4 Debuggers

本段演示我们使用下面中这段代码:

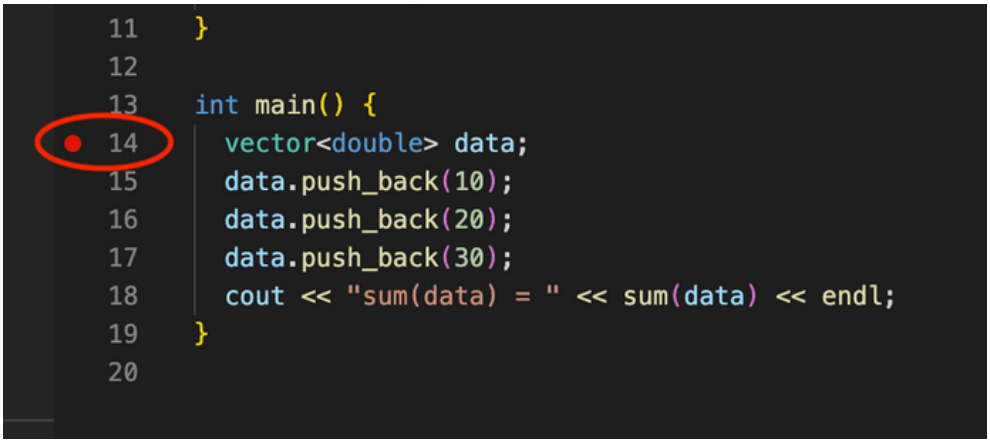
```
#include <iostream>
#include <vector>
using namespace std;

double sum (const vector<double> &data) {
  double total = 0;
  for (size_t i=0; i<data.size(); ++i) {
    total += data[i];
  }
  return total;
}

int main() {
  vector<double> data;
  data.push_back(10);
  data.push_back(20);
  data.push_back(30);
  cout << "sum(data) = " << sum(data) << endl;
}
```

4.1 Debugging Basis

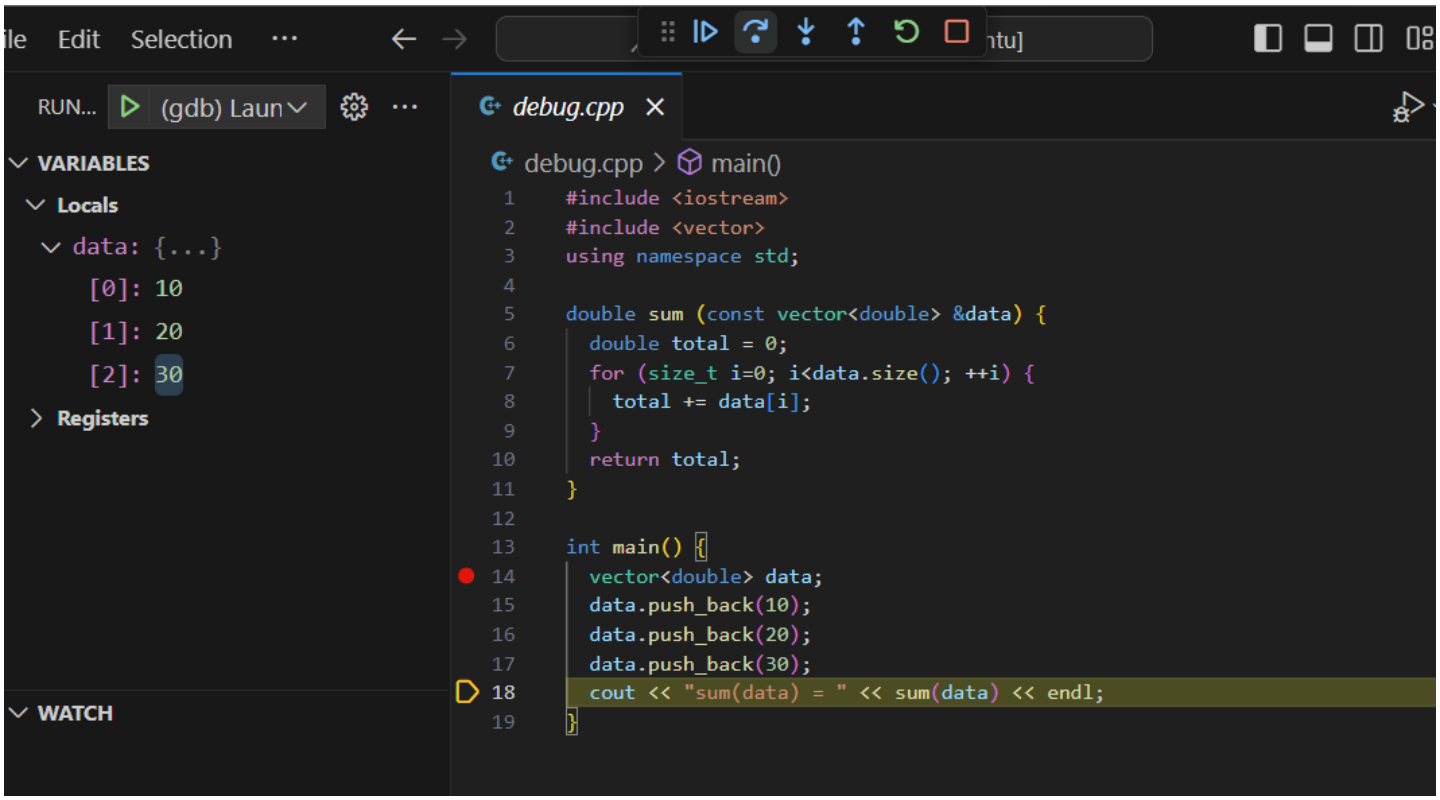
大部分 debugger 都支持以下的功能.

4.1.1 Breakpoint 设置间断点

Set a breakpoint by clicking to the left of a line number. A breakpoint 表示 debug 运行到这里停止. 这是 debug 的开端，就是从 breakpoint 开始可以逐行 debug

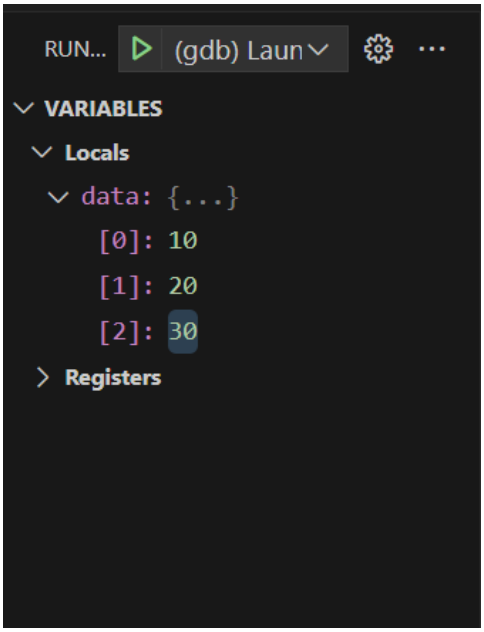


4.1.2 Step over 运行一行



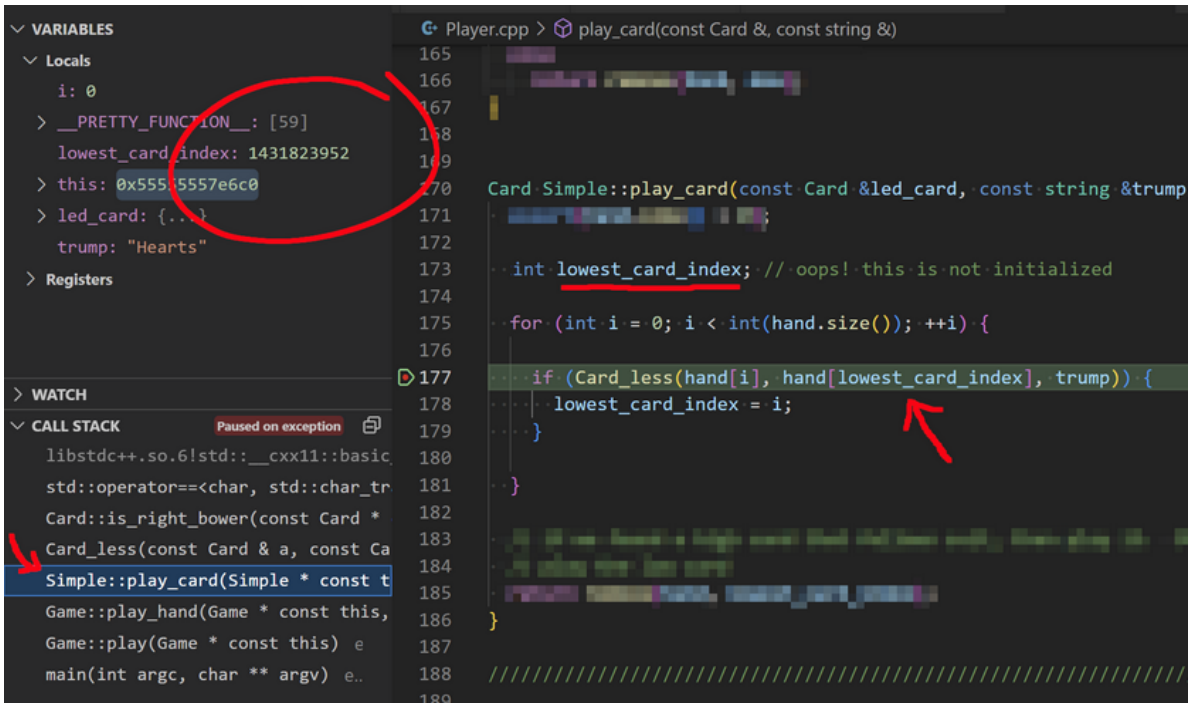
step over 就是继续运行一行的意思. 从 breakpoint 开始，我们每 stepover 一下就是运行一行.

4.1.3 Inspect 查看变量

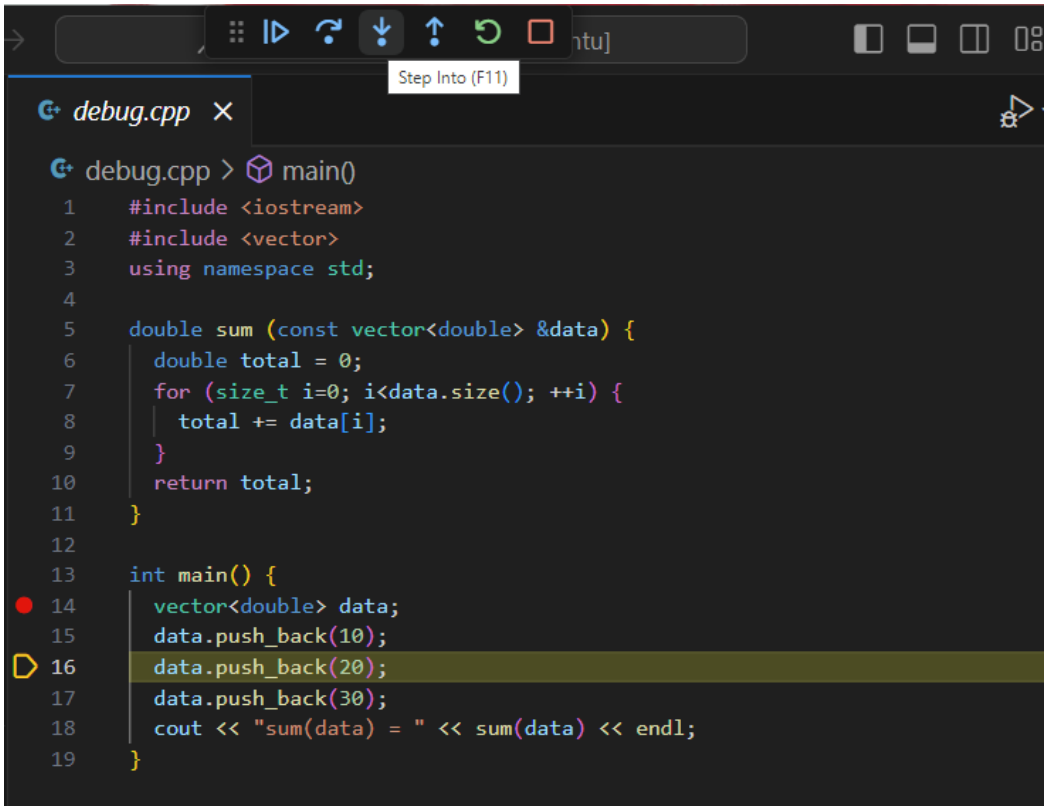


我们 stepover 的时候，左边的 local variables 会更新. 这个时候可以点开里面的数据进行 inspect，查看运行这一行之后的状态.

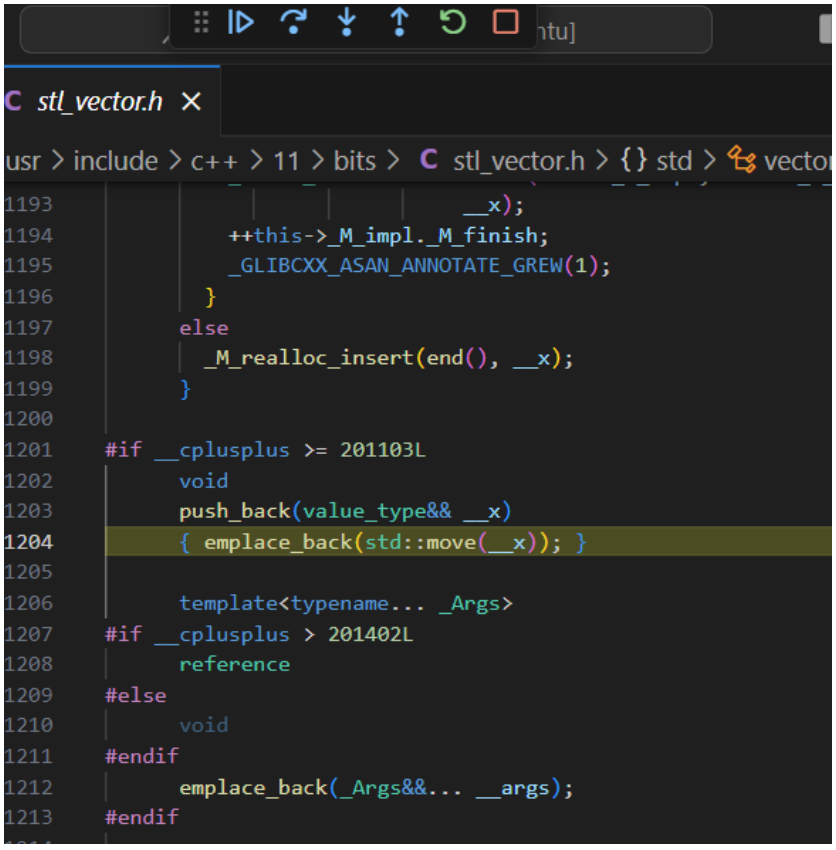
下面还能检查 call stack. 点击 call stack 会进入该函数的 stack frame 里面查看 varibles.



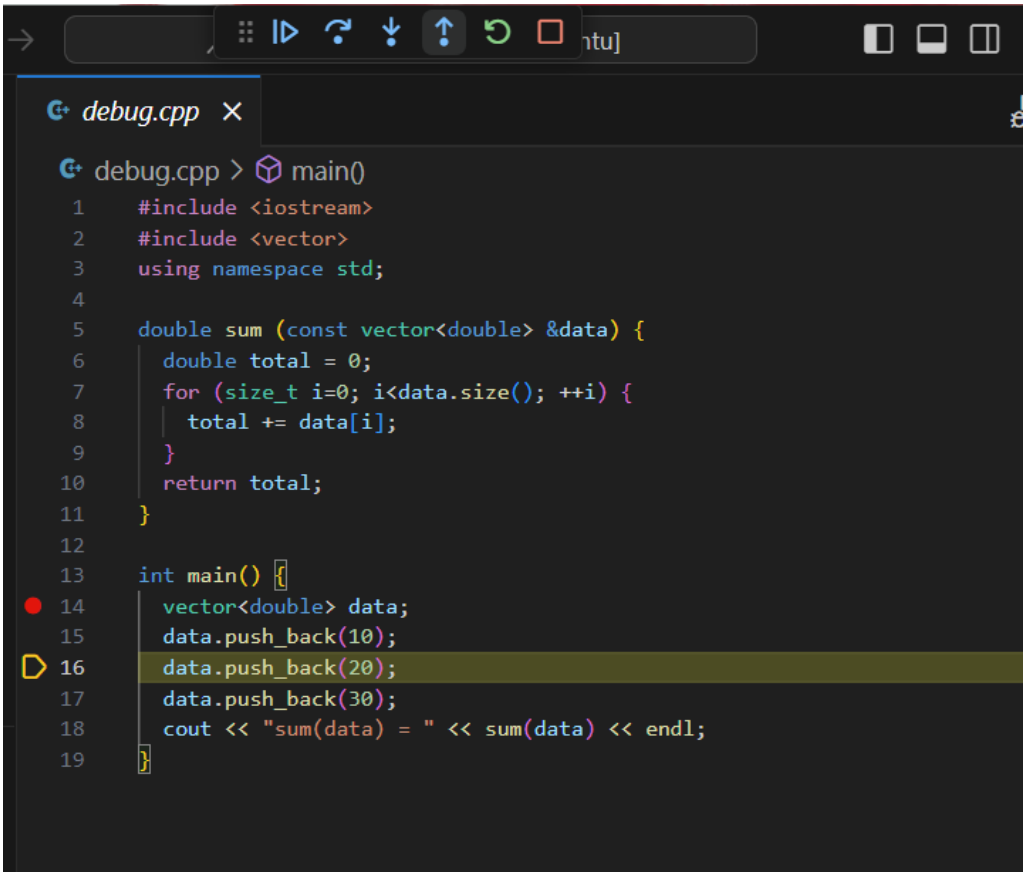
4.1.4 Step Into/Out 查看源码



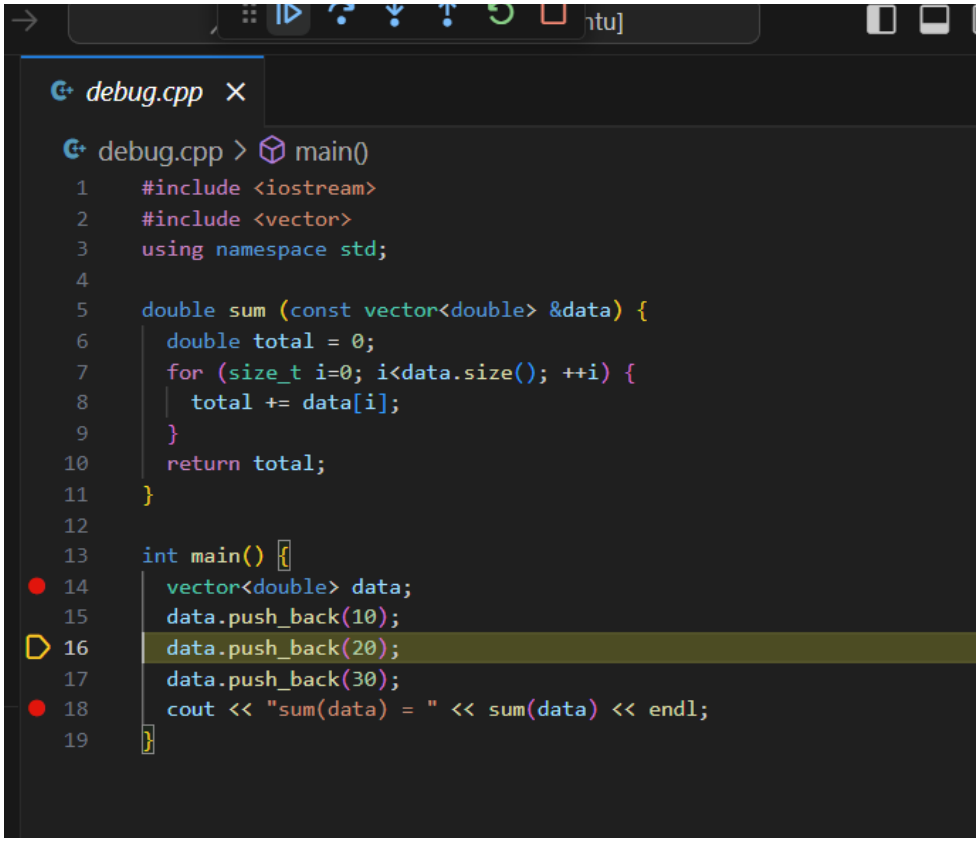
Step into 会直接进入这一行使用的函数的源代码；如果查看的是库函数，会直接进入C++的库源文件中进行查看. 如果是自己写的函数，会到自己的函数这里.



然后用 Step out 可以回到我们的文件.



4.1.5 Continue 快进到下一个间断点

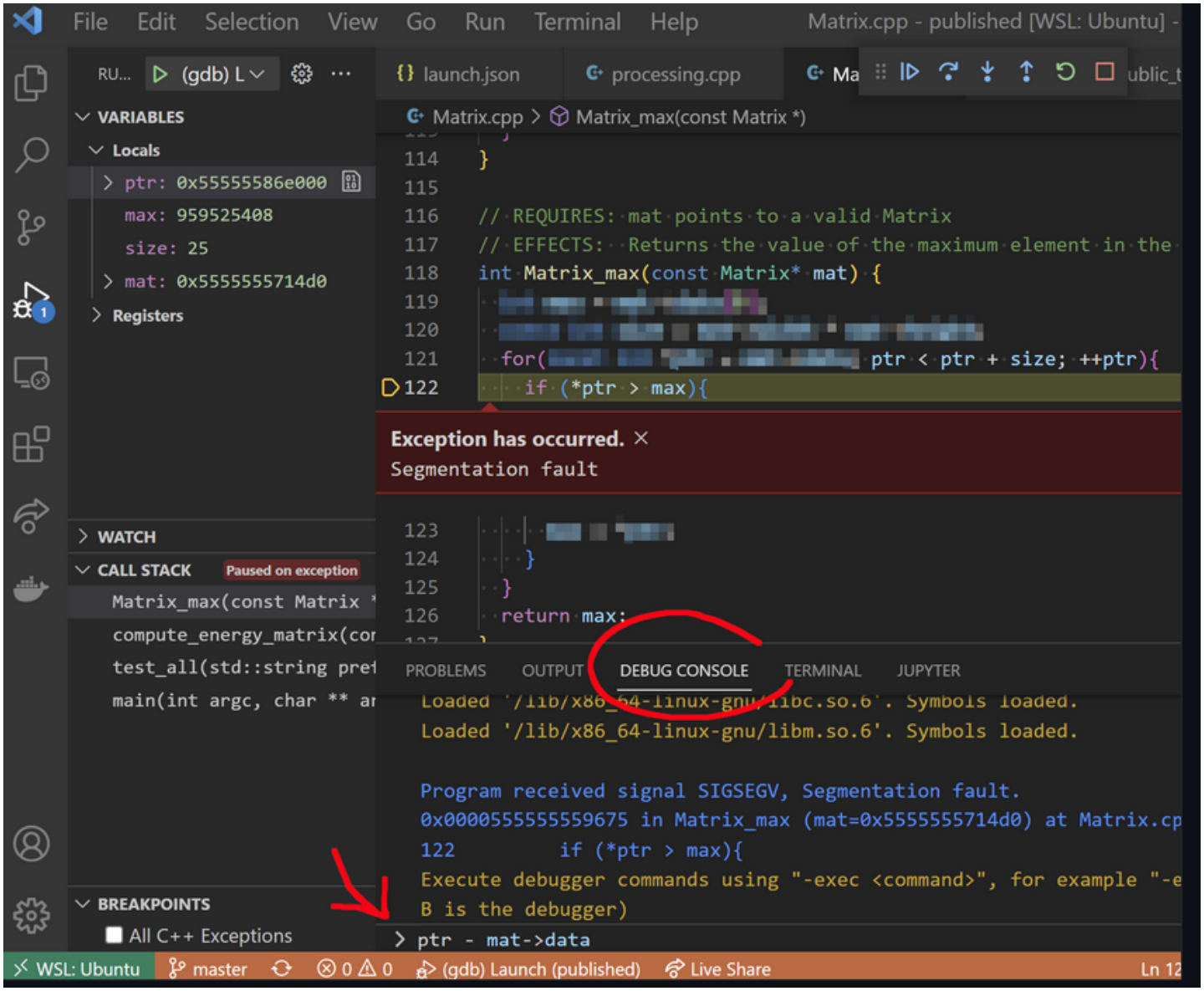


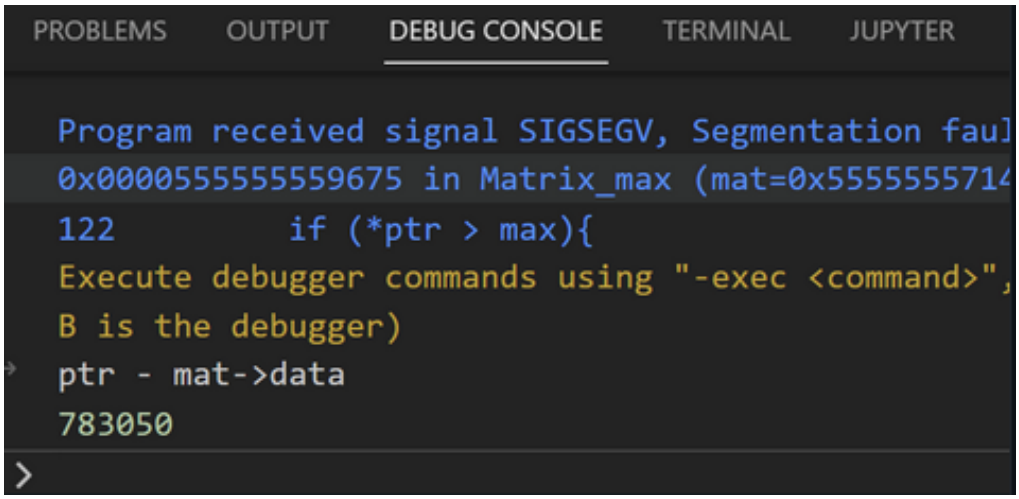
Continue 可以直接快进运行到现在的位置的下一个 breakpoint.

4.2 Debug Console

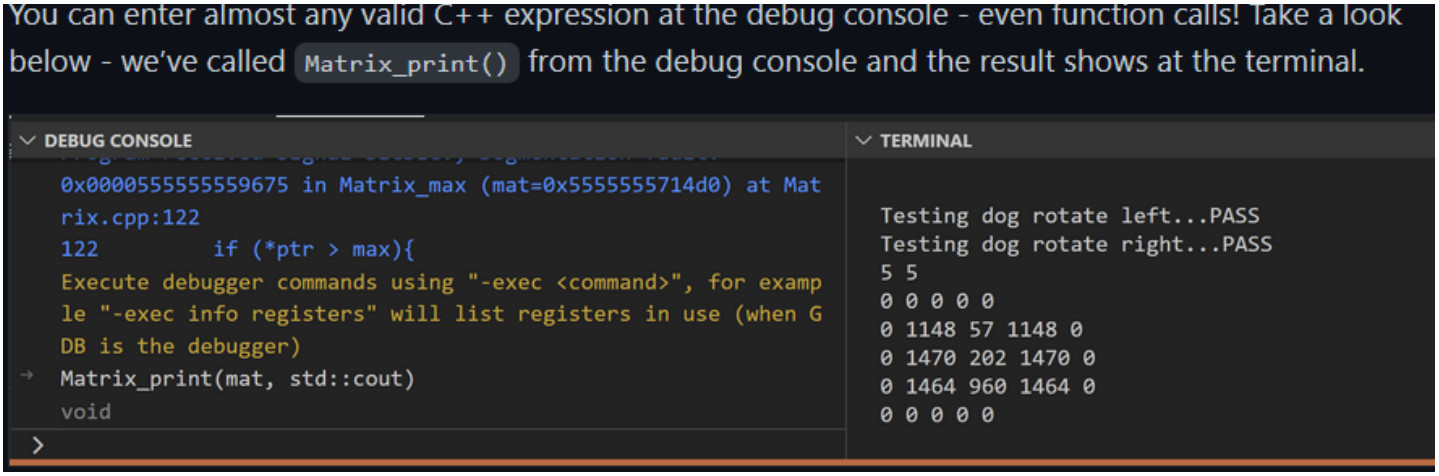
如果我们现在在进行一个 Matrix 的 debugging, 我们看到了 call stack 中的一个 ptr 变量的地址，但是不知道它指的是 Matrix 中的第几个 entry.

那么我们可以在 Debug Console 中输入 `ptr - mat->data` 来进行获取.





Debug Console 中可以输入任何 C++ expression，甚至包括 function call.



4.3 Address Sanitizer 地址检查器

We recommend enabling the **address sanitizer 地址错误检查器** and **undefined behavior sanitizer 未定义行为检查器**. These will help you find memory errors like going off the end of an array or vector.

1. 首先编辑 `Makefile` 添加这些 `CXXFLAGS`.

WSL or Linux: Add compiler flags (1) `-fsanitize=address`, (2) `-fsanitize=undefined`, (3) `-D_GLIBCXX_DEBUG`. For example:

```
CXXFLAGS = --std=c++17 -Wall -Werror -pedantic -g -fsanitize=address -fsanitize=undefined -D_GLIBCXX_DEBUG
```

macOS: Add compiler flags (1) `-fsanitize=address`, (2) `-fsanitize=undefined`. (ma cOS不添加 `-D_GLIBCXX_DEBUG`.) For example:

```
CXXFLAGS = --std=c++17 -Wall -Werror -pedantic -g -fsanitize=address -fsanitize=undefined
```

最后效果是：

```
CXX ?= g++
CXXFLAGS ?= --std=c++17 -Wall -Werror -pedantic -g

# Add sanitizer flags for identifying undefined behavior.  The flags are
# different on macOS (AKA Darwin) and Windows/WSL/Linux.
UNAME := $(shell uname -s)
ifeq "$(UNAME)" "Darwin"
  CXXFLAGS += -fsanitize=address -fsanitize=undefined
else
  CXXFLAGS += -fsanitize=address -fsanitize=undefined -D_GLIBCXX_DEBUG
endif
```

2. 在 [illegible] 中进行添加 [illegible] 的 [illegible]

2. 在 `launch.json` 中进行添加 address sanitizer 的 arguments.

For MacOS: 编辑 `"env"` property in your `launch.json`. 如果和下面这个不一样就replace it. 如果没有就添加下面这行到 `"args"` property.

```
"env": {
    "ASAN_OPTIONS": "abort_on_error=1:detect_leaks=0"
},
```

For WSL/Linux: 编辑 `"environment"` property in your `launch.json`. 如果和下面这个不一样就 replace it. 如果没有就添加下面这行到 `"args"` property.

```
"environment": [
  {
    "name": "ASAN_OPTIONS",
    "value": "abort_on_error=1:detect_leaks=0"
  }
],
```

3. 当 address sanitizer 发现 error 时会显示一页机器码，这没什么用而且很烦人. 关掉的方法是 Code > Settings > Settings> set the `lldb.showDisassembly` option to `never`.

4.3.1 Leak Checking

address sanitzer 还可以用来检测 memory leak. 但是仅限于 WSL/Linux.

macOS 要在 shell 里面在 make 后加入一行

```
make main.exe
MallocStackLogging=1 leaks -quiet -atExit -- ./main.exe
```

注意这个检测器和 address sanitizer 不兼容 (因而还要把 makefile 里面的 address sanitizer 去掉).

这样子在运行 exe 文件的时候就会告诉你 memory leaking 的问题.

```
make main.exe
./main.exe
# Hello Leaks!

# =================================================================
# ==1905936==ERROR: LeakSanitizer: detected memory leaks

# Direct leak of 4 byte(s) in 1 object(s) allocated from:
    #0 0x7f54a90ae7b0 in operator new(unsigned long) (/lib64/libasan.so.5+0xf17b0)
    #1 0x400a73 in main /home/awdeorio/leakcheck/main.cpp:6
    #2 0x7f54a8303cf2 in __libc_start_main (/lib64/libc.so.6+0x3acf2)

# SUMMARY: AddressSanitizer: 4 byte(s) leaked in 1 allocation(s).
```

4.4 Assertions

The `<cassert>` header defines an `assert()` macro，我们传给它布尔参数作为 condition：

- 如果 condition is true, nothing happens.
- 如果 condition is false, the program **crashes immediately.**

```
#include <cassert>

int main() {
  int x = 2;
  int y = 5;
  assert(x + 3 == y); // true, all good :)
  assert(x > y); // false, crash!! (ﾉ°□°)ﾉ ┻┻
}
```

terminal 会显示错误：

```
test.exe: test.cpp:7: int main(): Assertion `x > y' failed.
Aborted
```

这可以检测一些 precondition, invariant 等.

4.5 Command-Line Debuggers(gbd,lldb)

IDE 里面集成了 debugging 的流程，但是我们也可以在 terminal 直接用 gdb/llbd 来进行 debug.

但是这之前我们首先要用 g++ 来 compile 完 exe 文件.

4.5.1 CL Debugging 命令

command	what it does
`b main`	**breakpoint** on main function
`b 13`	**breakpoint** on line 13 of current file
`b main.cpp:13`	**breakpoint** on line 13 of main.cpp
`r`	**run** or rerun
`l`	list a few lines of code
`n`	**step over** (next)
`s`	**step into**
`up`	**step out** (up)
`c`	**continue**
`p myvar`	print variable `myvar`
`refresh`	refresh TUI view
`bt`	backtrace, useful for segfaults
`q`	**quit**

4.5.2 Input Redirection

自动化输入

gdb:

```
gdb main.exe
...
(gdb) r < main_test.in
...
```

而 lldb 要复杂一点：

```
lldb main.exe
...
(lldb) settings set target.input-path main_test.in
(lldb) r
...
```

4.5.3 Arguments and optins

我们之前在 VSCode 里在 `launch.json` 里面放 arguments and options，那么当然也可以直接用 command 实现.

```
./main.exe train_small.csv test_small.csv --debug
```

- `main.exe` is the name of the program
- `train_small.csv` and `test_small.csv` are arguments
- `--debug` is an option

4.6 More Pro Tips for debugging

4.6.1 Debug Logging 额外输出

在一些循环中我们发现异常，可以专门写一些额外的 output 用以 debug.

```
304         // announce card played
305         cout << c << " played by " << *player << "\n";
306
307         // update the high card
308         if (Card_less(high_card, c, trump)) {
309           leader = player;
310           high_card = c;
311         }
```

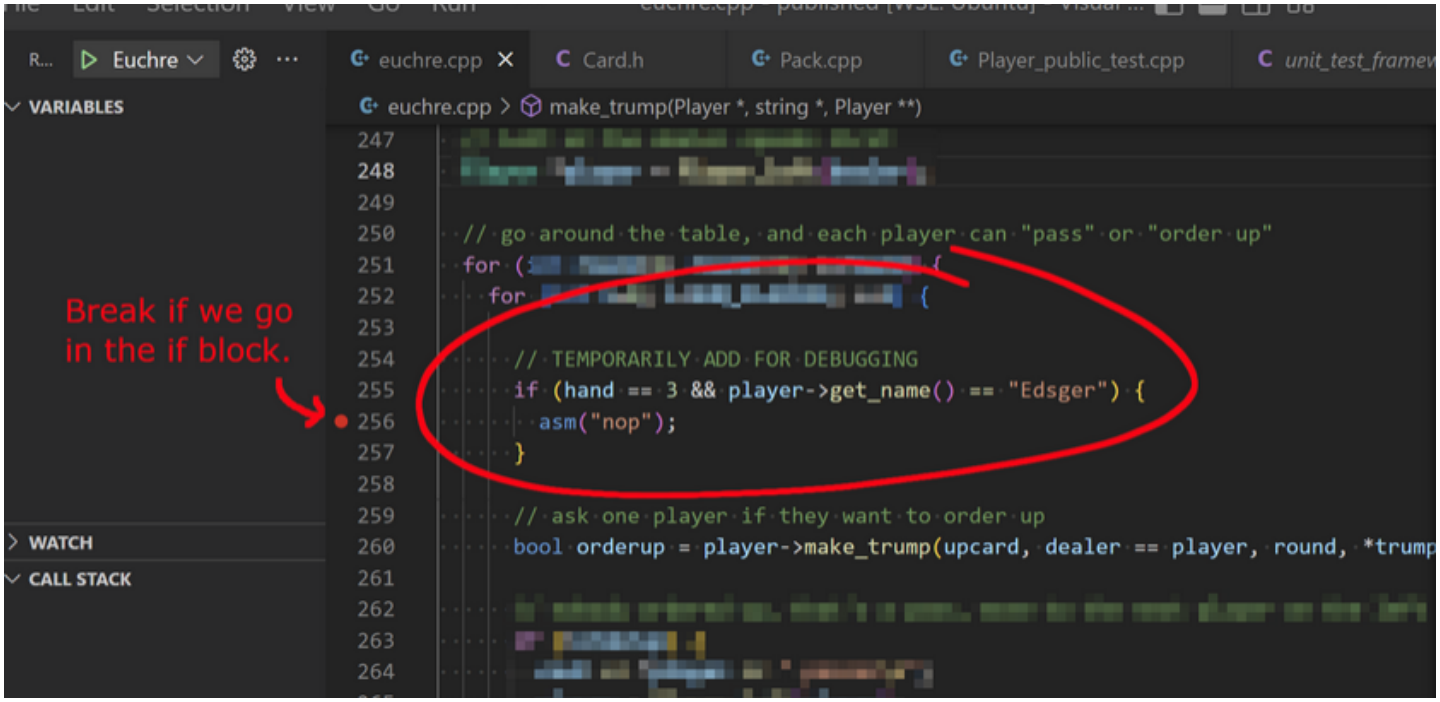
专门加一些话用来 Debug，并且加上标识来和普通的输出区分开.

```
304         // announce card played
305         cout << c << " played by " << *player << "\n";
306
307         // update the high card
308         cout << "DEBUG: Current best is: " << high_card << ", considering: " << c << endl;
309         if (Card_less(high_card, c, trump)) {
310           cout << "DEBUG: switching to " << c << " as new best." << endl;
311           leader = player;
312           high_card = c;
313         }
314
```

4.6.2 Conditional Breakpoint

接上一条，我们可以人为地加一些 if 语句来 debug，并且把 BreakPoint 放在 if 语句的内部时，就可以快速知道某一时刻某个时刻变量的值是不是预期的值.

这样就可以一眼检测某个时刻某个 variable 的值是不是我们想要的值，这样不仅可以 debug 还可以顺便 testing.


Euchre
euchre.cpp
Card.h
Pack.cpp
Player_public_test.cpp
VARIABLES
euchre.cpp > make_trump(Player *, string *, Player **)
Break if we go in the if block.
// go around the table, and each player can "pass" or "order up"
for (
for
{
// TEMPORARILY ADD FOR DEBUGGING
if (hand == 3 && player->get_name() == "Edsger") {
asm("nop");
}
// ask one player if they want to order up
bool orderup = player->make_trump(upcard, dealer == player, round, *trump
WATCH
CALL STACK