}], \ell, m, n, \text{ExtOp\$sig}] \\ \text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] + \text{OPE\$sse}\left(\text{OPE\$sse}\ \text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{eps}, \text{sig}, \text{sig}, \text{eps}], \ell, m, n, \text{ExtOp\$sig}] + \frac{1}{2}\ \text{OPE\$eee}\ \text{CB} \\ \text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] + \text{OPE\$sse}\left(-\text{OPE\$sse}\ \text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{eps}, \text{sig}, \text{sig}, \text{eps}], \ell, m, n, \text{ExtOp\$sig}] + \frac{1}{2}\ \text{OPE\$eee}\ \text{CB} \end{pmatrix}$$

In[23]:=
```
CrossVec["V$theta"] // MatrixForm
```

Out[23]//MatrixForm=

$$\begin{pmatrix} \begin{pmatrix} \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{sig}, \text{sig}], \ell, m, n, \text{ExtOp\$eps}] & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{eps}, \text{eps}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] \end{pmatrix} \\ \begin{pmatrix} \text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{sig}, \text{eps}, \text{sig}, \text{eps}], \ell, m, n, \text{ExtOp\$sig}] & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} \text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{eps}, \text{sig}, \text{sig}, \text{eps}], \ell, m, n, \text{ExtOp\$sig}] & \frac{1}{2}\ \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] \end{pmatrix} \end{pmatrix}$$

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```
SDPTemplate$IsingOE$ThetaPart[]:=Module[
{BC$normalization,BC$objective,BC$condition,sdp,V$theta},

V$theta=MapAt[{OPE$sse,OPE$eee}.#.{OPE$sse,OPE$eee}&,CrossVec["V$theta"],{All,1}];

BC$normalization=AutoCB3$Vector[CrossVec["identity"]];
BC$objective=AutoCB3$Vector[CrossVec["zero"]];
BC$condition=AutoCB3$Condition[1,V$theta,0,{0}];

sdp=SDPData[BC$objective,BC$normalization,BC$condition];

sdp
];
```

In[25]:=
```
MapAt[{OPE$sse, OPE$eee}.#.{OPE$sse, OPE$eee} &, CrossVec["V$theta"], {All, 1}] // MatrixForm
```

Out[25]//MatrixForm=

$$\begin{pmatrix} \text{OPE\$sse}^2\ \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{sig}, \text{sig} \\ \text{OPE\$eee}^2\ \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{eps}, \text{eps}, \text{eps}, \text{eps} \\ \text{OPE\$sse}^2\ \text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{sig}, \text{eps}, \text{sig}, \text{eps}] \\ \frac{1}{2}\ \text{OPE\$eee}\ \text{OPE\$sse}\ \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, \text{m}, \text{n}, \text{ExtOp\$eps}] + \text{OPE\$sse}\ (\text{OPE\$sse}\ \text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{eps}, \text{sig}, \text{si} \\ \frac{1}{2}\ \text{OPE\$eee}\ \text{OPE\$sse}\ \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, \text{m}, \text{n}, \text{ExtOp\$eps}] + \text{OPE\$sse}\ (-\text{OPE\$sse}\ \text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{eps}, \text{sig}, \text{s} \end{pmatrix}$$

In[23]:=
```
CrossVec["V$theta"] // MatrixForm
```

Out[23]//MatrixForm=

$$\begin{pmatrix} \text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{sig}, \text{sig}], \ell, \text{m}, \text{n}, \text{ExtOp\$eps}] & 0 \end{pmatrix}$$

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$$\begin{pmatrix} \frac{1}{2}\,\text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] & 0 \\ -\text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{eps}, \text{sig}, \text{sig}, \text{eps}], \ell, m, n, \text{ExtOp\$sig}] & \frac{1}{2}\,\text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] \\ \frac{1}{2}\,\text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] & 0 \end{pmatrix}$$

```
MapAt[{OPE$sse, OPE$eee}.#.{OPE$sse, OPE$eee} &, CrossVec["V$theta"], {All, 1}] // MatrixForm
```

$$\begin{pmatrix} & \text{OPE\$sse}^2\,\text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{sig}, \text{sig} \\ & \text{OPE\$eee}^2\,\text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{eps}, \text{eps}, \text{eps}, \text{eps} \\ & \text{OPE\$sse}^2\,\text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{sig}, \text{eps}, \text{sig}, \text{eps}] \\ \frac{1}{2}\,\text{OPE\$eee}\,\text{OPE\$sse}\,\text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] + \text{OPE\$sse}\,(\text{OPE\$sse}\,\text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{eps}, \text{sig}, \text{si} \\ \frac{1}{2}\,\text{OPE\$eee}\,\text{OPE\$sse}\,\text{CBPoly\$Hold}[\text{Fixed}, \text{FS}[\text{sig}, \text{sig}, \text{eps}, \text{eps}], \ell, m, n, \text{ExtOp\$eps}] + \text{OPE\$sse}\,(-\text{OPE\$sse}\,\text{CBPoly\$Hold}[\text{Fixed}, \text{F}[\text{eps}, \text{sig}, \text{s} \end{pmatrix}$$

```
AutoCB3$SaveSDPTemplate[SDPTemplate$IsingOE$MainPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"];
AutoCB3$SaveSDPTemplate[SDPTemplate$IsingOE$ThetaPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Theta.m"];
AutoCB3$SDPConsistencyCheck warning: find unresolved symbols. user should make sure those symbols are user-defined variables :
 {OPE$sse, OPE$eee}
```

Generate SDP

This function generate a SDP. It will be used by the Delaunay search scanner.
Input : a point to scan
Output : filename of the SDP

```
In[17]:= (* we need to seperate main part with theta part, because main part don't chang during the OPE scan *)

SDP$IsingOE$Main[point_List, filename_:Automatic]:=Module[
```

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```
AutoCB3$SaveSDPTemplate[SDPTemplate$IsingOE$MainPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"];
AutoCB3$SaveSDPTemplate[SDPTemplate$IsingOE$ThetaPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Theta.m"];
```

```
AutoCB3$SDPConsistencyCheck warning: find unresolved symbols. user should make sure those symbols are user-defined variables :
 {OPE$sse, OPE$eee}
```

Generate SDP

This function generate a SDP. It will be used by the Delaunay search scanner.
Input : a point to scan
Output : filename of the SDP

In[17]:=

```
(* we need to seperate main part with theta part, because main part don't chang during the OPE scan *)

SDP$IsingOE$Main[point_List,filename_:Automatic]:=Module[
{Δσ,Δε},
{Δσ,Δε}=SetPrec$Real[point];
AutoCB3$GenerateSDP$MMAExpr[{Δσ,Δε},{},filename,
ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"]
];

SDP$IsingOE$Theta[point_List,OPEs_List,filename_:Automatic]:=Module[
{Δσ,Δε,OPE$eee,OPE$sse},
{Δσ,Δε}=SetPrec$Real[point];
OPE$eee=1;
OPE$sse=OPEs[[1]]//SetPrec$Real;

AutoCB3$GenerateSDP$MMAExpr[{Δσ,Δε},{"OPE$eee"→OPE$eee,"OPE$sse"→OPE$sse},filename,
```

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```
{OPE$sse, OPE$eee}
```

Generate SDP

This function generate a SDP. It will be used by the Delaunay search scanner.
Input : a point to scan
Output : filename of the SDP

In[17]:=

```
(* we need to seperate main part with theta part, because main part don't chang during the OPE scan *)

SDP$IsingOE$Main[point_List,filename_:Automatic]:=Module[
{Δσ,Δε},
{Δσ,Δε}=SetPrec$Real[point];
AutoCB3$GenerateSDP$MMAExpr[{Δσ,Δε},{},filename,
ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"]
];

SDP$IsingOE$Theta[point_List,OPEs_List,filename_:Automatic]:=Module[
{Δσ,Δε,OPE$eee,OPE$sse},
{Δσ,Δε}=SetPrec$Real[point];
OPE$eee=1;
OPE$sse=OPEs[[1]]//SetPrec$Real;

AutoCB3$GenerateSDP$MMAExpr[{Δσ,Δε},{"OPE$eee"→OPE$eee,"OPE$sse"→OPE$sse},filename,
ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Theta.m"]
];
```

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Text

```
5
6
7 echo "Hello world!"
8
9 echo "Nodes list : "
10 scontrol show hostnames $SLURM_NODELIST
11
```

```
job1.sh  slurm-406031.out
nsu2@mn003:/gpfs/nsu2/tutorial/1$ cat slurm-406031.out
Hello world!
Nodes list :
cn075
cn076
```

Slide 6 of 14

Cluster basics : example : run SDPB over 2 nodes

job2.sh

```
1 #!/bin/bash
2 #SBATCH --nodes=2
3 #SBATCH --partition=debugq
4 #SBATCH --time=0-0:00:10
5
6 mpirun -n 80 /home/nsu2/packages/sdpb --procsPerNode 40 -s sdp1.sdp
7
```

100%

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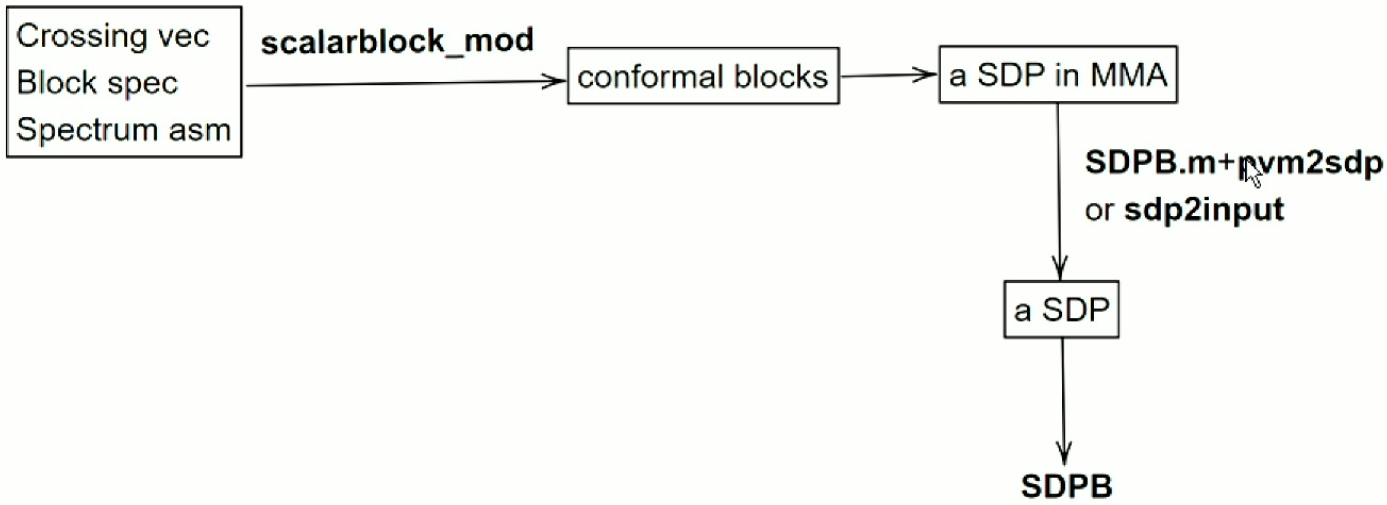
simpleboot : run a SDP (Mathematica mode)



Advantage : simpleboot access to explicit SDP data (such as explicit crossing vectors $V_{\Delta,\ell}$). Very useful in exploratory stage.

Disadvantage : Slower than the sdp2input_mod mode

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Output : filename of the SDP

In[17]:=
```
(* we need to seperate main part with theta part, because main part don't chang during the OPE scan *)

SDP$IsingOE$Main[point_List,filename_:Automatic]:=Module[
{Δσ,Δε},
{Δσ,Δε}=SetPrec$Real[point];
AutoCB3$GenerateSDP$MMAExpr[{Δσ,Δε},{},filename,
ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"]
];

SDP$IsingOE$Theta[point_List,OPEs_List,filename_:Automatic]:=Module[
{Δσ,Δε,OPE$eee,OPE$sse},
{Δσ,Δε}=SetPrec$Real[point];
OPE$eee=1;
OPE$sse=OPEs[[1]]//SetPrec$Real;

AutoCB3$GenerateSDP$MMAExpr[{Δσ,Δε},{"OPE$eee"→OPE$eee,"OPE$sse"→OPE$sse},filename,
ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Theta.m"]
];
```

OPE scan

In[18]:=
```
Cluster$SetConfig["[AutoCB3.sdp2input_mod]",False];
```

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```
AutoCB3$GenerateSDP$MMAExpr[{Δσ,Δε},{},filename,
ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"]
];

SDP$IsingOE$Theta[point_List,OPEs_List,filename_:Automatic]:=Module[
{Δσ,Δε,OPE$eee,OPE$sse},
{Δσ,Δε}=SetPrec$Real[point];
OPE$eee=1;
OPE$sse=OPEs[[1]]//SetPrec$Real;

AutoCB3$GenerateSDP$MMAExpr[{Δσ,Δε},{"OPE$eee"→OPE$eee,"OPE$sse"→OPE$sse},filename,
ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Theta.m"]
];
```

OPE scan

In[19]:=
```
Cluster$SetConfig["[AutoCB3.sdp2input_mod]",False];
```

In[20]:=
```
Cluster$SetConfig["[pvm2sdp.script]","mpirun -n $phys_cores_per_node /home/nsu2/packages/sdpb2.5.1/bin/pvm2sdp"];
```

```
SSH2$UploadCurrentNotebook[]
```

120%

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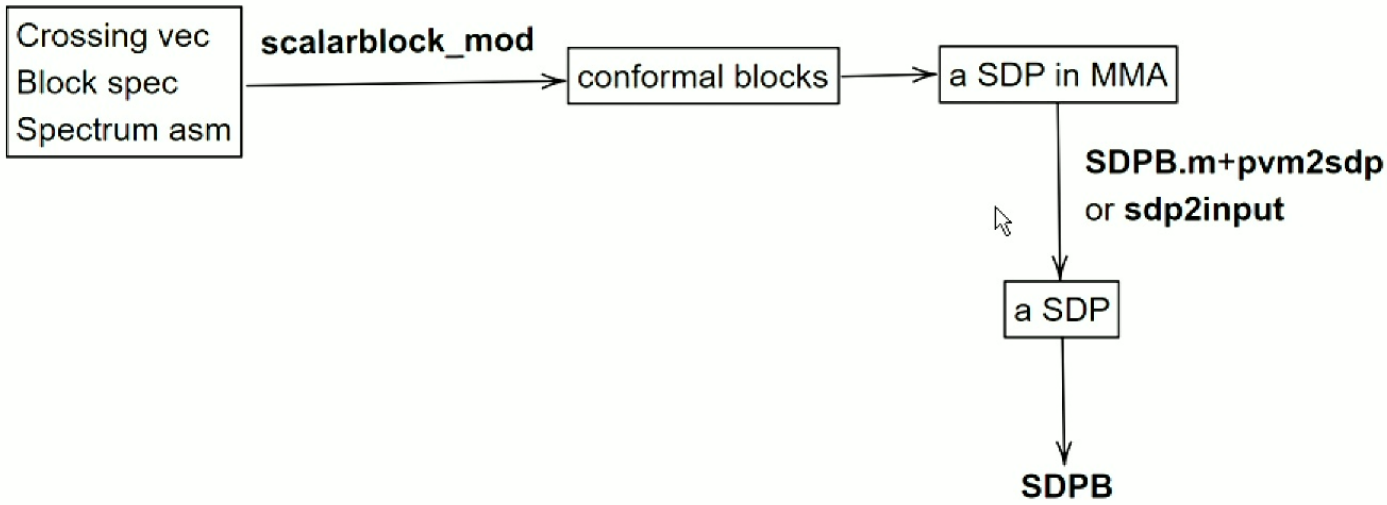
simpleboot : run a SDP (Mathematica mode)



Advantage : simpleboot access to explicit SDP data (such as explicit crossing vectors $V_{\Delta,\ell}$). Very useful in exploratory stage.

Disadvantage : Slower than the sdp2input_mod mode

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In[19]:= Cluster$SetConfig["[AutoCb3.sdp2input_mod]",False];

In[20]:= Cluster$SetConfig["[pvm2sdp.script]","mpirun -n $phys_cores_per_node /home/nsu2/packages/sdpb2.5.1/bin/pvm2sdp"];

SSH2$UploadCurrentNotebook[]

ClusterLoginNode$Evaluate@DeleteDirectory[ReconfigCmd@"[Cluster.ProjectDirectory]", DeleteContents → True]

```
Fri Apr 21 17:26:00 EDT 2023
CPU Information:
     48  Intel(R) Xeon(R) Silver 4214R CPU @ 2.40GHz
/gpfs/nsu2/simpleboot4_tutorial1A
Project director:
Proj_IsingOE_OPEscan
running MMA file:
/gpfs/nsu2/simpleboot4_package/boot.m
with parameter:
eyJJc2luZ09FX09QRXNjYW4ubSIsIEhvbGRbRGVsZXRlRGlyZWN0b3J5W1JlY29uZmlnQ21kWyJbQ2x1c3Rlci5Qcm9qZWN0RGlyZWN0b3J5XSJdLCBEZWxldGVD
   Db250ZW50cyAtPiBUcnVlXV19 evaluate
SSH$Evaluate: filename=IsingOE_OPEscan.m,
  expr=Hold[DeleteDirectory[ReconfigCmd[[Cluster.ProjectDirectory]], DeleteContents ï› True]]. Start evaluating...
Bootstapper packages Loaded. Version : 4.0
MMA Precision set to 200.
[RemoteExecuteReturnBegin]TnVsbA==[RemoteExecuteReturnEnd]
SSH$Evaluate result:
```

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```
 ]
 , 1]
```

{409283}

```
Table[
 ClusterAsyn$Evaluate[

  AutoCB3$SaveSDPDataTemplate[SDPTemplate$IsingOE$MainPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"];
  AutoCB3$SaveSDPDataTemplate[SDPTemplate$IsingOE$ThetaPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Theta.m"];

  initpts = {{0.5181489, 1.412625}} ~ Join ~ GeneratePointsInRectangular[{0.515, 0.523}, {1.38, 1.45}, 3, 3] // SetPrec;;

  SB$OPEScanner[SDP$IsingOE$Main, SDP$IsingOE$Theta, initpts, {{0.1}},
   {0.5 ≤ TS$Theta[1] ≤ 0.9},
   "--dualityGapThreshold=1e-20 --primalErrorThreshold=1e-60 --dualErrorThreshold=1e-60 --precision=400
     --initialMatrixScalePrimal=1e+20 --initialMatrixScaleDual=1e+20 --maxComplementarity=1e+100
     --detectPrimalFeasibleJump --detectDualFeasibleJump", {"Delaunay"}, 1000, False, False, False]
 ]
 , 1]
```

```
ClusterAsyn$JobOutput["408926"]
```

```
ClusterAsyn$SDPBOutput["0.518148900000_1.41262500000_1_0.100000000000_Apr21_16h54m46s.xml"]
```

```
SSH$DownloadFile@SB$Proj$FileName; (* download current project data from the cluster *)
SB$LoadProject[]; (* load current project data *)
```

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```
    --delta-34
    -0.894476099999999996192912021797383204102516174316406250000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
    --convolve 'Fsigepssigeps=
    0.96538695000000002144346922250406350940465927124023437500000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000'
    --precision 1024 -o
    ./Proj_IsingOE_OPEscan/BlockData/sig0.5181489000000_eps1.412625000000_dim3_pd11_kp12_rN48_lset0-52_hash8114343490104716598
    --out-file-suffix Fsigepssigeps
  mpirun --bind-to none -n 1 /gpfs/nsu2/bootstrap_bin/scalar_blocks_mod --num-threads $phys_cores_per_node
    --no-zzbDeriv --dim 3 --order 48 --max-derivs 6 --spin-ranges 0-52 --poles 12 --delta-12
    0.894476099999999996192912021797383204102516174316406250000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
    --delta-34
    -0.894476099999999996192912021797383204102516174316406250000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
    --convolve 'Fepssigsigeps=
    0.518148900000000023347013211605371907353401184082031250000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000'
    --precision 1024 -o
    ./Proj_IsingOE_OPEscan/BlockData/sig0.5181489000000_eps1.412625000000_dim3_pd11_kp12_rN48_lset0-52_hash8114343490104716598
    --out-file-suffix Fepssigsigeps
  [Fri 21 Apr 2023 17:14:39] AutoCB3$GenerateSDP$MMAExpr$Evaluate plugin block and variables begin.
  ObjSet warning:plugin was not in object set. ObjSet will add this member to the object
  Launching kernels...
  [Fri 21 Apr 2023 17:14:46] AutoCB3$GenerateSDP$MMAExpr$Evaluate plugin block and variables end.
  [Fri 21 Apr 2023 17:14:46] SDP done. Writing to xml file.
  [Fri 21 Apr 2023 17:15:06] END: Create common part of the xml file.
  [Fri 21 Apr 2023 17:15:06] AutoCB3$GenerateSDP$MMAExpr$Evaluate plugin block and variables begin.
  [Fri 21 Apr 2023 17:15:07] AutoCB3$GenerateSDP$MMAExpr$Evaluate plugin block and variables end.
```

120%

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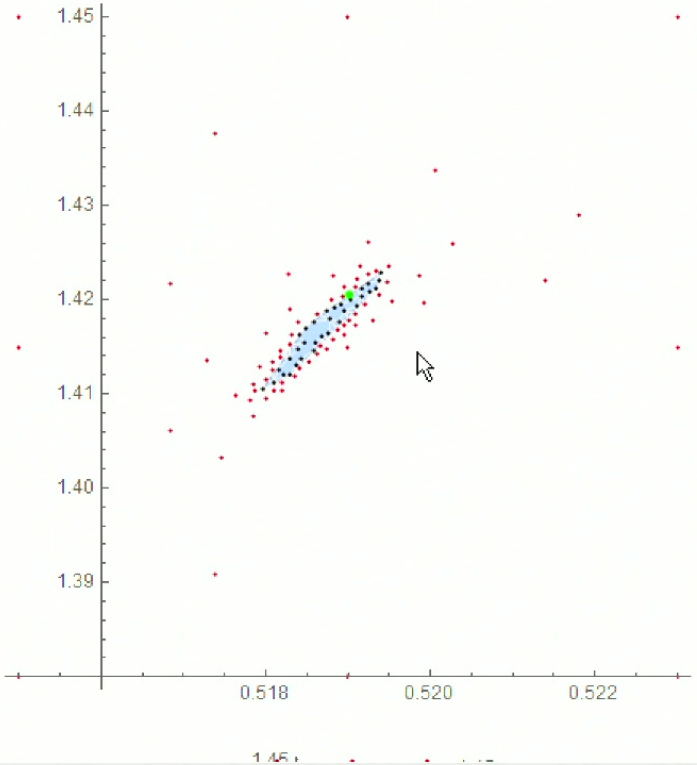
```
SSH$DownloadFile@SB$Proj$FileName; (* download current project data from the cluster *)
SB$LoadProject[]; (* load current project data *)

SB$DelaunayPlot[] (* plot the scan result *)
```



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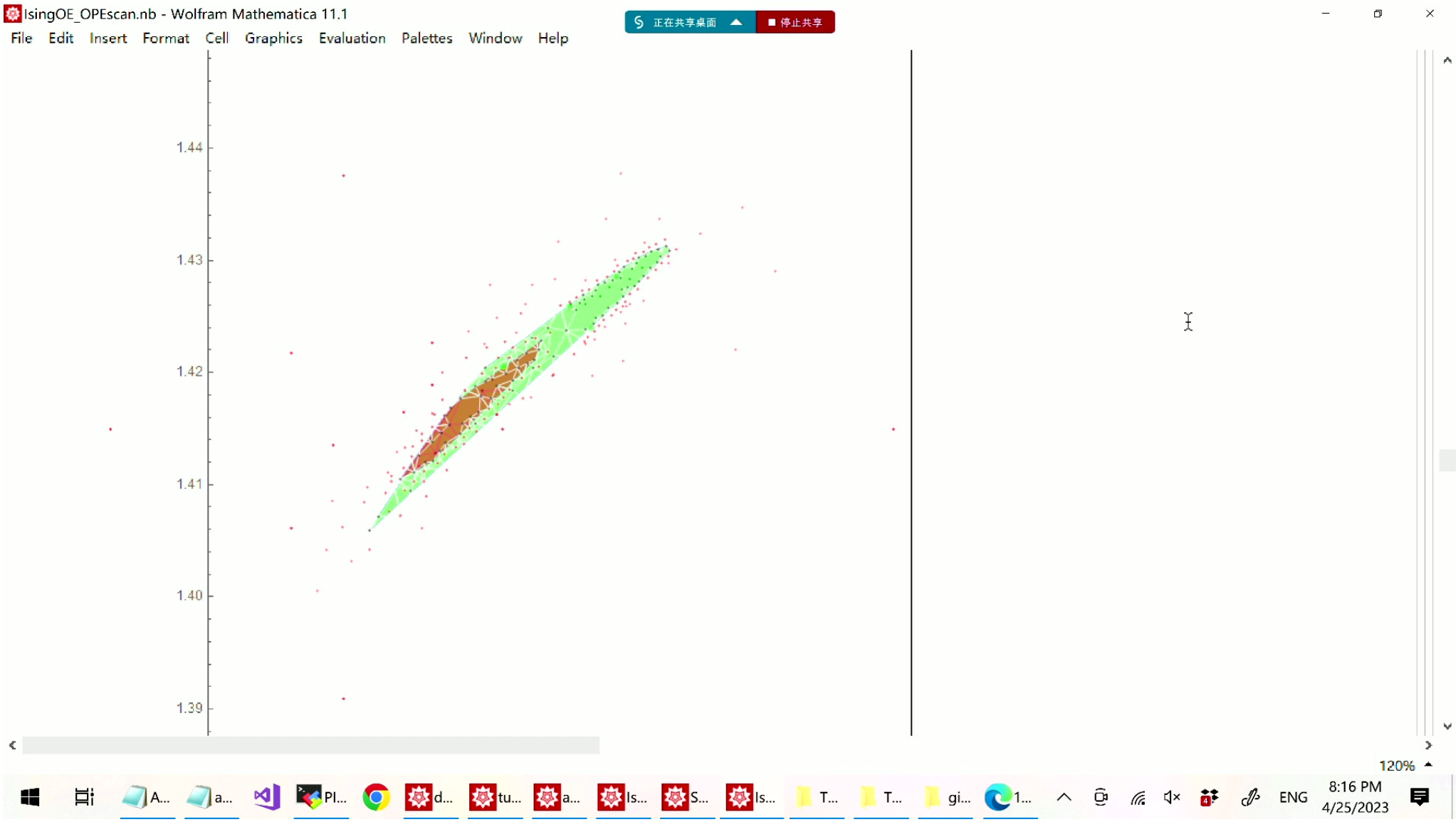
IsingOE_OPEscan.nb - Wolfram Mathematica 11.1
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停止共享
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```
      --initialMatrixScalePrimal=1e+20 --initialMatrixScaleDual=1e+20 --maxComplementarity=1e+100
      --detectPrimalFeasibleJump --detectDualFeasibleJump", 400, {"Delaunay"}, 200, False, True, False, False]
 ]
 , 1]
```

{409283}

```
Table[
 ClusterAsyn$Evaluate[

  AutoCB3$SaveSDPDataTemplate[SDPTemplate$IsingOE$MainPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"];
  AutoCB3$SaveSDPDataTemplate[SDPTemplate$IsingOE$ThetaPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Theta.m"];

  initpts = {{0.5181489, 1.412625}} ~ Join ~ GeneratePointsInRectangular[{0.515, 0.523}, {1.38, 1.45}, 3, 3] // SetPrec;;

  SB$OPEScanner[SDP$IsingOE$Main, SDP$IsingOE$Theta, initpts, {{0.1}},
   {0.5 ≤ TS$Theta[1] ≤ 0.9},
   "--dualityGapThreshold=1e-20 --primalErrorThreshold=1e-60 --dualErrorThreshold=1e-60 --precision=400
     --initialMatrixScalePrimal=1e+20 --initialMatrixScaleDual=1e+20 --maxComplementarity=1e+100
     --detectPrimalFeasibleJump --detectDualFeasibleJump", {"Delaunay"}, 1000, False, False, False]
 ]
 , 1]

ClusterAsyn$JobOutput["408926"]

ClusterAsyn$SDPBOutput["0.518148900000_1.41262500000_1_0.100000000000_Apr21_16h54m46s.xml"]

SSH$DownloadFile@SB$Proj$FileName; (* download current project data from the cluster *)
```

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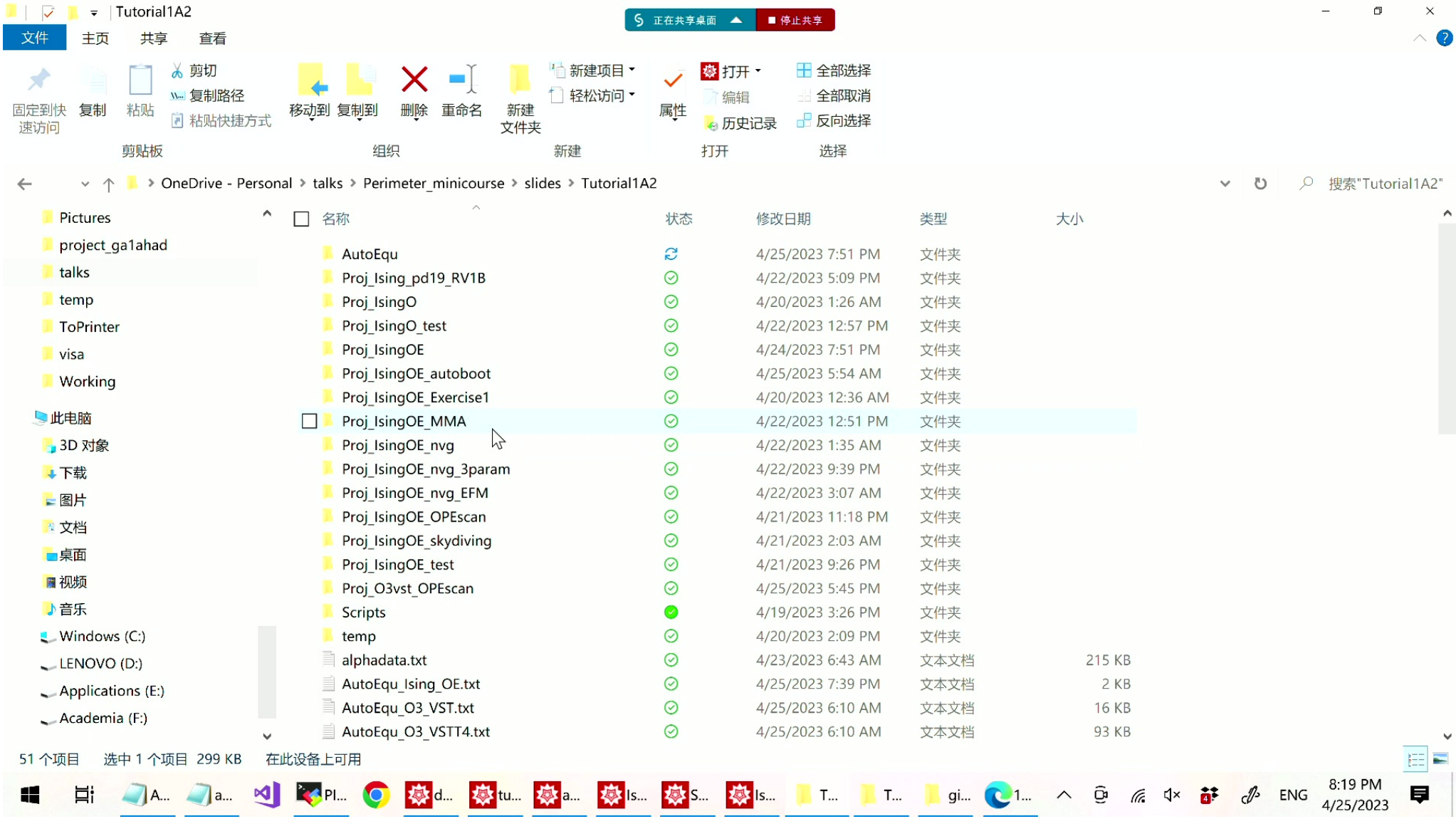
Tutorial1A2
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停止共享
文件
主页
共享
查看
固定到快速访问
复制
粘贴
剪切
复制路径
粘贴快捷方式
移动到
复制到
删除
重命名
新建文件夹
新建项目
轻松访问
属性
打开
编辑
历史记录
全部选择
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Proj_Ising_pd19_RV1B 4/22/2023 5:09 PM 文件夹
Proj_IsingO 4/20/2023 1:26 AM 文件夹
Proj_IsingO_test 4/22/2023 12:57 PM 文件夹
Proj_IsingOE 4/24/2023 7:51 PM 文件夹
Proj_IsingOE_autoboot 4/25/2023 5:54 AM 文件夹
Proj_IsingOE_Exercise1 4/20/2023 12:36 AM 文件夹
Proj_IsingOE_MMA 4/22/2023 12:51 PM 文件夹
Proj_IsingOE_nvg 4/22/2023 1:35 AM 文件夹
Proj_IsingOE_nvg_3param 4/22/2023 9:39 PM 文件夹
Proj_IsingOE_nvg_EFM 4/22/2023 3:07 AM 文件夹
Proj_IsingOE_OPEscan 4/21/2023 11:18 PM 文件夹
Proj_IsingOE_skydiving 4/21/2023 2:03 AM 文件夹
Proj_IsingOE_test 4/21/2023 9:26 PM 文件夹
Proj_O3vst_OPEscan 4/25/2023 5:45 PM 文件夹
Scripts 4/19/2023 3:26 PM 文件夹
temp 4/20/2023 2:09 PM 文件夹
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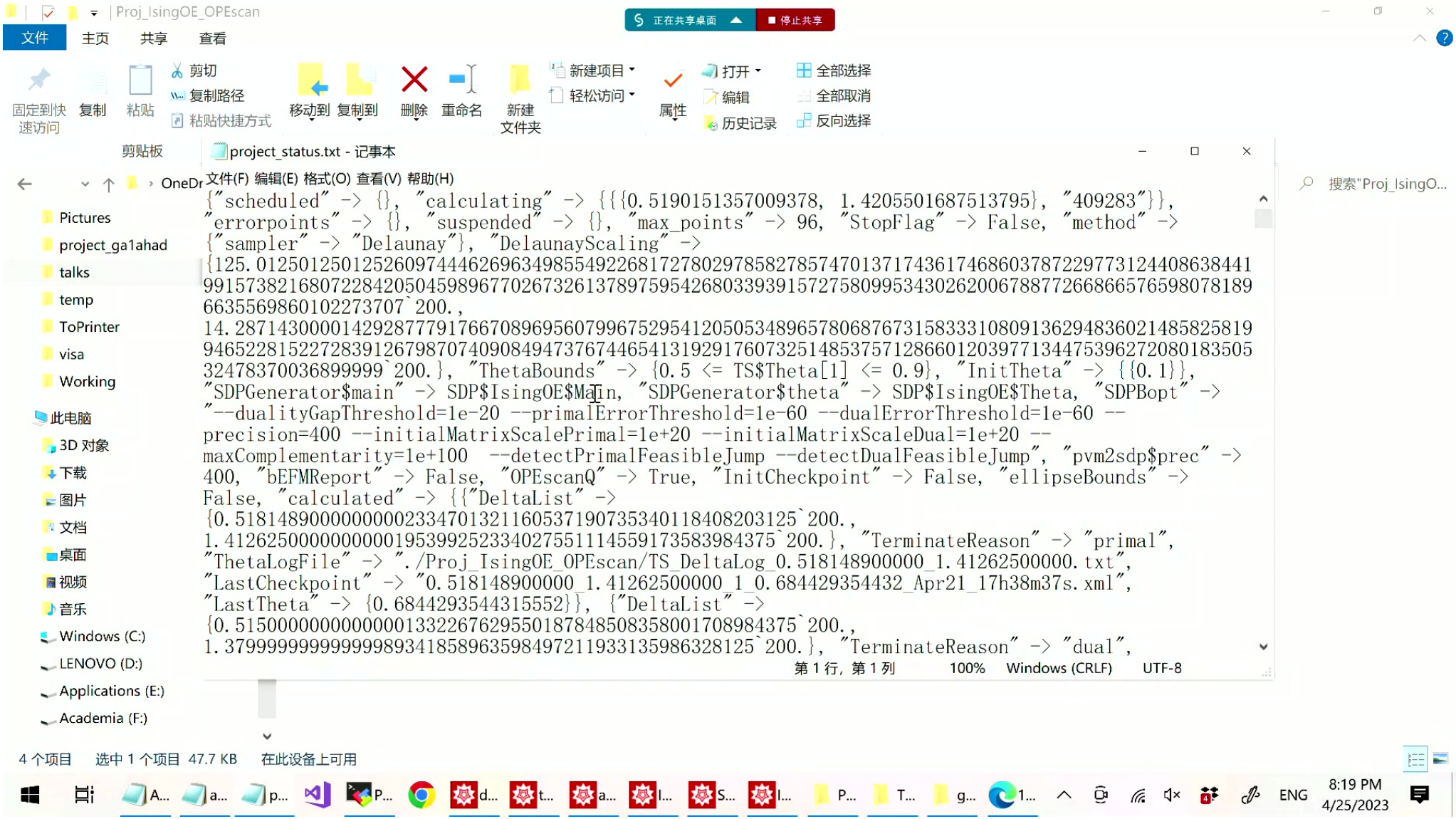
Proj_IsingOE_OPEscan
正在共享桌面
停止共享
文件
主页
共享
查看
project_status.txt - 记事本
文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)
{"scheduled" -> {}, "calculating" -> {{{0.5190151357009378, 1.4205501687513795}, "409283"}},
"errorpoints" -> {}, "suspended" -> {}, "max_points" -> 96, "StopFlag" -> False, "method" ->
{"sampler" -> "Delaunay"}, "DelaunayScaling" ->
{125.012501250125260974446269634985549226817278029785827857470137174361746860378722977312440863844199157382168072284205045989677026732613789759542680339391572758099534302620067887726686657659807818966355698601022737 07`200.,
14.287143000014292877791766708969560799675295412050534896578068767315833310809136294836021485825819946522815227283912679870740908494737674465413192917607325148537571286601203977134475396272080183505324783700368999997`200.}, "ThetaBounds" -> {0.5 <= TS$Theta[1] <= 0.9}, "InitTheta" -> {{0.1}},
"SDPGenerator$main" -> SDP$IsingOE$Main, "SDPGenerator$theta" -> SDP$IsingOE$Theta, "SDPBopt" ->
"--dualityGapThreshold=1e-20 --primalErrorThreshold=1e-60 --dualErrorThreshold=1e-60 --precision=400 --initialMatrixScalePrimal=1e+20 --initialMatrixScaleDual=1e+20 --maxComplementarity=1e+100 --detectPrimalFeasibleJump --detectDualFeasibleJump", "pvm2sdp$prec" ->
400, "bEFMReport" -> False, "OPEscanQ" -> True, "InitCheckpoint" -> False, "ellipseBounds" ->
False, "calculated" -> {{"DeltaList" ->
{0.5181489000000000233470132116053719073534011840820312 5`200.,
1.4126250000000000195399252334027551114559173583984375`200.}, "TerminateReason" -> "primal",
"ThetaLogFile" -> "./Proj_IsingOE_OPEscan/TS_DeltaLog_0.518148900000_1.41262500000.txt",
"LastCheckpoint" -> "0.518148900000_1.41262500000_1_0.684429354432_Apr21_17h38m37s.xml",
"LastTheta" -> {0.6844293544315552}}, {"DeltaList" ->
{0.5150000000000000133226762955018784850835800170898437 5`200.,
1.3799999999999999893418589635984972119331359863281 25`200.}, "TerminateReason" -> "dual",
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属性
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```
 --initialMatrixScalePrimal=1e+20 --initialMatrixScaleDual=1e+20 --maxComplementarity=1e+100
 --detectPrimalFeasibleJump --detectDualFeasibleJump", {"Delaunay"}, 1000, False, False, False]
]
, 1]

ClusterAsyn$JobOutput["408926"]

ClusterAsyn$SDPBOutput["0.518148900000_1.41262500000_1_0.100000000000_Apr21_16h54m46s.xml"]

In[27]:= SSH$DownloadFile@SB$Proj$FileName; (* download current project data from the cluster *)
SB$LoadProject[]; (* load current project data *)

In[29]:= SB$Proj

Out[29]= {scheduled → {}, calculating → {{{0.519015, 1.42055}, 409283}}, errorpoints → {},
 suspended → {}, max_points → 96, StopFlag → False, method → {sampler → Delaunay}, DelaunayScaling →
  {125.012501250125260974446269634985549226817278029785827857470137174361746860378722977312440863844199157382168072284205045989677026732613789759542680339391572758099534302620067887726686657659807818966361429.28714300001429287779176670896956079967529541205053489657806876731583331080913629483602148582581994652281522728391267987074090849473767446541319291760732514853757128660120397713447539627208018350532507409084947376744654131929176073251485375712866012039771344753962720801835053250},
 ThetaBounds → {0.5 ≤ TS$Theta[1] ≤ 0.9}, InitTheta → {{0.1}}, SDPGenerator$main → SDP$IsingOE$Main,
 SDPGenerator$theta → SDP$IsingOE$Theta, SDPBopt → --dualityGapThreshold=1e-20 --primalErrorThreshold=1e-60
    --dualErrorThreshold=1e-60 --precision=400 --initialMatrixScalePrimal=1e+20 --initialMatrixScaleDual=1e+20
    --maxComplementarity=1e+100  --detectPrimalFeasibleJump --detectDualFeasibleJump,
 pvm2sdp$prec → 400, bEFMReport → False, OPEscanQ → True, InitCheckpoint → False, ellipseBounds → False,
 calculated → {{DeltaList →
```

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IsingOE_OPEscan.nb * - Wolfram Mathematica 11.1

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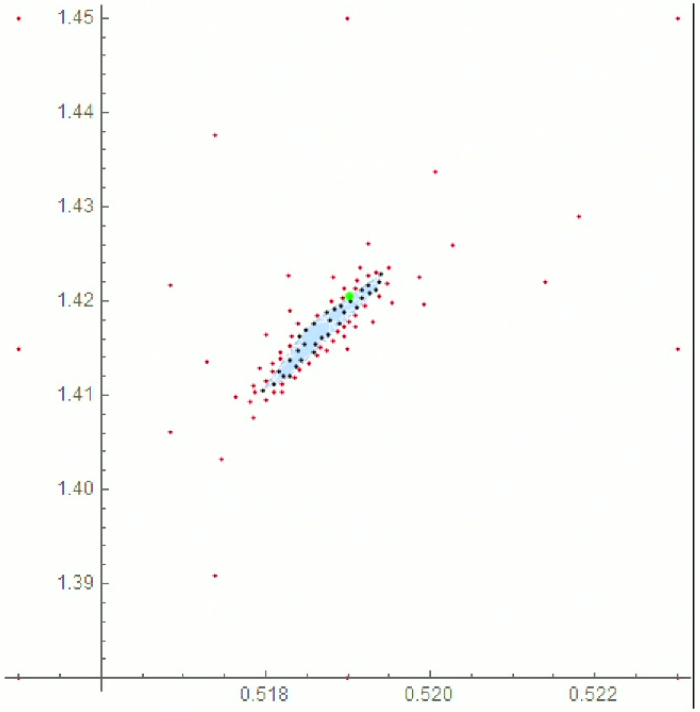
File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

In[27]:=
```
SSH$DownloadFile@SB$Proj$FileName; (* download current project data from the cluster *)
SB$LoadProject[]; (* load current project data *)
```

In[29]:=
```
SB$Proj
SB$DelaunayPlot[] (* plot the scan result *)
```



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File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

```
In[27]:= SSH$DownloadFile@SB$Proj$FileName; (* download current project data from the cluster *)
         SB$LoadProject[]; (* load current project data *)


         ObjGet[SB$Proj$calculated, 1,]

Out[30]= {{DeltaList →
           {0.5181489000000000233470132116053719073534011840820312500000000000000000000000000000000000000000000000000000000000000000000
            0000000000000000000000000000000000000000000000000000000000000000000000000000000000,
           1.41262500000000001953992523340275511145591735839843750000000000000000000000000000000000000000000000000000000000000000000000
            0000000000000000000000000000000000000000000000000000000000000000000000000000000000},
         TerminateReason → primal, ThetaLogFile → ./Proj_IsingOE_OPEscan/TS_DeltaLog_0.518148900000_1.41262500000.txt,
         LastCheckpoint → 0.518148900000_1.41262500000_1_0.684429354432_Apr21_17h38m37s.xml, LastTheta → {0.684429}}, {DeltaList →
           {0.5150000000000000133226762955018784850835800170898437500000000000000000000000000000000000000000000000000000000000000000000
            0000000000000000000000000000000000000000000000000000000000000000000000000000000000,
           1.37999999999999989341858963598497211933135986328125000000000000000000000000000000000000000000000000000000000000000000000000
            0000000000000000000000000000000000000000000000000000000000000000000000000000000000},
         TerminateReason → dual, ThetaLogFile → ./Proj_IsingOE_OPEscan/TS_DeltaLog_0.515000000000_1.38000000000.txt,
         LastCheckpoint → 0.515000000000_1.38000000000_1_0.733377472796_Apr21_17h41m19s.xml, LastTheta →
           {0.733377472796202806565640425454268782786964026852885087780910549914515273204833717770043163054693150042823699033038318200
            0681960903913161480639041918290658246886529110542292958805590302517824181003005 3}}, {DeltaList →
           {0.5150000000000000133226762955018784850835800170898437500000000000000000000000000000000000000000000000000000000000000000000
            0000000000000000000000000000000000000000000000000000000000000000000000000000000000,
           1.41499649999999990393462212523445487022399902343750000000000000000000000000000000000000000000000000000000000000000000000000
            0000000000000000000000000000000000000000000000000000000000000000000000000000000000},
         TerminateReason → dual, ThetaLogFile → ./Proj_IsingOE_OPEscan/TS_DeltaLog_0.515000000000_1.41499650000.txt,
```

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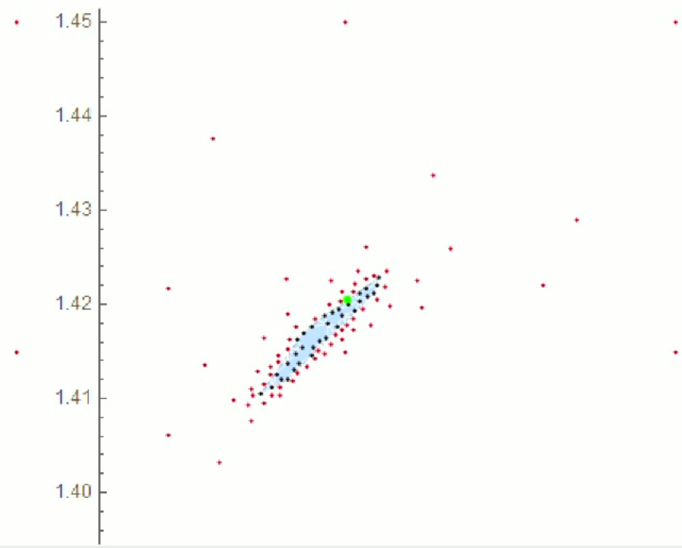
File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

```
In[27]:= SSH$DownloadFile@SB$Proj$FileName; (* download current project data from the cluster *)
         SB$LoadProject[]; (* load current project data *)

In[31]:= ObjGet[SB$Proj$calculated, 1, "DeltaList"]

Out[31]= {0.51814890000000002334701321160537190735340118408203125000000000000000000000000000000000000000000000000000000000000000000000000000
          0000000000000000000000000000000000000000000000000000000000000000000000000000000,
         1.41262500000000001953992523340275511145591735839843750000000000000000000000000000000000000000000000000000000000000000000000000
          000000000000000000000000000000000000000000000000000000000000000000000000000000}

SB$DelaunayPlot[] (* plot the scan result *)
```



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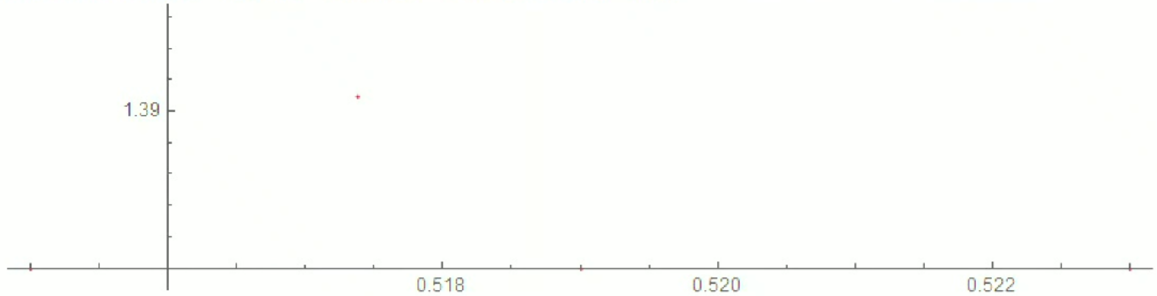


```
In[33]:= (* λσσε=1.0518537, λεεε=1.532435 from arXiv:1603.04436 .  λσσε/λεεε=0.6863936 *)
SB$Proj$calculated$primal

Out[33]= {{DeltaList →
  {0.518148900000000233470132116053719073534011840820312500000000000000000000000000000000000000000000000000000000000000000000
    00000000000000000000000000000000000000000000000000000000000000000000000000000000,
   1.412625000000000019539925233402755111455917358398437500000000000000000000000000000000000000000000000000000000000000000000
    0000000000000000000000000000000000000000000000000000000000000000000000000000000},
  TerminateReason → primal, ThetaLogFile → ./Proj_IsingOE_OPEscan/TS_DeltaLog_0.518148900000_1.41262500000.txt,
  LastCheckpoint → 0.518148900000_1.41262500000_1_0.684429354432_Apr21_17h38m37s.xml, LastTheta → {0.684429}},
 {DeltaList → {0.518382, 1.41469}, TerminateReason → primal,
  ThetaLogFile → ./Proj_IsingOE_OPEscan/TS_DeltaLog_0.518381990123_1.4146895.txt,
  LastCheckpoint → 0.518381990123_1.41468950000_1_0.685162801574_Apr21_18h09m55s.xml, LastTheta →
   {0.68516280157430139575161524021867607751223683116319193624036717875345805753562184639959769239027177129602119898200717321
    488490755718782571630211169884198184456057402854700934260601037891406901716445178}}, {DeltaList → {0.51846, 1.41538},
  TerminateReason → primal, ThetaLogFile → ./Proj_IsingOE_OPEscan/TS_DeltaLog_0.518459686831_1.41537766667.txt,
  LastCheckpoint → 0.518459686831_1.41537766667_1_0.685162076956_Apr21_18h16m49s.xml, LastTheta →
```

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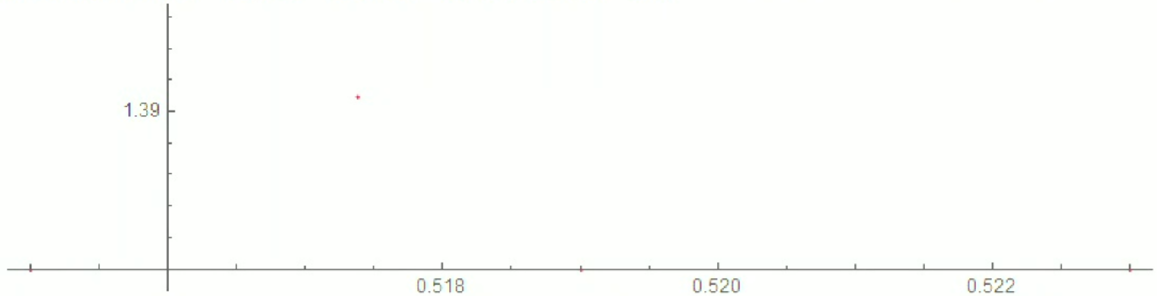
File Edit Insert Format Cell Graphics Evaluation Palettes Window Help




```
(* λσσε=1.0518537, λεεε=1.532435 from arXiv:1603.04436 .  λσσε/λεεε=0.6863936 *)
SB$Proj$calculated$primal[[]]

{DeltaList →
  {0.518148900000000023347013211605371907353401184082031250000000000000000000000000000000000000000000000000000000000000000000
   000000000000000000000000000000000000000000000000000000000000000000000000000,
  1.4126250000000001953992523340275511145591735839843750000000000000000000000000000000000000000000000000000000000000000000
   000000000000000000000000000000000000000000000000000000000000000000000000000}, TerminateReason → primal,
 ThetaLogFile → ./Proj_IsingOE_OPEscan/TS_DeltaLog_0.518148900000_1.41262500000.txt,
 LastCheckpoint → 0.518148900000_1.41262500000_1_0.684245707435_Apr21_17h17m38s.xml, LastTheta →
  {0.68424570743516211794290516723300527637623432177882937557441631259800103039854535625369281093341257389729390305152950981432
   0318123511838827264871335997561495097117763664351531003758501183261670780004701}}
```

utility codes

120%

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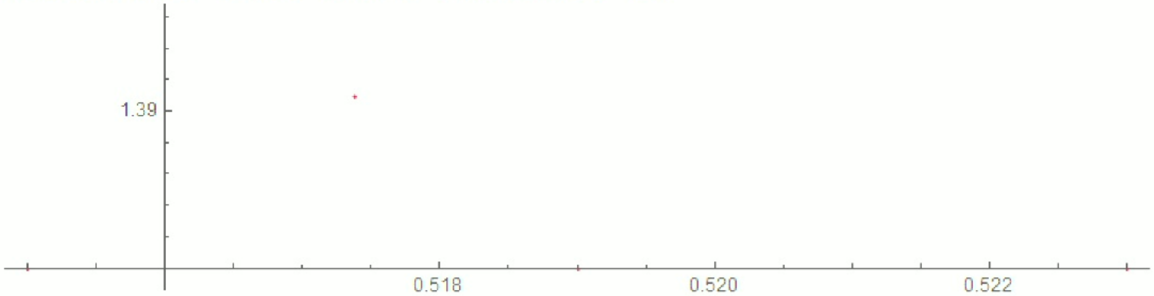


```
In[34]:= (* λσσϵ=1.0518537, λϵϵϵ=1.532435 from arXiv:1603.04436 .  λσσϵ/λϵϵϵ=0.6863936 *)
SB$Proj$calculated$primal[[1]]

Out[34]= {DeltaList →
  {0.5181489000000002334701321160537190735340118408203125000000000000000000000000000000000000000000000000000000000000000000000
   00000000000000000000000000000000000000000000000000000000000000000000000000000000,
  1.4126250000000001953992523340275511145591735839843750000000000000000000000000000000000000000000000000000000000000000000000
   0000000000000000000000000000000000000000000000000000000000000000000000000000000}, TerminateReason → primal,
 ThetaLogFile → ./Proj_IsingOE_OPEscan/TS_DeltaLog_0.518148900000_1.41262500000.txt,
 LastCheckpoint → 0.518148900000_1.41262500000_1_0.684429354432_Apr21_17h38m37s.xml, LastTheta → {0.684429}}
```

utility codes

check job output and SDPB output

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O3VST_OPEscan.nb - Wolfram Mathematica 11.1

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File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

```
Bootstapper packages Loaded. Version : 4.0
MMA Precision set to 200.
```

```
Cluster$SetConfig["[Cluster.ProjectDirectory]","Proj_O3VST_OPEscan"];  (* folder for the current project (inside the workspace) *)
CheckDirectory[Cluster$GetConfig["[Cluster.ProjectDirectory]"]];  (* create the folder if it doesn't exist *)
```

Input : bootstrap condition

Crossing vectors

```
crossvecobj=LoadExpression["AutoEqu_O3_VST.txt"];
```

```
ObjGet[crossvecobj, "VBlock"][[All, 1]]
```

```
{op[op, v[1, -1], 1, -1], op[op, v[1, -1], 1, 1], op[op, v[2, 1], 1, 1], op[op, v[2, -1], 1, -1],
 op[op, v[2, -1], 1, 1], op[op, v[3, -1], 1, -1], op[op, v[3, -1], 1, 1], op[op, v[2, 1], 1, -1],
 op[op, v[1, 1], 1, -1], op[op, v[3, 1], 1, -1], op[op, v[4, 1], 1, 1], op[op, v[0, 1], 1, 1]}
```

```
ObjGet[crossvecobj, "VBlock", op[op, v[1, 1], 1, -1]] // MatrixForm
```

$$\begin{pmatrix} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \end{pmatrix}$$

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O3VST_OPEscan.nb * (Running...) - Wolfram Mathematica 11.1

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```
Bootstapper packages Loaded. Version : 4.0
MMA Precision set to 200.
```

```
Cluster$SetConfig["[Cluster.ProjectDirectory]","Proj_O3VST_OPEscan"];  (* folder for the current project (inside the workspace) *)
CheckDirectory[Cluster$GetConfig["[Cluster.ProjectDirectory]"]];  (* create the folder if it doesn't exist *)
```

Input : bootstrap condition

Crossing vectors

```
crossvecobj=LoadExpression["AutoEqu_O3_VST.txt"];
```

```
ObjGet[crossvecobj, "VBlock"][[All, 1]]
```

```
{op[op, v[1, -1], 1, -1], op[op, v[1, -1], 1, 1], op[op, v[2, 1], 1, 1], op[op, v[2, -1], 1, -1],
 op[op, v[2, -1], 1, 1], op[op, v[3, -1], 1, -1], op[op, v[3, -1], 1, 1], op[op, v[2, 1], 1, -1],
 op[op, v[1, 1], 1, -1], op[op, v[3, 1], 1, -1], op[op, v[4, 1], 1, 1], op[op, v[0, 1], 1, 1]}
```

```
ObjGet[crossvecobj, "VBlock", op[op, v[1, 1], 1, -1]] // MatrixForm
```

$$\begin{pmatrix} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \end{pmatrix}$$

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```
CheckDirectory[Cluster$GetConfig["[Cluster.ProjectDirectory]"]];  (* create the folder if it doesn't exist *)
```

Input : bootstrap condition

Crossing vectors

In[9]:=
```
crossvecobj=LoadExpression["AutoEqu_O3_VST.txt"];
```

In[21]:=
```
ObjGet[crossvecobj, "VBlock"][[All, 1]]
```

Out[21]=
```
{op[op, v[1, -1], 1, -1], op[op, v[1, -1], 1, 1], op[op, v[2, 1], 1, 1], op[op, v[2, -1], 1, -1],
 op[op, v[2, -1], 1, 1], op[op, v[3, -1], 1, -1], op[op, v[3, -1], 1, 1], op[op, v[2, 1], 1, -1],
 op[op, v[1, 1], 1, -1], op[op, v[3, 1], 1, -1], op[op, v[4, 1], 1, 1], op[op, v[0, 1], 1, 1]}
```

```
ObjGet[crossvecobj, "VBlock", op[op, v[1, 1], 1, -1]] // MatrixForm
```

$$\begin{pmatrix} \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \end{pmatrix}$$

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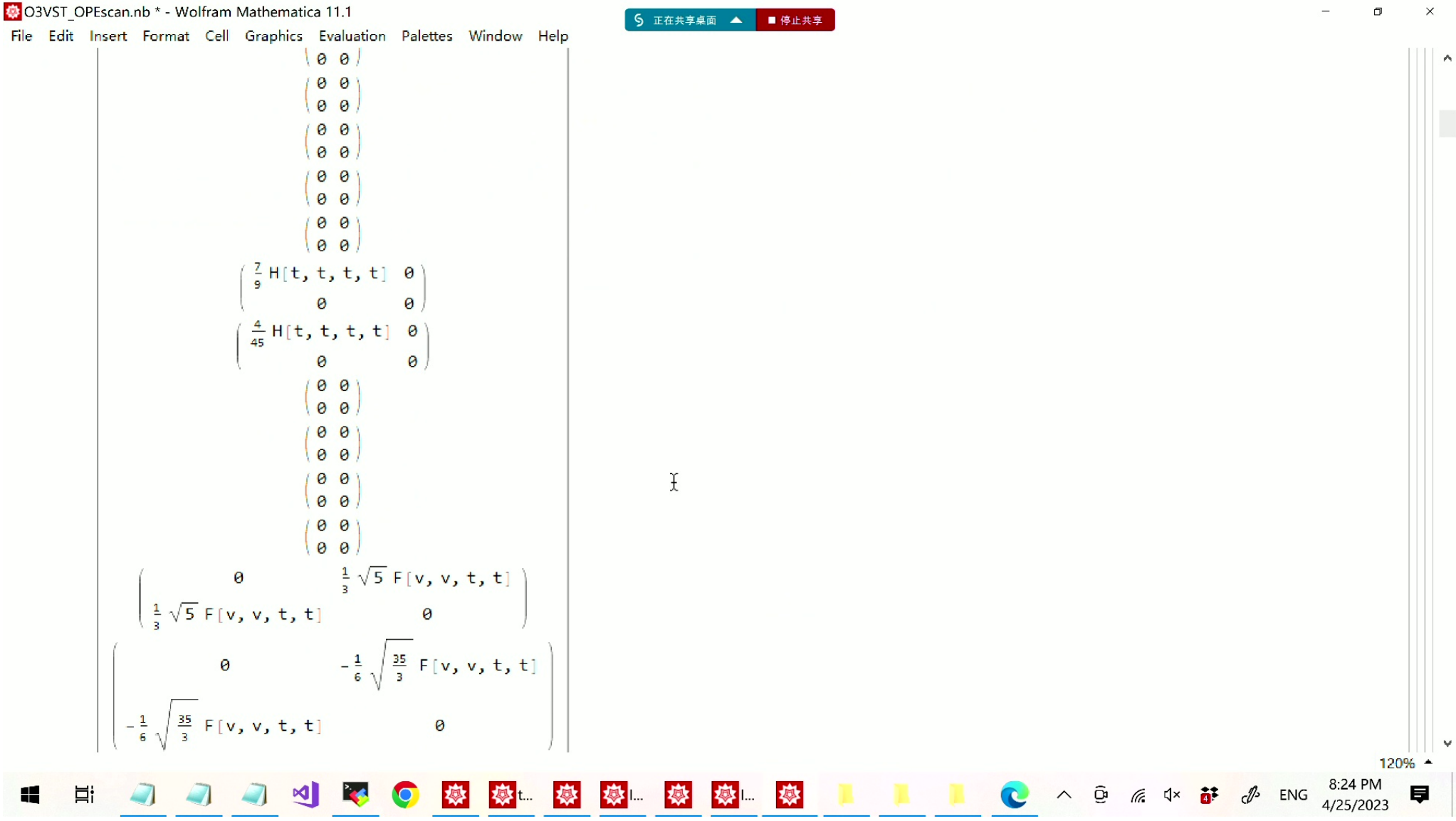
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$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} \frac{7}{9} H[t, t, t, t] & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} \frac{4}{45} H[t, t, t, t] & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & \frac{1}{3}\sqrt{5} F[v, v, t, t] \\ \frac{1}{3}\sqrt{5} F[v, v, t, t] & 0 \end{pmatrix}$
$\begin{pmatrix} 0 & -\frac{1}{6}\sqrt{\frac{35}{3}} F[v, v, t, t] \\ -\frac{1}{6}\sqrt{\frac{35}{3}} F[v, v, t, t] & 0 \end{pmatrix}$
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$$\begin{pmatrix} 0 & 0 \\ 0 & \frac{1}{6} H[v, v, v, v] \end{pmatrix}$$

$$\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$$

Block specifications

In[10]:=
```
(* conformal block specifications : spacetime dimension, derivative order, pole keeping order, r* order, spins *)
blockconfobj={"dim"→3,"Λmax"→11,"κ"→12,"rN"→48,"lset"→Range[0,20]~Join~{49,52}};
```

```
dim = 3;
Lambda = 27;
AutoCB3$BlockSetting["DSD"][dim, Lambda] (* some presetting in simpleboot *)
```

```
{dim → 3, Λmax → 27, κ → 20, rN → 80, lset → {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11,
   12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 29, 30, 33, 34, 37, 38, 41, 42, 45, 46, 49, 50}}
```

Initialize simpleboot

In[11]:=
```
(* tell simpleboot about the crossing vectors and block specs *)
AutoCB3$Init[crossvecobj,blockconfobj];
```

AutoCB3$Init[crossvecobj,blockconfobj] : this function tells simpleboot about the crossing vectors and block specs.

Gaps

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Format :

GapConfiguration is a List of element in one of the following format:

{channel,gap,spins} // this means demand $\alpha \cdot V_{\text{channel}} \geq 0$ for $\Delta >$ gap and L in spins. spins can be a integer or set of integers.

{channel,IndividualOperator[Δ0],spin} // this means demand $\alpha \cdot (V_{\text{channel},\Delta 0,\text{spin}}) \geq 0$

{channel,IndividualOperator[Δ0,ope_List],spin} // this means demand $\alpha \cdot (\text{ope}.V_{\text{channel},\Delta 0,\text{spin}}.\text{ope}) \geq 0$

{channel,IntervalPositivity[Δmin,Δmax],spin} // this means demand $\alpha \cdot V_{\text{channel},\Delta,\text{spin}} \geq 0$ for $\Delta\text{min} < \Delta < \Delta\text{max}$

In[12]:=

```
Clear@GapConfiguration;
GapConfiguration[dim_,lset_]:={

{op[op,v[0,1],1,1],3,{0}},
{op[op,v[1,-1],1,1],3,{0}},
{op[op,v[2,1],1,1],3,{0}},

{op[op,v[0,1],1,1],Δunitary[dim,ℓ],{0}},
{op[op,v[1,-1],1,1],Δunitary[dim,ℓ],{0}},
{op[op,v[2,1],1,1],Δunitary[dim,ℓ],{0}},

{op[op,v[1,-1],1,-1],Δunitary[dim,ℓ],Select[lset,OddQ]},
{op[op,v[1,-1],1,1],Δunitary[dim,ℓ],Select[lset,EvenQ[#]&&#>0&]},
{op[op,v[2,1],1,1],Δunitary[dim,ℓ],Select[lset,EvenQ[#]&&#>0&]},
{op[op,v[2,-1],1,-1],Δunitary[dim,ℓ],Select[lset,OddQ]},
{op[op,v[2,-1],1,1],Δunitary[dim,ℓ],Select[lset,EvenQ]},
{op[op,v[3,-1],1,-1],Δunitary[dim,ℓ],Select[lset,OddQ]},
{op[op,v[3,-1],1,1],Δunitary[dim,ℓ],Select[lset,EvenQ]},
{op[op,v[2,1],1,-1],Δunitary[dim,ℓ],Select[lset,OddQ]},
{op[op,v[1,1],1,-1],Δunitary[dim,ℓ],Select[lset,OddQ]},
```

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$\alpha \cdot V_{even}(\Delta, l) \geq 0$ for $\Delta \geq 3,\ l = 0$

$\alpha \cdot V_{odd}(\Delta, l) \geq 0$ for $\Delta \geq 3,\ l = 0$

$\alpha \cdot V_{even}(\Delta, l) \geq 0$ for $\Delta \geq \Delta_{unitary},\ l = 2, 4, 6, \ldots$

$\alpha \cdot V_{odd}(\Delta, l) \geq 0$ for $\Delta \geq \Delta_{unitary},\ l = 1, 2, 3, 4, \ldots$

$\alpha . V_\theta \geq 0$ where $V_\theta = V_{even}(\Delta = \Delta_\epsilon, l = 0) + V_{odd}(\Delta = \Delta_\sigma, l = 0) \otimes \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$

In[14]:=

```
SDPTemplate$O3VST$MainPart[]:=Module[
{BC$normalization,BC$objective,BC$condition,sdp,V$theta},

BC$normalization=AutoCB3$Vector[CrossVec["identity"]];  (* α.V_identity=1 *)
BC$objective=AutoCB3$Vector[CrossVec["zero"]];
BC$condition=AutoCB3$Condition[GapConfiguration];  (* the rest positivity conditions *)

sdp=SDPData[BC$objective,BC$normalization,BC$condition];

sdp
];

SDPTemplate$O3VST$ThetaPart[]:=Module[
{BC$normalization,BC$objective,BC$condition,sdp,V$theta},

V$theta=MapAt[
{OPE$vvs,OPE$vtv,OPE$tts,OPE$ttt,OPE$sss}.#.{OPE$vvs,OPE$vtv,OPE$tts,OPE$ttt,OPE$sss}&,
CrossVec["V$theta"],{All,1}];

BC$normalization=AutoCB3$Vector[CrossVec["identity"]];
BC$objective=AutoCB3$Vector[CrossVec["zero"]];
```

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```
SSH$Evaluate result:
Null

Table[
 ClusterAsyn$Evaluate[
  AutoCB3$SaveSDPDataTemplate[SDPTemplate$O3VST$MainPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Main.m"];
  AutoCB3$SaveSDPDataTemplate[SDPTemplate$O3VST$ThetaPart[], ReconfigCmd@"[Cluster.ProjectDirectory]_SDPTemplate_Theta.m"];

  initpts = {{0.518936, 1.59488, 1.20954}, {0.518936, 1.7, 1.20954}} // SetPrec;;

  SB$OPEScanner[SDP$O3VST$Main, SDP$O3VST$Theta, initpts, {{0.1}},
   {2.7 ≤ TS$Theta[1] ≤ 3.3, 2.1 ≤ TS$Theta[1] ≤ 2.9, 3.5 ≤ TS$Theta[1] ≤ 4.5, 0.2 ≤ TS$Theta[1] ≤ 0.8},
   "--dualityGapThreshold=1e-20 --primalErrorThreshold=1e-60 --dualErrorThreshold=1e-60 --precision=400
     --initialMatrixScalePrimal=1e+20 --initialMatrixScaleDual=1e+20 --maxComplementarity=1e+100
     --detectPrimalFeasibleJump --detectDualFeasibleJump", {"Delaunay"}, 1000, False, False, False]
 ]
 , 1]
{410118}

ClusterAsyn$JobOutput["410035"]
ClusterAsyn$SDPBOutput["0.518148900000_1.41262500000_1_0.100000000000_Apr21_16h54m46s.xml"]

SSH$DownloadFile@SB$Proj$FileName; (* download current project data from the cluster *)
SB$LoadProject[]; (* load current project data *)
```

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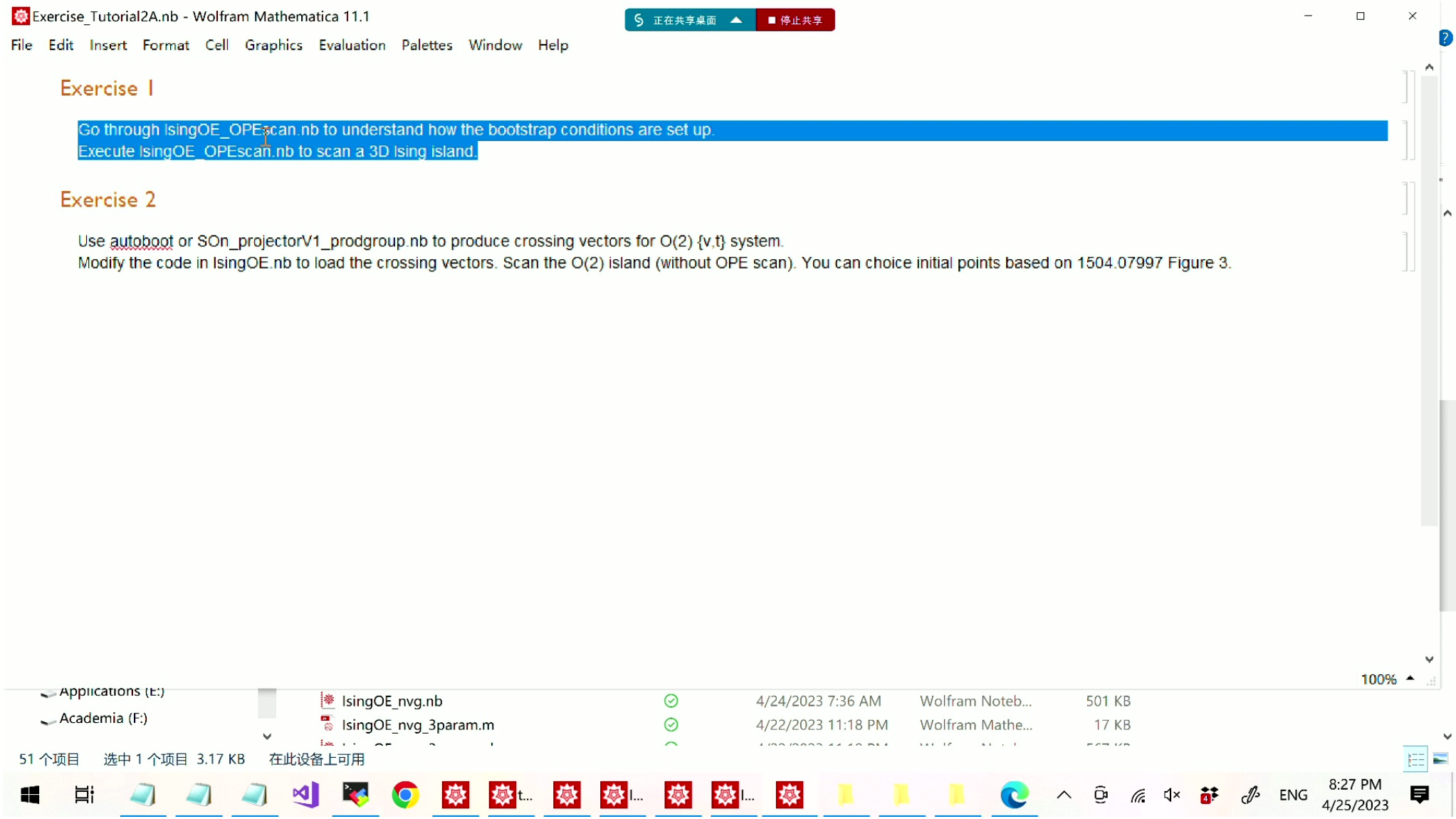
Exercise_Tutorial2A.nb - Wolfram Mathematica 11.1
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Exercise 1
Go through IsingOE_OPEscan.nb to understand how the bootstrap conditions are set up.
Execute IsingOE_OPEscan.nb to scan a 3D Ising island.
Exercise 2
Use autoboot or SOn_projectorV1_prodgroup.nb to produce crossing vectors for O(2) {v,t} system.
Modify the code in IsingOE.nb to load the crossing vectors. Scan the O(2) island (without OPE scan). You can choice initial points based on 1504.07997 Figure 3.
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Applications (E:)
Academia (F:)
IsingOE_nvg.nb 4/24/2023 7:36 AM Wolfram Noteb... 501 KB
IsingOE_nvg_3param.m 4/22/2023 11:18 PM Wolfram Mathe... 17 KB
51 个项目 选中 1 个项目 3.17 KB 在此设备上可用
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