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Dynamische Programmanalysen für nebenläufige Programme - Data Race Prediction mit TSan V2

Seminararbeit

Student:	Frank Ling
Matrikelnummer:	79496
Universität:	Hochschule Karlsruhe – Technik und Wirtschaft
Studiengang:	Informatik, Master
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Dozent:	Prof. Martin Sulzmann
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1 Introduction

Nowadays concurrent programs are very common in order to make use of 'hyper-threading and multi-core architectures'[1, p. 14]. 'Due to the highly non-deterministic behavior of concurrent programs' [2, p. 1] data races may arise but can also be hard to find, as they also 'may only arise under a specific schedule' [2, p. 1]. This seminar work shows the motivation and background for the data prediction tool ThreadSanitizer (TSan) V2, which differentiates itself from the first version by utilizing happens-before methods instead of the lockset method. Afterwards the concepts of the FastTrack [3] algorithm will be shown as TSan uses a slightly modified version of the FastTrack algorithm. Examples showing the limits of FastTrack and TSan follow, as they are both incomplete and thus do not find every data race. In the following the same notation as in [2] will be used for traces and events.

2 Motivation and Examples

As stated in the introduction concurrent programs are commonly used and are inherently prone to data races. Data races can be hard to find and might not be apparent. This chapter will show a few examples from [4] but rewritten in the programming language C++. The following example shows a program, which exhibits a data race (see chapter 3):

```
1  #include "pthread.h"
2
3  int x;
4  pthread_mutex_t y;
5
6  void *Thread1(void *x) {
7      // w(x)1
8      x++;
9      // acq(y)1
10     pthread_mutex_lock(&y);
11     // rel(y)1
12     pthread_mutex_unlock(&y);
13     return NULL;
14 }
15
16 void *Thread2(void *x) {
17     // acq(y)2
18     pthread_mutex_lock(&y);
19     // w(x)2
20     x--;
21     // rel(y)2
22     pthread_mutex_unlock(&y);
23     return NULL;
```

```
24 }
25
26 int main() {
27     pthread_t t[2];
28     pthread_create(&t[0], NULL, Thread1, NULL);
29     pthread_create(&t[1], NULL, Thread2, NULL);
30     pthread_join(t[0], NULL);
31     pthread_join(t[1], NULL);
32 }
```

Listing 1: Program containing conflicting events

The listing 1 can be represented by the following trace:

	1#	2#
1.	w(x)	
2.	acq(y)	
3.	rel(y)	
4.		acq(y)
5.		w(x)
6.		rel(y)

Table 1: Possible trace of listing 1

3 Background

3.1 Data Race

Sulzmann and Stadtmüller [2, p. 1] define data races as follows: 'A data race arises if two unprotected, conflicting read/write operations from different threads happen at the same time.' Further they state that a data race can be described as follows:

> Let e, f be two read/write events on the same variable where at least one of them is a write event and both events result from different threads. Then, we say that e and f are two *conflicting events*. [...] [I]f two conflicting events can appear right next to each other [,then s]uch a situation represents a *data race*.

List of Literature

[1] A. R. Molla, G. Sharma, P. Kumar, and S. Rawat, Eds., *Distributed computing and intelligent technology : 19th international conference, icdcit 2023, bhubaneswar, india, january 18–22, 2023, proceedings*, Cham, 2023. [Online]. Available: https://link.springer.com/book/10.1007/978-3-031-24848-1.

[2] M. Sulzmann and K. Stadtmüller, "Efficient, near complete and often sound hybrid dynamic data race prediction (extended version)," *CoRR*, vol. abs/2004.06969, 2020. arXiv: 2004.06969. [Online]. Available: https://arxiv.org/abs/2004.06969.

[3] C. Flanagan and S. Freund, "Fasttrack: Efficient and precise dynamic race detection," vol. 53, Jun. 2009, pp. 121–133. DOI: 10.1145/1542476.1542490.

[4] M. Sulzmann, *Dynamic data race prediction*. [Online]. Available: https://sulzmann.github.io/AutonomeSysteme/lec-data-race.html, accessed Jun. 5, 2023.

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