HPC Übungen

Release 1.0

Sarah Blume, Sebastian Rieger

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Inhaltsverzeichnis

1 Übung 1

1.1 Aufgabe 1

1. ```
   cd hello-world
   make run
   ```

2. ```
   #include <stdio.h>
   #include <stdlib.h>
   #include <unistd.h>
   #include <omp.h>

   int main(int argc, char **argv) {

     #pragma omp parallel num_threads(4)
     {
       int num_threads = omp_get_num_threads();
       int this_num = omp_get_thread_num();
       printf("Hello World %d von %d\n", this_num, num_threads);
     }
     return 0;
   }
   ```

3. Die Ausgabe ist nicht konstant, weil die Threads bei jeder Ausgabe unterschiedlich schnell sind.

4. ```
   #include <stdio.h>
   #include <stdlib.h>
   ```
   ```

```
#include <unistd.h>
#include <omp.h>

int main(int argc, char **argv) {
  #pragma omp parallel sections num_threads(4)
  {
    #pragma omp section
    {
      printf("Hola Mundo from thread %d of %d\n",
        omp_get_thread_num(), omp_get_num_threads());
      printf("Hej varlden from thread %d of %d\n",
        omp_get_thread_num(), omp_get_num_threads());
    }

    #pragma omp section
    {
      printf("Bonjour tout from thread %d of %d\n",
        omp_get_thread_num(), omp_get_num_threads());
    }

    #pragma omp section
    {
      printf("Hallo Welt from thread %d of %d\n",
        omp_get_thread_num(), omp_get_num_threads());
    }
    #pragma omp section
    {
      printf("Hello World from thread %d of %d\n",
        omp_get_thread_num(), omp_get_num_threads());
    }
  }
  return 0;
}
```

1.2 Aufgabe 2

1. Der Fehler in error1 tritt nur auf, wenn mehr als 2 Threads verwendet werden.

   Von l.36 bis l.55 wird das Programm in zwei Sections aufgeteilt welche von 2 Threads abgearbeitet werden. Wegen dem “nowait” Befehl laufen alle anderen Threads gegen die Barrier in l.58 und warten auf die Threads, welche den Sectionblock abarbeiten.

   Diese Threads laufen aber gegen die Barrier in l.86 und warten dort auf die anderen Threads, welche diesen Codeteil nicht ausführen.

   Für die Behebung gibt es also 2 Möglichkeiten.

   (a) OMP_NUM_THREADS=2

   (b) l.86 löschen

2. Der Fehler tritt durch ein Deadlock auf, dies geschieht da die beiden Sections ihre Locks nicht zu Beginn setzen.

   In l.45 locked der erste Thread locka und zeitgleich in l. 59 wird durch den anderen Thread lockb gelocked. Laufen nun beide Threads weiter wartet der erste Thread in l.48 auf das unlock von lockb und der andere Thread in l.62 auf das unlock von locka.

   Der Fehler kann wieder durch mindesten 3 Arten gelöst werden.

   (a) Der Bereich wird nicht paraellisiert sondern sequentiell hintereinander ausgeführt.

   (b) Nur einen CPU Core verwenden, weil denn die Sections auch sequentiell und nicht parallel ausgeführt werden.

(c) Jede Section locked zu beginn all ihre locks in der gleichen Reihenfolge.

```
#include <omp.h>
#include <stdio.h>
#include <stdlib.h>
#define N 1000000
#define PI 3.1415926535
#define DELTA .01415926535

int main (int argc, char *argv[])
{
int nthreads, tid, i;
float a[N], b[N];
omp_lock_t locka, lockb;

/* Initialize the locks */
omp_init_lock(&locka);
omp_init_lock(&lockb);

/* Fork a team of threads giving them their own copies of variables */
#pragma omp parallel shared(a, b, nthreads, locka, lockb) private(tid)
  {

  /* Obtain thread number and number of threads */
  tid = omp_get_thread_num();
  #pragma omp master
    {
    nthreads = omp_get_num_threads();
    printf("Number of threads = %d\n", nthreads);
    }
  printf("Thread %d starting...\n", tid);
  #pragma omp barrier

  #pragma omp sections nowait
    {
    #pragma omp section
      {
      printf("Thread %d initializing a[]\n",tid);
      omp_set_lock(&locka);
      omp_set_lock(&lockb);
      for (i=0; i<N; i++)
        a[i] = i * DELTA;
      printf("Thread %d adding a[] to b[]\n",tid);
      for (i=0; i<N; i++)
        b[i] += a[i];
      omp_unset_lock(&lockb);
      omp_unset_lock(&locka);
      }

    #pragma omp section
      {
      printf("Thread %d initializing b[]\n",tid);
      omp_set_lock(&locka);
      omp_set_lock(&lockb);
      for (i=0; i<N; i++)
        b[i] = i * PI;
      printf("Thread %d adding b[] to a[]\n",tid);
      for (i=0; i<N; i++)
        a[i] += b[i];
      omp_unset_lock(&locka);
      omp_unset_lock(&lockb);
      }
    }  /* end of sections */
```

```
    }  /* end of parallel region */
  }
```

1.3 Aufgabe 3

1. `make run`

2. ```
   #include <stdio.h>
   #include <stdlib.h>
   #include <unistd.h>
   #include <omp.h>

   #define TRYS 5000000

   static int throw() {
     double x, y;
     x = (double)rand() / (double)RAND_MAX;
     y = (double)rand() / (double)RAND_MAX;
     if ((x*x + y*y) <= 1.0) return 1;

     return 0;
   }

   int main(int argc, char **argv) {
     int globalCount = 0, globalSamples=TRYS, i;

     #pragma omp parallel for private(i) shared(globalCount)
     for(i = 0; i < globalSamples; ++i) {
       int add = throw();
       if (add != 0){
         #pragma omp atomic
               globalCount += add;
       }
     }

     double pi = 4.0 * (double)globalCount / (double)(globalSamples);

     printf("pi is %.9lf\n", pi);

     return 0;
   }
   ```

3. ```
   #include <stdio.h>
   #include <stdlib.h>
   #include <unistd.h>
   #include <omp.h>

   #define TRYS 5000000

   static int throw() {
     double x, y;
     x = (double)rand() / (double)RAND_MAX;
     y = (double)rand() / (double)RAND_MAX;
     if ((x*x + y*y) <= 1.0) return 1;

     return 0;
   }

   int main(int argc, char **argv) {
     int globalCount = 0, globalSamples=TRYS, i;
   ```

```
  #pragma omp parallel for reduction(+:globalCount)
  for(i = 0; i < globalSamples; ++i) {
    int add = throw();
    if (add != 0){
            globalCount += add;
    }
  }

  double pi = 4.0 * (double)globalCount / (double)(globalSamples);

  printf("pi is %.9lf\n", pi);

  return 0;
}
```

4.
```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <omp.h>

#define TRYS 5000000

static int throw() {
  double x, y;
  x = (double)rand() / (double)RAND_MAX;
  y = (double)rand() / (double)RAND_MAX;
  if ((x*x + y*y) <= 1.0) return 1;

  return 0;
}

int main(int argc, char **argv) {
  int globalCount = 0, globalSamples=TRYS, i;

  #pragma omp parallel reduction(+:globalCount)
  {
    #pragma omp for
      for(i = 0; i < globalSamples; ++i) {
        int add = throw();
        if (add != 0){
          globalCount += add;
        }
      }

    printf("thread %d: i = %d\n", omp_get_thread_num(), globalCount);
  }


  double pi = 4.0 * (double)globalCount / (double)(globalSamples);

  printf("pi is %.9lf\n", pi);

  return 0;
}
```

5.
```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <omp.h>

#define TRYS 5000000

static int throw() {
```

```
  double x, y;
  x = (double)rand() / (double)RAND_MAX;
  y = (double)rand() / (double)RAND_MAX;
  if ((x*x + y*y) <= 1.0) return 1;

  return 0;
}

int main(int argc, char **argv) {
  int globalCount = 0, globalSamples=TRYS, i;

  #pragma omp parallel reduction(+:globalCount) num_threads(6)
  {
    #pragma omp for
      for(i = 0; i < globalSamples; ++i) {
        int add = throw();
        if (add != 0){
          globalCount += add;
        }
      }

    printf("thread %d: i = %d\n", omp_get_thread_num(), globalCount);
  }


  double pi = 4.0 * (double)globalCount / (double)(globalSamples);

  printf("pi is %.9lf\n", pi);

  return 0;
}
```

Durch das `num_threads(6)` wird unterbunden, dass der Benutzer die Threadanzahl verändern kann. Er könnte dies ohne diese Angabe durch setzen von `OMP_NUM_THREADS` tun.

2 Übung 2

2.1 Aufgabe 1

1. Bei der Ausführung kann beobachtet werden, das ein Philosoph immer mehrmals hintereinander denkt und isst.

   Nach einer Weile erfolgt ein Wechsel und ein anderer Philosoph isst bzw. denkt. Diese Beobachtung wiederholt sich endlos.

2. Unsere Philosophen sind höflich, nachdem sie geggessen haben, denken sie ersteinmal wieder eine weile nach, dies verhindert Deadlocks, da ihre Kolegen, welche essen wollen in der Zwischenzeit sich die Gabel nehmen/locken können.

```
#include <omp.h>
#include <stdio.h>
#include <stdlib.h>

// number of philosophers
#define N 5
// left neighbour
#define LEFT  (id)
// right neighbour
#define RIGHT ((id + 1) % num_threads)

#define TRUE  1
```

```
#define FALSE 0

// Global variables
int num_threads;
omp_lock_t forks[N];

void think(int philosopher) {
  printf("%d is thinking.\n", philosopher);
}
void eat(int philosopher) {
  printf("%d is eating.\n", philosopher);
}

void philosopher(int id) {
  while(TRUE) {
    think(id);
    sleep(1);

    omp_set_lock(&forks[LEFT]);
    omp_set_lock(&forks[RIGHT]);
    eat(id);
    omp_unset_lock(&forks[LEFT]);
    omp_unset_lock(&forks[RIGHT]);
  }
}

int main (int argc, char *argv[]) {
  int i;
  int id;

  for (i = 0; i < N; i++){
    omp_init_lock(&forks[i]);
  }

  omp_set_num_threads(N);
  #pragma omp parallel private(id) shared(num_threads, forks)
  {
    id = omp_get_thread_num();
    num_threads = omp_get_num_threads();

    philosopher(id);
  }

  for (i = 0; i < N; i++){
    omp_destroy_lock(&forks[i]);
  }
  return 0;
}
```

2.2 Aufgabe 2

1. Ohne weitere Ändungerung am Programm passiert nichts außer das 2 Threads mit jeweils 100% Auslastung starten.

2. ```
   #include <stdio.h>
   #include <unistd.h>
   #include <stdlib.h>
   #include <omp.h>

   #define NUMITER 26
   ```
   ```

```
#define TRUE 1
#define FALSE 0

typedef struct parallelstack {
  omp_lock_t stacklock;  //lock for accessing the stack
  int cancel;            //flag that indicates if threads should stop working
  char *buffer;          //stack elements
  int size;              //size of the stack
  int count;             //current position in the stack
} ParallelStack;

static inline ParallelStack* newParallelStack() {
  return calloc(1, sizeof(ParallelStack));
}

static inline ParallelStack* ParallelStack_init(ParallelStack* pq, int size) {
  omp_init_lock(&pq[0].stacklock);

  return pq;
}

static inline ParallelStack* ParallelStack_deinit(ParallelStack* pq) {

  omp_destroy_lock(&pq[0].stacklock);
  return pq;
}

static inline ParallelStack* freeParallelStack(ParallelStack* pq) {
  free(pq);
  return pq;
}

static int ParallelStack_put(ParallelStack* pq, char item) {
  int writtenChars = FALSE; // TRUE if the stack was abel to put the data,
    FALSE if the stack is full, the data will be rejected
  omp_set_lock(&pq[0].stacklock);

  omp_unset_lock(&pq[0].stacklock);
  return writtenChars;
}

int ParallelStack_get(ParallelStack* pq, char *c) {
  int numReadedChars = 0; // TRUE if the stack was abel to get the data,
    FALSE if the stack is empty
  omp_set_lock(&pq[0].stacklock);

  omp_unset_lock(&pq[0].stacklock);
  return numReadedChars;
}

void ParallelStack_setCanceled(ParallelStack* pq) {
  omp_set_lock(&pq[0].stacklock);

  omp_unset_lock(&pq[0].stacklock);
}


int ParallelStack_isCanceled(ParallelStack* pq) {
  int canceled = FALSE;
  omp_set_lock(&pq[0].stacklock);

  omp_unset_lock(&pq[0].stacklock);
  return canceled;
```

```
}

//////////////////////////////////////
// DO NOT EDIT BEYOND THIS LINE !!!!
//////////////////////////////////////

void producer(int tid, ParallelStack* pq) {
  int i = 0;
  char item;
  while( i < NUMITER) {
    item = 'A' + (i % 26);

    if ( ParallelStack_put(pq, item) == 1) {
      i++;
      printf("->Thread %d is Producing %c ...\n",tid, item);
    }
    //sleep(1);
   }
   ParallelStack_setCanceled(pq);
}


void consumer(int tid, ParallelStack* pq)
{
  char item;
  while( ParallelStack_isCanceled(pq) == FALSE) {

    if (ParallelStack_get(pq, &item) == 1) {
      printf("<-Thread %d is Consuming %c\n",tid, item);
    }
    sleep(2);
  }
}

int main()
{
    int tid;
    ParallelStack* pq = ParallelStack_init(newParallelStack(), 5);

    #pragma omp parallel private(tid) num_threads(4)
    {
       tid=omp_get_thread_num();

       if(tid==1)
       {
         producer(tid, pq);
       } else
       {
         consumer(tid, pq);
       }
    }

    freeParallelStack(ParallelStack_deinit(pq));

    return 0;
}
```

3. ```
   #include <stdio.h>
   #include <unistd.h>
   #include <stdlib.h>
   #include <omp.h>

   #define NUMITER 26
   ```
   ```

```
#define TRUE 1
#define FALSE 0

typedef struct parallelstack {
  omp_lock_t stacklock;  //lock for accessing the stack
  int cancel;            //flag that indicates if threads should stop working
  char *buffer;          //stack elements
  int size;              //size of the stack
  int count;             //current position in the stack
} ParallelStack;

static inline ParallelStack* newParallelStack() {
  return calloc(1, sizeof(ParallelStack));
}

static inline ParallelStack* ParallelStack_init(ParallelStack* pq, int size) {
  omp_init_lock(&pq[0].stacklock);
  char array[size];

  omp_set_lock(&pq[0].stacklock);
    pq[0].buffer = array;
    pq[0].size = size;
    pq[0].count = -1;
  omp_unset_lock(&pq[0].stacklock);
  return pq;
}

static inline ParallelStack* ParallelStack_deinit(ParallelStack* pq) {

  omp_destroy_lock(&pq[0].stacklock);
  return pq;
}

static inline ParallelStack* freeParallelStack(ParallelStack* pq) {
  free(pq);
  return pq;
}

static int ParallelStack_put(ParallelStack* pq, char item) {
  int writtenChars = FALSE; // TRUE if the stack was abel to put the data, FALSE if the stack
    if(pq[0].count < pq[0].size){
      omp_set_lock(&pq[0].stacklock);
        pq[0].count++;
        pq[0].buffer[pq[0].count] = item;
        writtenChars = TRUE;
      omp_unset_lock(&pq[0].stacklock);
    }
  return writtenChars;
}

int ParallelStack_get(ParallelStack* pq, char *c) {
  int numReadedChars = 0; // TRUE if the stack was abel to get the data, FALSE if the stack i
    if(pq[0].count > -1){
      omp_set_lock(&pq[0].stacklock);
        *c = pq[0].buffer[pq[0].count];
        pq[0].count--;
        numReadedChars = TRUE;
      omp_unset_lock(&pq[0].stacklock);
    }
  return numReadedChars;
}
```

```
void ParallelStack_setCanceled(ParallelStack* pq) {
  omp_set_lock(&pq[0].stacklock);
    pq[0].cancel = TRUE;
  omp_unset_lock(&pq[0].stacklock);
}


int ParallelStack_isCanceled(ParallelStack* pq) {
  int canceled = FALSE;
  omp_set_lock(&pq[0].stacklock);
    canceled = pq[0].cancel;
  omp_unset_lock(&pq[0].stacklock);
  return canceled;
}

////////////////////////////////////////
// DO NOT EDIT BEYOND THIS LINE !!!!
////////////////////////////////////////

void producer(int tid, ParallelStack* pq) {
  int i = 0;
  char item;
  while( i < NUMITER) {
    item = 'A' + (i % 26);

    if ( ParallelStack_put(pq, item) == 1) {
      i++;
      printf("->Thread %d is Producing %c ...\n",tid, item);
    }
    //sleep(1);
   }
   ParallelStack_setCanceled(pq);
}


void consumer(int tid, ParallelStack* pq)
{
  char item;
  while( ParallelStack_isCanceled(pq) == FALSE) {

    if (ParallelStack_get(pq, &item) == 1) {
      printf("<-Thread %d is Consuming %c\n",tid, item);
    }
    sleep(2);
  }
}

int main()
{
    int tid;
    ParallelStack* pq = ParallelStack_init(newParallelStack(), 5);

    #pragma omp parallel private(tid) num_threads(4)
    {
       tid=omp_get_thread_num();

       if(tid==1)
       {
         producer(tid, pq);
       } else
       {
         consumer(tid, pq);
       }
```

```
    }

    freeParallelStack(ParallelStack_deinit(pq));

    return 0;
}
```

4. ```
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
#include <omp.h>

#define NUMITER 26

#define TRUE 1
#define FALSE 0

typedef struct parallelstack {
  omp_lock_t stacklock; //lock for accessing the stack
  int cancel;   //flag that indicates if threads should stop working
  char *buffer;   //stack elements
  int size;   //size of the stack
  int count;   //current position in the stack
} ParallelStack;

static inline ParallelStack* newParallelStack() {
  return calloc(1, sizeof(ParallelStack));
}

static inline ParallelStack* ParallelStack_init(ParallelStack* pq, int size) {
  omp_init_lock(&pq[0].stacklock);
  char array[size];

  omp_set_lock(&pq[0].stacklock);
    pq[0].buffer = array;
    pq[0].size = size;
    pq[0].count = -1;
  omp_unset_lock(&pq[0].stacklock);
  return pq;
}

static inline ParallelStack* ParallelStack_deinit(ParallelStack* pq) {

  omp_destroy_lock(&pq[0].stacklock);
  return pq;
}

static inline ParallelStack* freeParallelStack(ParallelStack* pq) {
  free(pq);
  return pq;
}

static int ParallelStack_put(ParallelStack* pq, char item) {
  int writtenChars = FALSE; // TRUE if the stack was abel to put the data,
    FALSE if the stack is full, the data will be rejected
  omp_set_lock(&pq[0].stacklock);
    if(pq[0].count < pq[0].size){
      pq[0].count++;
      pq[0].buffer[pq[0].count] = item;
      writtenChars = TRUE;
    }
  omp_unset_lock(&pq[0].stacklock);
  return writtenChars;
```
```

```
}

int ParallelStack_get(ParallelStack* pq, char *c) {
  int numReadedChars = 0; // TRUE if the stack was abel to get the data,
    FALSE if the stack is empty
  omp_set_lock(&pq[0].stacklock);
    if(pq[0].count > -1){
      *c = pq[0].buffer[pq[0].count];
      pq[0].count--;
      numReadedChars = TRUE;
    }
  omp_unset_lock(&pq[0].stacklock);
  return numReadedChars;
}

void ParallelStack_setCanceled(ParallelStack* pq) {
  omp_set_lock(&pq[0].stacklock);
    pq[0].cancel = TRUE;
  omp_unset_lock(&pq[0].stacklock);
}


int ParallelStack_isCanceled(ParallelStack* pq) {
  int canceled = FALSE;
  omp_set_lock(&pq[0].stacklock);
    canceled = pq[0].cancel;
  omp_unset_lock(&pq[0].stacklock);
  return canceled;
}

////////////////////////////////////////
// DO NOT EDIT BEYOND THIS LINE !!!!
////////////////////////////////////////

void producer(int tid, ParallelStack* pq) {
  int i = 0;
  char item;
  while( i < NUMITER) {
    item = 'A' + (i % 26);

    if ( ParallelStack_put(pq, item) == 1) {
      i++;
      printf("->Thread %d is Producing %c ...\n",tid, item);
    }
    //sleep(1);
   }
   ParallelStack_setCanceled(pq);
}


void consumer(int tid, ParallelStack* pq)
{
  char item;
  while( ParallelStack_isCanceled(pq) == FALSE) {

    if (ParallelStack_get(pq, &item) == 1) {
      printf("<-Thread %d is Consuming %c\n",tid, item);
    }
    sleep(2);
  }
}

int main()
```

```
{
    int tid;
    ParallelStack* pq = ParallelStack_init(newParallelStack(), 5);

    #pragma omp parallel private(tid) num_threads(4)
    {
       tid=omp_get_thread_num();

       if(tid==1)
       {
         producer(tid, pq);
       } else
       {
         consumer(tid, pq);
       }
    }

    freeParallelStack(ParallelStack_deinit(pq));

    return 0;
}
```

5. Die folgene Implemenierung ist nur die schnellste Art aus dem gegegben Sourcecode eine Queue zu machen. Es ist nicht umbedingt die performateste Art und Weise.

```
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
#include <omp.h>

#define NUMITER 26

#define TRUE 1
#define FALSE 0

typedef struct parallelstack {
  omp_lock_t stacklock;  //lock for accessing the stack
  int cancel;            //flag that indicates if threads should stop working
  char *buffer;          //stack elements
  int size;              //size of the stack
  int count;             //current position in the stack
} ParallelStack;

static inline ParallelStack* newParallelStack() {
  return calloc(1, sizeof(ParallelStack));
}

static inline ParallelStack* ParallelStack_init(ParallelStack* pq, int size) {
  omp_init_lock(&pq[0].stacklock);
  char array[size];

  omp_set_lock(&pq[0].stacklock);
    pq[0].buffer = array;
    pq[0].size = size;
    pq[0].count = -1;
  omp_unset_lock(&pq[0].stacklock);
  return pq;
}

static inline ParallelStack* ParallelStack_deinit(ParallelStack* pq) {

  omp_destroy_lock(&pq[0].stacklock);
  return pq;
```

```
}

static inline ParallelStack* freeParallelStack(ParallelStack* pq) {
  free(pq);
  return pq;
}

static int ParallelStack_put(ParallelStack* pq, char item) {
  int writtenChars = FALSE; // TRUE if the stack was abel to put the data, FALSE if the stack
  omp_set_lock(&pq[0].stacklock);
    if(pq[0].count < pq[0].size){
      pq[0].count++;
      pq[0].buffer[pq[0].count] = item;
      writtenChars = TRUE;
    }
  omp_unset_lock(&pq[0].stacklock);
  return writtenChars;
}

int ParallelStack_get(ParallelStack* pq, char *c) {
  int numReadedChars = 0; // TRUE if the stack was abel to get the data, FALSE if the stack i
  omp_set_lock(&pq[0].stacklock);
    if(pq[0].count > -1){
      *c = pq[0].buffer[0];
      for(int i = 0; i < pq[0].count; ++i){
        pq[0].buffer[i] = pq[0].buffer[i+1];
      }
      pq[0].count--;
      numReadedChars = TRUE;
    }
  omp_unset_lock(&pq[0].stacklock);
  return numReadedChars;
}

void ParallelStack_setCanceled(ParallelStack* pq) {
  omp_set_lock(&pq[0].stacklock);
    pq[0].cancel = TRUE;
  omp_unset_lock(&pq[0].stacklock);
}


int ParallelStack_isCanceled(ParallelStack* pq) {
  int canceled = FALSE;
  omp_set_lock(&pq[0].stacklock);
    canceled = pq[0].cancel;
  omp_unset_lock(&pq[0].stacklock);
  return canceled;
}

////////////////////////////////////////
// DO NOT EDIT BEYOND THIS LINE !!!!
////////////////////////////////////////

void producer(int tid, ParallelStack* pq) {
  int i = 0;
  char item;
  while( i < NUMITER) {
    item = 'A' + (i % 26);

    if ( ParallelStack_put(pq, item) == 1) {
      i++;
      printf("->Thread %d is Producing %c ...\n",tid, item);
    }
```

```
    //sleep(1);
   }
   ParallelStack_setCanceled(pq);
}


void consumer(int tid, ParallelStack* pq)
{
  char item;
  while( ParallelStack_isCanceled(pq) == FALSE) {

    if (ParallelStack_get(pq, &item) == 1) {
      printf("<-Thread %d is Consuming %c\n",tid, item);
    }
    sleep(2);
  }
}

int main()
{
    int tid;
    ParallelStack* pq = ParallelStack_init(newParallelStack(), 5);

    #pragma omp parallel private(tid) num_threads(4)
    {
       tid=omp_get_thread_num();

       if(tid==1)
       {
         producer(tid, pq);
       } else
       {
         consumer(tid, pq);
       }
    }

    freeParallelStack(ParallelStack_deinit(pq));

    return 0;
}
```

6. Wenn bei einer Queue nur ein Lock verwendet wird, dann kann ein hinzufügen eines Elements zu der Queue den Zugriff auf das vorderste Elemet der Queue blockieren. Im Gegensatz zum Stack sind diese beiden Operationen nicht immer von einander abhängig. Sie blockieren sich nur, wenn die Queue leer ist.