

Breaking of Program Invariants

This lesson explains challenges related to the breaking of program invariants during the implementation of concurrency in C++.

Program invariants are invariants that should hold for the entire lifetime of your program.

Malicious [race condition](#) breaks an invariant of the program. The invariant of the following program is that the sum of all balances should be the same amount. In our case, this is 200 euros because each account starts with 100 euro (line 9). I neither want to create money by transferring it nor do I want to destroy it.

```
// breakingInvariant.cpp

#include <atomic>
#include <functional>
#include <iostream>
#include <thread>

struct Account{
    std::atomic<int> balance{100};
};

void transferMoney(int amount, Account& from, Account& to){
    using namespace std::chrono_literals;
    if (from.balance >= amount){
        from.balance -= amount;
        std::this_thread::sleep_for(1ns);
        to.balance += amount;
    }
}

void printSum(Account& a1, Account& a2){
    std::cout << (a1.balance + a2.balance) << std::endl;
}

int main(){

    std::cout << std::endl;

    Account acc1;
    Account acc2;

    std::cout << "Initial sum: ";
```



```

printSum(acc1, acc2);

std::thread thr1(transferMoney, 5, std::ref(acc1), std::ref(acc2));

std::thread thr2(transferMoney, 13, std::ref(acc2), std::ref(acc1));
std::cout << "Intermediate sum: ";
std::thread thr3(printSum, std::ref(acc1), std::ref(acc2));

thr1.join();
thr2.join();
thr3.join();

std::cout << "    acc1.balance: " << acc1.balance << std::endl;
std::cout << "    acc2.balance: " << acc2.balance << std::endl;

std::cout << "Final sum: ";
printSum(acc1, acc2);

std::cout << std::endl;
}

```



In the beginning, the sum of the accounts is 200 euros. Line 33 displays the sum by using the function `printSum` in lines 21 - 23. Line 38 makes the invariant visible. Because there is a short sleep of 1ns in line 16, the intermediate sum is 182 euro. In the end, all is fine; each account has the right balance (line 44 and line 45) and the sum is 200 euro (line 48).