din_philo.c

```
[ryonosuke_araki@RyonosukenoMacBook-Air                    13:27:37]                    $                    cat                    din_philo.c
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
#include <errno.h>
#include <assert.h>
#define PHILOS 5
#define DELAY 5000
#define FOOD 50

void *philosopher (void *id);
void grab_chopstick (int, int, char *);
void down_chopsticks (int, int);
int food_on_table ();

pthread_mutex_t chopstick[PHILOS];
pthread_t philo[PHILOS];
pthread_mutex_t food_lock;
int sleep_seconds = 0;


int main (int argn, char **argv)
{
    int i;

    if (argn == 2)
        sleep_seconds = atoi (argv[1]);

    pthread_mutex_init (&food_lock, NULL);
    for (i = 0; i < PHILOS; i++)
        pthread_mutex_init (&chopstick[i], NULL);
    for (i = 0; i < PHILOS; i++)
        pthread_create (&philo[i], NULL, philosopher, (void *)i);
    for (i = 0; i < PHILOS; i++)
       pthread_join (philo[i], NULL);
    return 0;
}

void *philosopher (void *num)
{
    int id;
    int i, left_chopstick, right_chopstick, f;

    id = (int)num;
    printf("Philosopher %d is done thinking and now ready to eat.¥n", id);
    right_chopstick = id;
    left_chopstick = id + 1;

    /* 箸が一巡した */
    if (left_chopstick == PHILOS)
        left_chopstick = 0;

    while (f = food_on_table ()) {
        /* 箸を手に取る前にうたた寝をする哲学者 1 のおかげで、ほかの
        * 哲学者達は、デッドロックに陥ることなく食事をすることが
        * できます。                    */
        if (id == 1)
            sleep (sleep_seconds);

        grab_chopstick (id, right_chopstick, "right ");
        grab_chopstick (id, left_chopstick, "left");

        printf ("Philosopher %d: eating.¥n", id);
        usleep (DELAY * (FOOD - f + 1));
        down_chopsticks (left_chopstick, right_chopstick);
    }

    printf ("Philosopher %d is done eating.¥n", id);
    return (NULL);
}

int food_on_table ()
{
    static int food = FOOD;
    int myfood;

    pthread_mutex_lock (&food_lock);
    if (food > 0) {
        food--;
    }
    myfood = food;
    pthread_mutex_unlock (&food_lock);
    return myfood;
}

void
grab_chopstick (int phil, int c, char *hand)
{
    pthread_mutex_lock (&chopstick[c]);
    printf ("Philosopher %d: got %s chopstick %d¥n", phil, hand, c);
}

void
down_chopsticks (int c1, int c2)
{
    pthread_mutex_unlock (&chopstick[c1]);
    pthread_mutex_unlock (&chopstick[c2]);
}
```

din_philo の実行結果

```
[ryonosuke_araki@RyonosukenoMacBook-Air 13:17:54] $ cc din_philo.c
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
din_philo.c:33:55: warning: cast to 'void *' from smaller integer type 'int' [-Wint-to-void-pointer-cast]
        pthread_create (&philo[i], NULL, philosopher, (void *)i);
                                                      ^
din_philo.c:53:14: warning: using the result of an assignment as a condition without parentheses [-Wparentheses]
    while (f = food_on_table ()) {
```

```
                ~~^~~~~~~~~~~~~~~~~~
din_philo.c:53:14: note: place parentheses around the assignment to silence this warning
      while (f = food_on_table ()) {
                 ^
               (                    )
din_philo.c:53:14: note: use '==' to turn this assignment into an equality comparison
      while (f = food_on_table ()) {
                 ^
                 ==
2 warnings generated.

[ryonosuke_araki@RyonosukenoMacBook-Air                    13:19:34]                    $                    ./a.out
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
Philosopher 0 is done thinking and now ready to eat.
Philosopher 1 is done thinking and now ready to eat.
Philosopher 2 is done thinking and now ready to eat.
Philosopher 2: got right    chopstick 2
Philosopher 4 is done thinking and now ready to eat.
Philosopher 4: got right    chopstick 4
Philosopher 1: got right    chopstick 1
Philosopher 3 is done thinking and now ready to eat.
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 0: got right    chopstick 0
Philosopher 2: got right    chopstick 2
Philosopher 3: got right    chopstick 3
^Z
zsh: suspended    ./a.out
[ryonosuke_araki@RyonosukenoMacBook-Air 13:24:02] $
```

トークンを用いたシステムを使用して、哲学者がトークンを受け取ってから食事をとるようにする。用意するトークンの数は、席についている哲学者の人数より少ない。哲学者はトークンを受け取ったあと、テーブルの規則に従って食事をとることができる。食事をしたあと、哲学者はトークンを返却し、プロセスを繰り返す。

din_philo_fix.c

```
[ryonosuke_araki@RyonosukenoMacBook-Air              13:49:17]              $              cat              din_philo_fix.c
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
#include <errno.h>
#include <assert.h>

#define PHILOS 5
#define DELAY 5000
#define FOOD 50

void *philosopher (void *id);
void grab_chopstick (int, int, char *);
void down_chopsticks (int, int);
int food_on_table ();
int get_token ();
void return_token ();

pthread_mutex_t chopstick[PHILOS];
pthread_t philo[PHILOS];
```

```
pthread_mutex_t food_lock;
pthread_mutex_t num_can_eat_lock;
int sleep_seconds = 0;
uint32_t num_can_eat = PHILOS - 1;


int main (int argn, char **argv)
{
    int i;

    pthread_mutex_init (&food_lock, NULL);
    pthread_mutex_init (&num_can_eat_lock, NULL);
    for (i = 0; i < PHILOS; i++)
        pthread_mutex_init (&chopstick[i], NULL);
    for (i = 0; i < PHILOS; i++)
        pthread_create (&philo[i], NULL, philosopher, (void *)i);
    for (i = 0; i < PHILOS; i++)
        pthread_join (philo[i], NULL);
    return 0;
}

void *philosopher (void *num)
{
    int id;
    int i, left_chopstick, right_chopstick, f;

    id = (int)num;
    printf ("Philosopher %d is done thinking and now ready to eat.¥n", id);
    right_chopstick = id;
    left_chopstick = id + 1;

    /* 箸が一巡した */
    if (left_chopstick == PHILOS)
        left_chopstick = 0;

    while (f = food_on_table ()) {
        get_token ();

        grab_chopstick (id, right_chopstick, "right ");
        grab_chopstick (id, left_chopstick, "left");

        printf ("Philosopher %d: eating.¥n", id);
        usleep (DELAY * (FOOD - f + 1));
        down_chopsticks (left_chopstick, right_chopstick);

        return_token ();
    }

    printf ("Philosopher %d is done eating.¥n", id);
    return (NULL);
}

int food_on_table ()
{
    static int food = FOOD;
    int myfood;
    pthread_mutex_lock (&food_lock);
    if (food > 0) {
        food--;
    }
    myfood = food;
    pthread_mutex_unlock (&food_lock);
    return myfood;
}

void grab_chopstick (int phil, int c, char *hand)
{
    pthread_mutex_lock (&chopstick[c]);
    printf ("Philosopher %d: got %s chopstick %d¥n", phil, hand, c);
}

void down_chopsticks (int c1, int c2)
{
    pthread_mutex_unlock (&chopstick[c1]);
    pthread_mutex_unlock (&chopstick[c2]);
}

int get_token ()
{
    int successful = 0;

    while (!successful) {
        pthread_mutex_lock (&num_can_eat_lock);
        if (num_can_eat > 0) {
            num_can_eat--;
            successful = 1;
        }
        else {
            successful = 0;
        }
        pthread_mutex_unlock (&num_can_eat_lock);
    }
}

void return_token ()
{
    pthread_mutex_lock (&num_can_eat_lock);
    num_can_eat++;
    pthread_mutex_unlock (&num_can_eat_lock);
}
```

din_philo_fix.c の実行結果

```
[ryonosuke_araki@RyonosukenoMacBook-Air 13:48:17] $ ./a.out
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
Philosopher 1 is done thinking and now ready to eat.
Philosopher 0 is done thinking and now ready to eat.
Philosopher 2 is done thinking and now ready to eat.
Philosopher 3 is done thinking and now ready to eat.
Philosopher 0: got right   chopstick 0
Philosopher 3: got right   chopstick 3
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 2: got right   chopstick 2
Philosopher 4 is done thinking and now ready to eat.
Philosopher 1: got right   chopstick 1
Philosopher 3: got right   chopstick 3
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 4: got right   chopstick 4
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 1: got left chopstick 2
Philosopher 1: eating.
Philosopher 3: got right   chopstick 3
Philosopher 2: got right   chopstick 2
Philosopher 0: got left chopstick 1
Philosopher 0: eating.
Philosopher 0: got right   chopstick 0
Philosopher 0: got left chopstick 1
Philosopher 0: eating.
Philosopher 1: got right   chopstick 1
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 3: got right   chopstick 3
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 3: got right   chopstick 3
Philosopher 4: got right   chopstick 4
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 4: got right   chopstick 4
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 3: got right   chopstick 3
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 4: got right   chopstick 4
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 3: got right   chopstick 3
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 4: got right   chopstick 4
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 3: got right   chopstick 3
Philosopher 1: got left chopstick 2
Philosopher 1: eating.
Philosopher 2: got right   chopstick 2
Philosopher 0: got right   chopstick 0
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 1: got right　chopstick 1
Philosopher 3: got right　chopstick 3
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 3: got right　chopstick 3
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 1: got left chopstick 2
Philosopher 1: eating.
Philosopher 2: got right　chopstick 2
Philosopher 0: got left chopstick 1
Philosopher 0: eating.
Philosopher 4: got right　chopstick 4
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 1: got right　chopstick 1
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 1: got left chopstick 2
Philosopher 1: eating.
Philosopher 0: got right　chopstick 0
Philosopher 4: got right　chopstick 4
Philosopher 2: got right　chopstick 2
Philosopher 0: got left chopstick 1
Philosopher 0: eating.
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 1: got right　chopstick 1
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 3: got right　chopstick 3
Philosopher 1: got left chopstick 2
Philosopher 1: eating.
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 0: got right　chopstick 0
Philosopher 0: got left chopstick 1
Philosopher 0: eating.
Philosopher 2: got right　chopstick 2
Philosopher 4: got right　chopstick 4
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 1: got right　chopstick 1
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 1: got left chopstick 2
Philosopher 1: eating.
Philosopher 4: got right　chopstick 4
Philosopher 0: got right　chopstick 0
Philosopher 2: got right　chopstick 2
Philosopher 0: got left chopstick 1
Philosopher 0: eating.
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 1: got right    chopstick 1
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 3: got right    chopstick 3
Philosopher 1: got left chopstick 2
Philosopher 1: eating.
Philosopher 0: got right    chopstick 0
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 2: got right    chopstick 2
Philosopher 0: got left chopstick 1
Philosopher 0: eating.
Philosopher 3: got right    chopstick 3
Philosopher 4: got right    chopstick 4
Philosopher 1: got right    chopstick 1
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 0: got right    chopstick 0
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 3: got right    chopstick 3
Philosopher 3: got left chopstick 4
Philosopher 3: eating.
Philosopher 3 is done eating.
Philosopher 4: got right    chopstick 4
Philosopher 2: got left chopstick 3
Philosopher 2: eating.
Philosopher 2 is done eating.
Philosopher 1: got left chopstick 2
Philosopher 1: eating.
Philosopher 1 is done eating.
Philosopher 0: got left chopstick 1
Philosopher 0: eating.
Philosopher 0 is done eating.
Philosopher 4: got left chopstick 0
Philosopher 4: eating.
Philosopher 4 is done eating.
```

din_philo.java

```
[ryonosuke_araki@RyonosukenoMacBook-Air 14:28:01] $ cat din_philo.java
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
// 共有オブジェクト
class Fork {
	// どの哲学者の左手にあるか識別する番号
	private int id;
	// いずれかの哲学者の手にとられているかどうか
	private boolean eating = false;

	// コンストラクタ
	Fork(int i) {
		// メソッド引数の哲学者の左手に置かれている
		id = i;
	}

	// 手にとられる
	public synchronized void pick(int i) {
		while (eating == true) {
		// 隣の哲学者の手に取られている間は繰り返し
			try {
				System.out.println(i + " is starving.");
				// 待機プールへ
				wait();
			} catch (InterruptedException e) {
				System.out.println(e);
			}
		}
		// 手に取れたら true をセット
		eating = true;
	}

	// 手から離される
	public synchronized void down() {
		// 食事が済んだら false をセット
		eating = false;
		// 待機プールのスレッドをロック探索状態に
		notifyAll();
	}
}

class Philosopher implements Runnable {
	int id;			// 哲学者の識別番号
	int eatTime;		// 食事時間
	int thinkTime;	// 思索時間
	int left;			// 左手のフォークの番号
	int right;		// 右手のフォークの番号
	Fork[] forks = new Fork[4];		// 共有オブジェクト

	// コンストラクタ
	Philosopher(int i) {
		id = i;
	}

	// 哲学者のプロパティのセット
	public void setProperties(int eating, int thinking, Fork[] objs) {
		left = id;
		if (id != 0) {
			right = id - 1;
		} else {
			right = 4;
		}
		eatTime = eating;
		thinkTime = thinking;
		forks = objs;
	}

	// 空腹を感じるとフォークを手に取る
	public void feelHungry() {
		// 左手のフォークを手に取る
		forks[left].pick(id);

		// ここの待機時間が長いとデッドロック発生
		try {
			Thread.sleep(500);
		} catch (InterruptedException e) {
			System.out.println(e);
		}

		// 右手のフォークを手に取る
		forks[right].pick(id);

		System.out.println(id + " is eating.");
		try {
			// 食事中
			Thread.sleep(eatTime);
		} catch (InterruptedException e) {
			System.out.println(e);
		}
		// 食事終了
		// 左手のフォークを離す
		forks[left].down();
		// 右手のフォークを離す
		forks[right].down();
	}

	// 思索
	public void think() {
		try {
			// 思索中
			Thread.sleep(thinkTime);
		} catch (InterruptedException e) {
			System.out.println(e);
		}
	}

	// スレッドの run() メソッド
	public void run() {
		while (true) {
			// 思索中
			System.out.println(id + " is thinking.");
			think();
			// 空腹を感じる
			System.out.println(id + " feels hungry.");
			feelHungry();
		}
	}
}

class Dining {
	public static void main(String[] args) {
		// 共有オブジェクト
		Fork[] forks = new Fork[5];
		// 哲学者
		Philosopher[] phils = new Philosopher[5];

		// インスタンス化
		for (int i=0; i<5; i++) {
			forks[i] = new Fork(i);
```

```
                phils[i] = new Philosopher(i);
            }

            // 哲学者のプロパティ
            //                          eating, thinking, shared object
            phils[0].setProperties(2000,    1000,       forks);
            phils[1].setProperties(1900,    1100,       forks);
            phils[2].setProperties(1800,    1200,       forks);
            phils[3].setProperties(1700,    1300,       forks);
            phils[4].setProperties(1600,    1400,       forks);

            // スレッド
            Thread[] thres = new Thread[5];
            for (int i=0; i<5; i++) {
                // 哲学者をスレッドに委譲
                thres[i] = new Thread(phils[i]);
            }

            // スレッドの開始
            for (int i=0; i<5; i++) {
                thres[i].start();
            }
        }
}
```

din_philo.java の実行結果

```
[ryonosuke_araki@RyonosukenoMacBook-Air 14:25:42] $ javac din_philo.java
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
[ryonosuke_araki@RyonosukenoMacBook-Air 14:25:57] $ java Dining
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
1 is thinking.
2 is thinking.
0 is thinking.
4 is thinking.
3 is thinking.
0 feels hungry.
1 feels hungry.
2 feels hungry.
3 feels hungry.
4 feels hungry.
0 is starving.
1 is starving.
2 is starving.
3 is starving.
4 is starving.
^Z
zsh: suspended    java Dining
```

DinningPhilosophers.java（共有資源に優先順位を与えるという手法によって、デッドロックを回避）

```
public class DiningPhilosophers {

  // 哲学者（箸）の数
  static final int N = 5;

  // 箸の配列
```

```
    static ChopStick[] chopsticks;

    // 哲学者の配列
    static Philosopher[] philosophers;

    public static void main(String[] args) {

        // 箸オブジェクトを N 本用意する
        chopsticks = new ChopStick[N];

        // オブジェクトの初期化
        for (int i = 0; i < N; i++) {
            chopsticks[i] = new ChopStick();
        }


        // 哲学者オブジェクトの生成と、
        // 各自が使える箸の登録
        philosophers = new Philosopher[N];

        for (int i = 0; i < N; i++) {
            philosophers[i] = new Philosopher(chopsticks[i],
chopsticks[(i+1)%N]);
        }


        // 表示用
        for (int i = 0; i < N; i++) {
            System.out.printf("Philosopher %d                ", i);
        }
        System.out.println();

        for (int i = 0; i < N; i++) {
            System.out.print("--------------------    ");
        }
        System.out.println();

        // 哲学者達に食事を始めさせる。
        for (int i = 0; i < N; i++) {
            philosophers[i].start();
        }
    }
}

// 箸クラス
class ChopStick {

    static int counter = 0;

    // 使用中か否か
    boolean isUsed;

    // 優先度
    int rank;

    ChopStick() {
        isUsed = false;

        // それぞれの箸に異なる優先度を与える
        rank = counter++;
    }
}

// 哲学者クラス
class Philosopher extends Thread {

    static int counter = 0;

    // 待ち時間の最大値。適当に設定してください。
    final long WAITTIME = 100;

    // 識別番号。哲学者オブジェクトを複数作るので、
    // 表示の際に見やすいよう、各々に異なる ID を与えます。
    int number;

    // 自分のテリトリーにある 2 本の箸。
    // lower :  優先度の低い箸,
    // higher:  優先度の高い箸
    ChopStick lowerStick;
    ChopStick higherStick;

    // 自分が箸を持っているか否か
    boolean hasLowerStick;
    boolean hasHigherStick;

    // message
    String msg;

    Philosopher(ChopStick c1, ChopStick c2) {
        // ID の付与
        number = counter++;

        // 自分が使える箸を登録
        if (c1.rank < c2.rank) {
            lowerStick = c1;
            higherStick = c2;
        } else {
            lowerStick = c2;
            higherStick = c1;
        }

        // 最初は箸を持っていない状態
        hasLowerStick = false;
        hasHigherStick = false;
    }

    // 哲学者の行動を登録したメソッド群

    public void run () {
        for (int i = 0; i < 5; i++) {
            // 優先度の高い箸を取る
            picUpHigherStick();
            // 考え事をする
            if(hasHigherStick)
                think();

            // 優先度の低い箸を取る
            picUpLowerStick();

            // 食べる
            eat();

            // また考える

            think();

            // 優先度の高い箸を置く
            putDownHigherStick();

            // 優先度の低い箸を置く
            putDownLowerStick();

            // またまた考え事をする
            think();
        }
    }

    // 優先度の高い箸を取る
    synchronized void picUpHigherStick() {

        // 優先度の高い箸が空くまで待つ
        while(higherStick.isUsed)
            await();

            higherStick.isUsed = true;
            hasHigherStick = true;
            printAnEvent("pick up stick No." + higherStick.rank);
    }

    // 優先度の低い箸を取る
    synchronized void picUpLowerStick() {
        if (hasHigherStick) {

            // 優先度の低い箸が空くまで待つ
            while(lowerStick.isUsed)
                await();

            lowerStick.isUsed = true;
            hasLowerStick = true;
            printAnEvent("pick up stick No." + lowerStick.rank);
        }
    }


    // 食事をするメソッド
    void eat() {
        if (hasLowerStick && hasHigherStick) {
            printAnEvent("***eating***");

            // ランダム時間だけ待機
            waitRandom();
        }
    }

    // 考え事
    void think() {
        printAnEvent("            ***thinking***");

        waitRandom();
    }

    // 優先度の高い箸を置く
    synchronized void putDownHigherStick() {
        // この条件は、単に（hasHigherStick）だけでもよい。
        if (hasLowerStick && hasHigherStick) {
            higherStick.isUsed = false;
            hasHigherStick = false;

            printAnEvent("put down stick No." + higherStick.rank);
        }
    }

    // 優先度の低い箸を置く
    synchronized void putDownLowerStick() {
        if (hasLowerStick) {
            lowerStick.isUsed = false;
            hasLowerStick = false;

            printAnEvent("put down stick No." + lowerStick.rank);
        }
    }

    // 表示用
    synchronized void printAnEvent(String str) {

        msg = "";

        for(int i = 0; i < 22 * number; i++) {
            msg += " ";
        }
        msg += str;
        System.out.println(msg);
    }

    // 適当な時間だけ待つ
    void waitRandom() {
        try {
            sleep((long)(Math.random() * WAITTIME));
        } catch (InterruptedException e) { }
    }

    // 一瞬だけ待つ（これ、別に waitRandom()メソッドでも代用可）
    synchronized void await() {
        try {
          sleep(1);
        } catch (InterruptedException e) { }
      }
    }
```

DinningPhilosophers.java の実行結果

```
[ryonosuke_araki@RyonosukenoMacBook-Air 18:46:25] $ java DiningPhilosophers
[ ~/OneDrive - The University of Tokyo/soubunkiso2 ]
Philosopher 0          Philosopher 1          Philosopher 2          Philosopher 3          Philosopher 4
--------------------    --------------------    --------------------    --------------------    --------------------
pick up stick No.1
                                                pick up stick No.3
                        pick up stick No.2
                              ***thinking***
                                                                        pick up stick No.4
      ***thinking***
                                                      ***thinking***
                                                                              ***thinking***
pick up stick No.0
***eating***
      ***thinking***
put down stick No.1
put down stick No.0
      ***thinking***
                        pick up stick No.1
                        ***eating***
                              ***thinking***
                        put down stick No.2
                        put down stick No.1
                              ***thinking***
pick up stick No.1
      ***thinking***
                                                pick up stick No.2
                                                ***eating***
pick up stick No.0
***eating***
      ***thinking***
                                                      ***thinking***
                                                put down stick No.3
                                                put down stick No.2
                                                      ***thinking***
                        pick up stick No.2
                                                                        pick up stick No.3
                              ***thinking***
                                                                        ***eating***
put down stick No.1
put down stick No.0
      ***thinking***
                                                                              ***thinking***
                        pick up stick No.1
                        ***eating***
                                                                        put down stick No.4
                                                                        put down stick No.3
                                                                              ***thinking***
```

```
                                        pick up stick No.3
                                                                                pick up stick No.4
                                             ***thinking***
                                                                                     ***thinking***
                         ***thinking***
                                                                                pick up stick No.0
                                                                                ***eating***
                    put down stick No.2
                    put down stick No.1
pick up stick No.1
                                        pick up stick No.2
     ***thinking***
                         ***thinking***
                                        ***eating***
                                                                                     ***thinking***
                                             ***thinking***
                                                                                put down stick No.4
                                                                                put down stick No.0
                                                                                     ***thinking***
pick up stick No.0
***eating***
                                                            pick up stick No.4
                                                                 ***thinking***
     ***thinking***
put down stick No.1
put down stick No.0
     ***thinking***
                                        put down stick No.3
                                        put down stick No.2
                                             ***thinking***
                    pick up stick No.2
                                                            pick up stick No.3
                         ***thinking***
                                                            ***eating***
                                                                 ***thinking***
pick up stick No.1
     ***thinking***
pick up stick No.0
***eating***
                                                            put down stick No.4
                                                            put down stick No.3
                                                                 ***thinking***
                                        pick up stick No.3
                                                                                pick up stick No.4
                                             ***thinking***
                                                                                     ***thinking***
     ***thinking***
put down stick No.1
put down stick No.0
     ***thinking***
                    pick up stick No.1
                    ***eating***
                         ***thinking***
                                                                                pick up stick No.0
                                                                                ***eating***
                    put down stick No.2
```

```
                        put down stick No.1
                              ***thinking***
pick up stick No.1
      ***thinking***
                                                pick up stick No.2
                                                ***eating***
                                                                                                      ***thinking***
                                                      ***thinking***
                                                                                                put down stick No.4
                                                                        pick up stick No.4
                                                                                                put down stick No.0
                                                                              ***thinking***
                                                                                                      ***thinking***
pick up stick No.0
***eating***
                                                put down stick No.3
                                                put down stick No.2
                                                      ***thinking***
                        pick up stick No.2
                              ***thinking***
                                                                        pick up stick No.3
                                                                        ***eating***
      ***thinking***
put down stick No.1
put down stick No.0
      ***thinking***
                                                                              ***thinking***
                        pick up stick No.1
                        ***eating***
                                                                        put down stick No.4
                                                                        put down stick No.3
                                                                              ***thinking***
                                                pick up stick No.3
                                                                                                pick up stick No.4
                                                      ***thinking***
                                                                                                      ***thinking***
                              ***thinking***
                                                                                                pick up stick No.0
                                                                                                ***eating***
                        put down stick No.2
                        put down stick No.1
                              ***thinking***
                                                pick up stick No.2
                                                ***eating***
                                                                                                      ***thinking***
                                                      ***thinking***
                                                put down stick No.3
                                                put down stick No.2
                                                      ***thinking***
                        pick up stick No.2
                              ***thinking***
                                                                                                put down stick No.4
                                                                                                put down stick No.0
                                                                                                      ***thinking***
                                                                        pick up stick No.4
                                                                              ***thinking***
                                                pick up stick No.3
                                                      ***thinking***
                        pick up stick No.1
                        ***eating***
                              ***thinking***
                        put down stick No.2
                        put down stick No.1
                              ***thinking***
                                                pick up stick No.2
                                                ***eating***
                                                      ***thinking***
                                                                        pick up stick No.3
                                                put down stick No.3
                                                                        ***eating***
                                                put down stick No.2
                                                      ***thinking***
                                                                              ***thinking***
                                                                        put down stick No.4
                                                                        put down stick No.3
                                                                              ***thinking***
                                                                                                pick up stick No.4
                                                                                                      ***thinking***
                                                                                                pick up stick No.0
                                                                                                ***eating***
                                                                                                      ***thinking***
                                                                                                put down stick No.4
                                                                                                put down stick No.0
                                                                                                      ***thinking***
                                                                        pick up stick No.4
                                                                              ***thinking***
                                                                        pick up stick No.3
                                                                        ***eating***
                                                                              ***thinking***
                                                                        put down stick No.4
                                                                        put down stick No.3
                                                                              ***thinking***
                                                                                                pick up stick No.4
                                                                                                      ***thinking***
                                                                                                pick up stick No.0
                                                                                                ***eating***
                                                                                                      ***thinking***
                                                                                                put down stick No.4
                                                                                                put down stick No.0
                                                                                                      ***thinking***
```