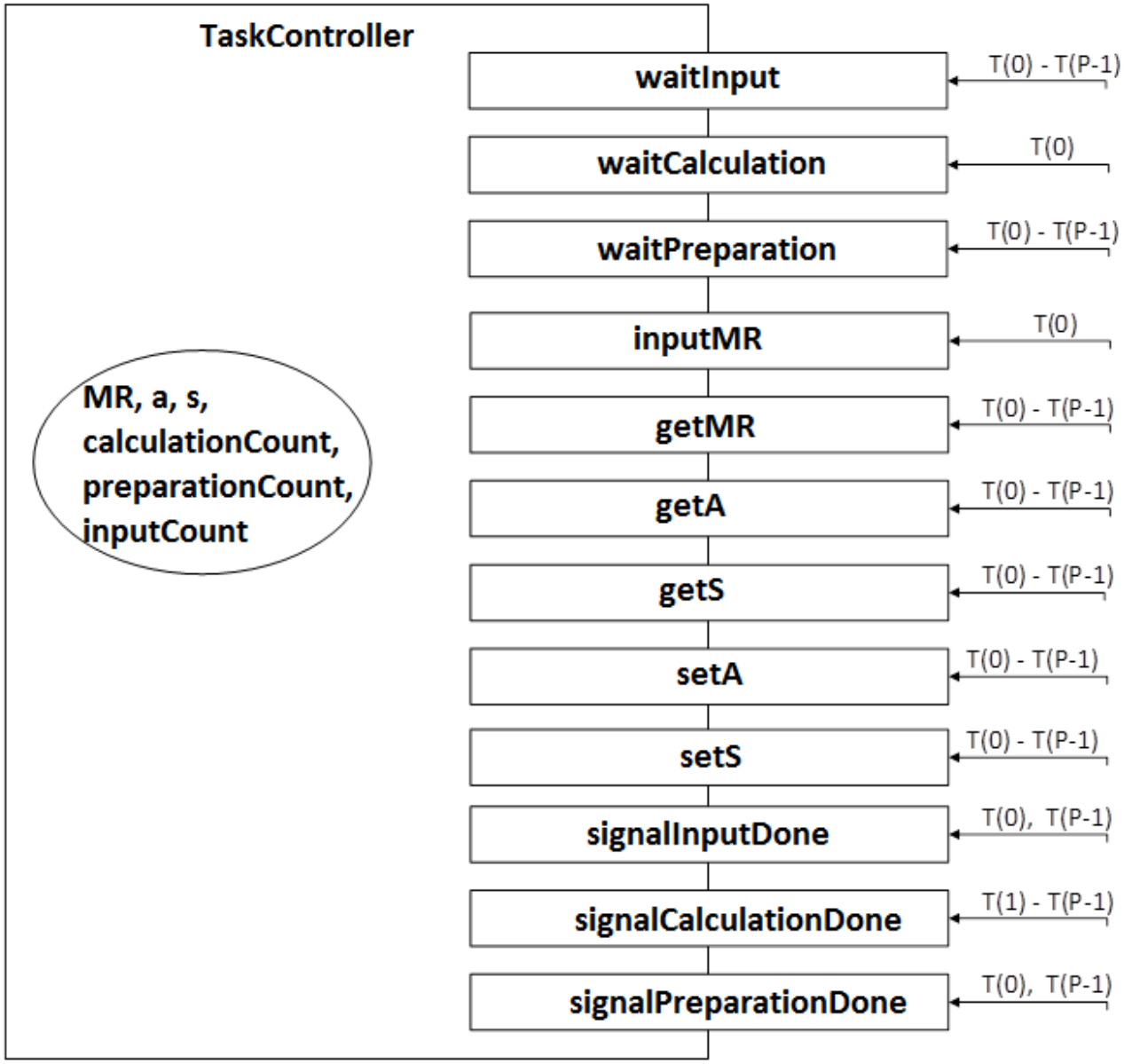
ДОДАТКИ

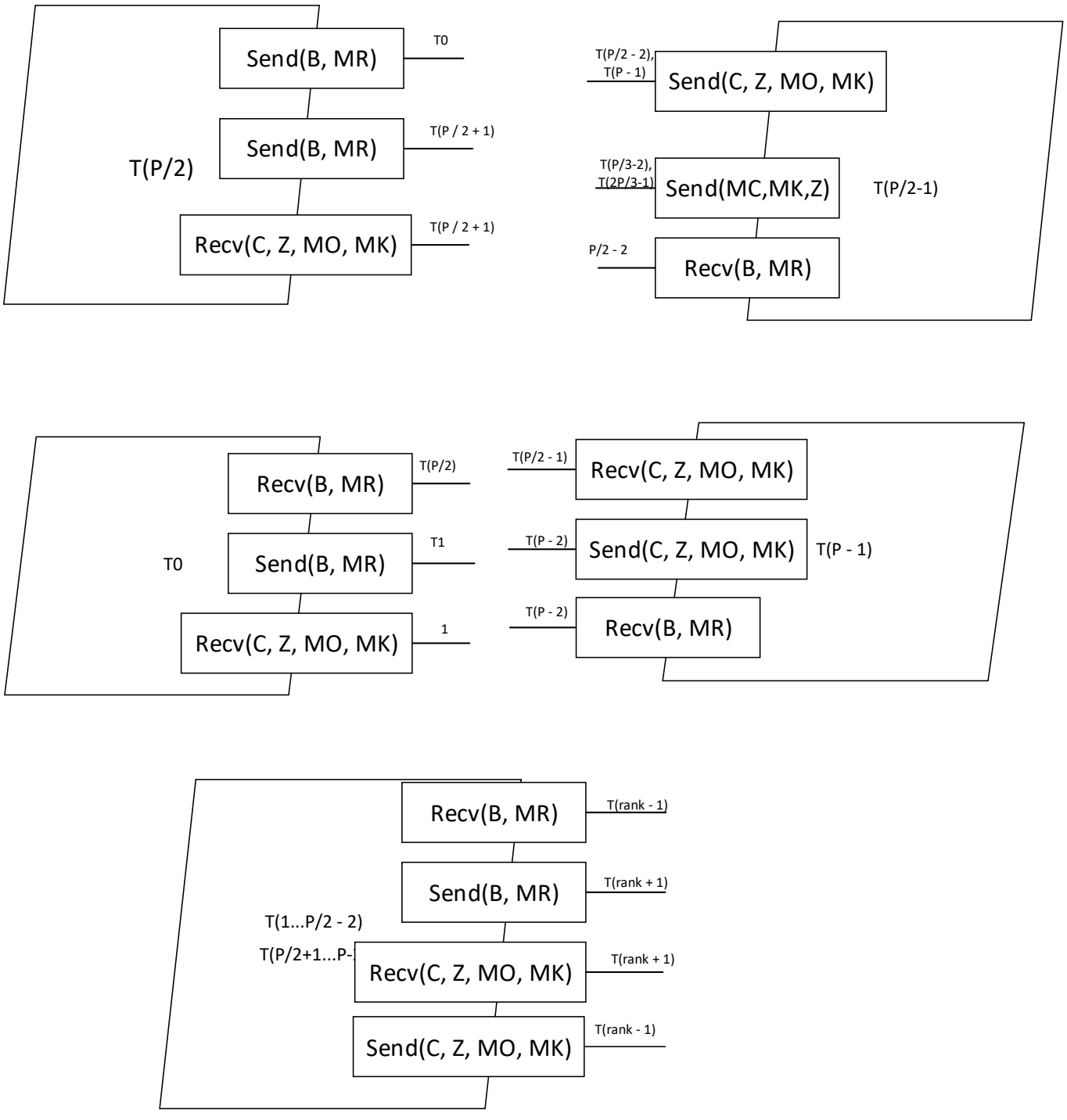
Додаток А

Структура класу TaskController ПРГ1



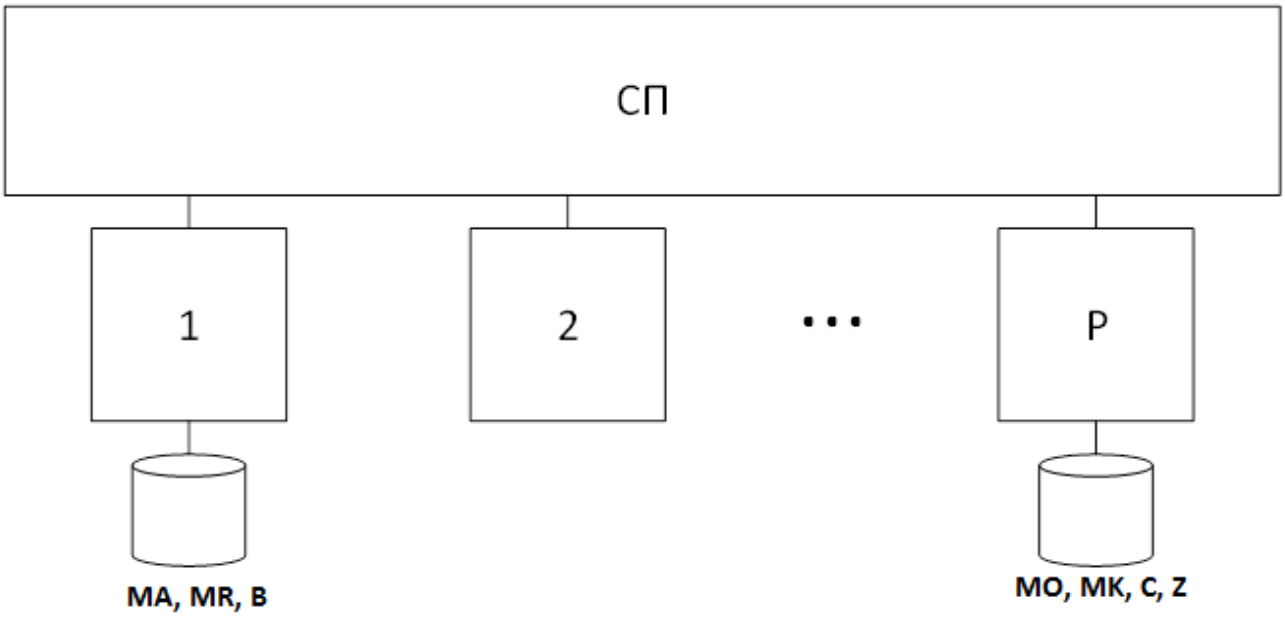
Додаток Б

Структурна схема взаємодії задач ПГР2



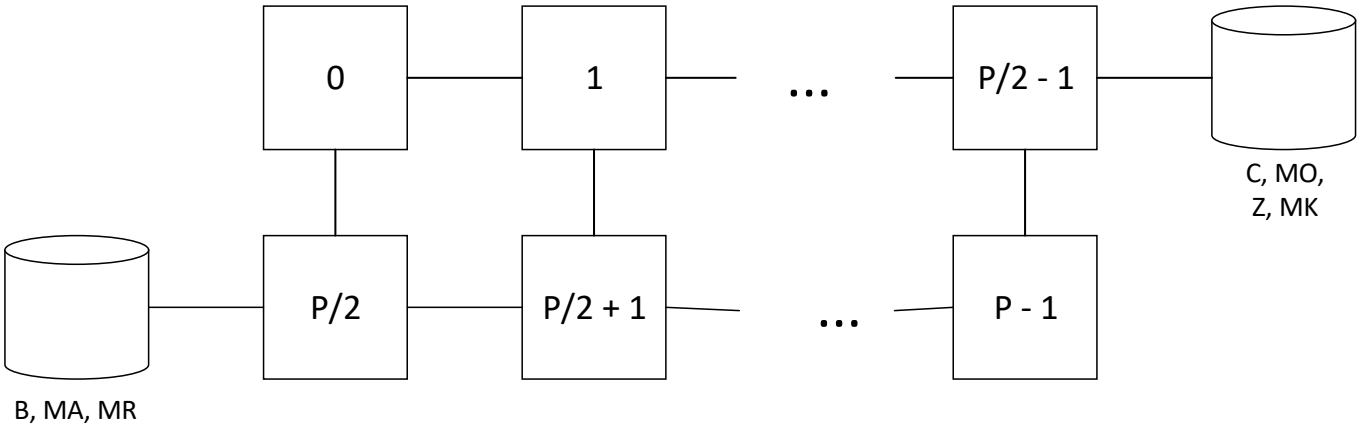
Додаток В

Структурна схема ПКС СП



Додаток Г

Структурна схема ПК ЛП



Додаток Д

Лістинг програми ПРГ1

Director.java

```
package com.vodotiiets.directors;

import com.vodotiiets.controllers.TaskController;
import com.vodotiiets.primitives.Matrix;
import com.vodotiiets.primitives.Vector;
import com.vodotiiets.workers.TaskWorker;

/**
 * Created by Denys Vodotiiets.
 */
public class Director {

    private static int N = 2500;
    private static int P = 1;
    private static int H = N / P;

    private static int maxValue = 5;
    private static long startTime;
    private static long endTime;

    private static Matrix MA = new Matrix(N);
    private static Matrix MO = new Matrix(N);
    private static Matrix MK = new Matrix(N);

    private static Vector B = new Vector(N);
    private static Vector C = new Vector(N);
    private static Vector Z = new Vector(N);

    public static void main(String[] args) {

        if(P > N) {
            P = N;
            H = 1;
        }

        Thread[] tasks = new Thread[P];
        TaskController monitor = new TaskController();

        for (int i = 0; i < P; i++) {
            tasks[i] = new Thread(new TaskWorker(i, monitor));
        }

        startTime = System.currentTimeMillis();
        for (int i = 0; i < P; i++) {
```

```
            tasks[i].start();
        }
    }

    public static int getN() {
        return N;
    }

    public static int getP() {
        return P;
    }

    public static int getH() {
        return H;
    }

    public static int getMaxValue() {
        return maxValue;
    }

    public static void setEndTime(long endTime) {
        Director.endTime = endTime;
    }

    public static long getTime() {
        return endTime - startTime;
    }

    public static Matrix getMA() {
        return MA;
    }

    public static Matrix getMO() {
        return MO;
    }

    public static Matrix getMK() {
        return MK;
    }

    public static Vector getB() {
        return B;
    }

    public static Vector getC() {
        return C;
    }

    public static Vector getZ() {
        return Z;
```

```
    }
}
```

TaskController.java

```
package com.vodotiiets.controllers;

import com.vodotiiets.directors.Director;
import com.vodotiiets.primitives.Matrix;

/**
 * Created by Denys Vodotiiets.
 */
public class TaskController {

    private int inputCount;
    private int preparationCount;
    private int calculationCount;

    private int a = Integer.MIN_VALUE;
    private int s;
    private Matrix MR = new Matrix(Director.getN());

    public synchronized void waitInput() {
        while (inputCount < 2) {
            try {
                wait();
            } catch (InterruptedException e) {
                System.out.println("Error has occurred in " + getClass().getSimpleName()
                        + "when running waitInput()!" + e.getMessage());
            }
        }
    }

    public synchronized void waitCalculation() {
        while (calculationCount < Director.getP() - 1) {
            try {
                wait();
            } catch (InterruptedException e) {
                System.out.println("Error has occurred in " + getClass().getSimpleName()
                        + "when running waitCalculation()!" + e.getMessage());
            }
        }
    }

    public synchronized void waitPreparation() {
        while (preparationCount < Director.getP()) {
            try {
                wait();
            } catch (InterruptedException e) {
```

```
            System.out.println("Error has occurred in " + getClass().getSimpleName()
                    + "when running waitPreparation()!" + e.getMessage());
        }
    }
}

public synchronized void inputMR() {
    MR.generate(Director.getMaxValue());
}

public synchronized void setA(int a) {
    if(a > this.a) {
        this.a = a;
    }
}

public synchronized void setS(int s) {
    this.s += s;
}

public synchronized Matrix getMR() {
    return new Matrix(MR);
}

public synchronized int getA() {
    return a;
}

public synchronized int getS() {
    return s;
}

public synchronized void signalInputDone() {
    inputCount++;
    if(inputCount == 2) {
        notifyAll();
    }
}

public synchronized void signalCalculationDone() {
    calculationCount++;
    if (calculationCount == Director.getP() - 1) {
        notifyAll();
    }
}

public synchronized void signalPreparationDone() {
    preparationCount++;
    if (preparationCount == Director.getP()) {
        notifyAll();
    }
}
```

}

TaskWorker.java

```
package com.vodotiiets.workers;

import com.vodotiiets.ParallelTasks.MaxTask;
import com.vodotiiets.ParallelTasks.VectorMultipleTask;
import com.vodotiiets.controllers.TaskController;
import com.vodotiiets.directors.Director;
import com.vodotiiets.primitives.Matrix;

import java.util.concurrent.ForkJoinPool;

/**
 * Created by Denys Vodotiiets.
 */
public class TaskWorker implements Runnable {
    private int tid;
    private TaskController monitor;

    private Matrix MRcopy;
    private int aCopy;
    private int sCopy;

    public TaskWorker(int tid, TaskController monitor) {
        this.monitor = monitor;
        this.tid = tid;
    }

    @Override
    public void run() {
        if (tid == 0) {
            monitor.inputMR();
            Director.getMA().generate(Director.getMaxValue());
            Director.getB().generate(Director.getMaxValue());

            monitor.signalInputDone();
        }

        if (tid == Director.getP() - 1) {
            Director.getC().generate(Director.getMaxValue());
            Director.getMO().generate(Director.getMaxValue());
            Director.getMK().generate(Director.getMaxValue());
            Director.getZ().generate(Director.getMaxValue());

            monitor.signalInputDone();
        }
```

```
        monitor.waitInput();

        int startIndex = tid * Director.getH();
        int endIndex = (tid != Director.getP() - 1) ? (tid + 1) * Director.getH() : Director.getN();

        MaxTask maxTask = new MaxTask(Director.getZ().getPart(startIndex, endIndex));
        int a = new ForkJoinPool().invoke(maxTask);
        monitor.setA(a);

        VectorMultipleTask vectorMultipleTask = new
    VectorMultipleTask(Director.getB().getPart(startIndex, endIndex),
                                                    Director.getC().getPart(startIndex, endIndex));
        int s = new ForkJoinPool(Director.getP()).invoke(vectorMultipleTask);

        monitor.setS(s);

        monitor.signalPreparationDone();
        monitor.waitPreparation();

        MRcopy = monitor.getMR();
        aCopy = monitor.getA();
        sCopy = monitor.getS();

        for (int i = 0; i < Director.getN(); i++) {
           for (int j = startIndex; j < endIndex; j++) {
              int sum = 0;
              for (int k = 0; k < Director.getN(); k++) {
                 sum += MRcopy.get(i, k) * Director.getMK().get(k, j);
              }

              int value = sCopy * Director.getMO().get(i, j) + aCopy * sum;
              Director.getMA().set(i, j, value);
           }
        }

        if (tid == 0) {
           monitor.waitCalculation();
        } else {
           monitor.signalCalculationDone();
        }

        if (tid == 0) {
           Director.setEndTime(System.currentTimeMillis());
           System.out.println("All threads ended calculations. Result time(ms): " + Director.getTime());

           if(Director.getMA().getDimension() < 10) {
              System.out.println("Result MA:\n" + Director.getMA());
           } else {
              System.out.println("Result was calculated. Matrix is too large");
           }
        }
```

```
    }
}
```

MaxTask.java

```
package com.vodotiiets.ParallelTasks;

import com.vodotiiets.directors.Director;
import com.vodotiiets.primitives.Vector;

import java.util.ArrayList;
import java.util.List;
import java.util.concurrent.RecursiveTask;

/**
 * Created by Denys Vodotiiets.
 */
public class MaxTask extends RecursiveTask<Integer> {
    private Vector vector;

    public MaxTask(Vector vector) {
        this.vector = vector;
    }

    @Override
    protected Integer compute() {
        if(vector.getDimension() > Director.getH() / Director.getP()) {
            List<MaxTask> subtasks = createSubtasks();

            for(MaxTask subtask : subtasks) {
                subtask.fork();
            }

            int result = Integer.MIN_VALUE;
            for(MaxTask subtask : subtasks) {
                int temp = subtask.join();
                if(temp > result) {
                    result = temp;
                }
            }

            return result;
        } else {
            return vector.getMaxElement(0, vector.getDimension());
        }
    }

    private List<MaxTask> createSubtasks() {
        List<MaxTask> subtasks = new ArrayList<>();
```

```
        MaxTask subtask1 = new MaxTask(this.vector.getPart(0, this.vector.getDimension()/2));
        MaxTask subtask2 = new MaxTask(this.vector.getPart(this.vector.getDimension()/2 + 1,
this.vector.getDimension()));

        subtasks.add(subtask1);
        subtasks.add(subtask2);

        return subtasks;
    }
}
```

VectorMultiple.java

```
package com.vodotiiets.ParallelTasks;

import com.vodotiiets.directors.Director;
import com.vodotiiets.primitives.Vector;

import java.util.ArrayList;
import java.util.List;
import java.util.concurrent.RecursiveTask;

/**
 * Created by Denys Vodotiiets.
 */
public class VectorMultipleTask extends RecursiveTask<Integer> {

    private Vector vector1;
    private Vector vector2;
    private int dimension;

    public VectorMultipleTask(Vector vector1, Vector vector2) {
        this.vector1 = vector1;
        this.vector2 = vector2;

        dimension = vector1.getDimension();
    }

    @Override
    protected Integer compute() {
        if(dimension > Director.getH() / Director.getP()) {
            List<VectorMultipleTask> subtasks = createSubtasks();

            for(VectorMultipleTask subtask : subtasks) {
                subtask.fork();
            }

            int result = 0;
            for(VectorMultipleTask subtask : subtasks) {
```

```
            result += subtask.join();
        }

        return result;
    } else {
        int result = 0;
        for (int i = 0; i < dimension; i++) {
            result += vector1.get(i) * vector2.get(i);
        }
        return result;
    }
}

private List<VectorMultipleTask> createSubtasks() {
    List<VectorMultipleTask> subtasks = new ArrayList<>();

    VectorMultipleTask subtask1 = new VectorMultipleTask(vector1.getPart(0, vector1.getDimension()
/ 2),
                                vector2.getPart(0, vector2.getDimension() / 2));
    VectorMultipleTask subtask2 = new VectorMultipleTask(vector1.getPart(vector1.getDimension() / 2
+ 1,
            vector1.getDimension()), vector2.getPart(vector2.getDimension() / 2 + 1,
vector2.getDimension()));

    subtasks.add(subtask1);
    subtasks.add(subtask2);

    return subtasks;
}
}
```

Vector.java

```
package com.vodotiiets.primitives;

import java.util.Random;

/**
 * Created by Denys Vodotiiets.
 */
public class Vector {
    private int dimension;
    private int[] array;

    public Vector(int dimension) {
        this.dimension = dimension;
        array = new int[dimension];
    }

    public Vector(int[] array) {
        this.array = array;
        this.dimension = array.length;
```

```
}

public void generate(int maxValue) {
   Random generator = new Random();

   for (int i = 0; i < dimension; i++) {
      array[i] = generator.nextInt(maxValue);
   }
}

public int getMaxElement(int startIndex, int endIndex) {
   if (startIndex < 0 || endIndex > dimension || startIndex >= endIndex)
      throw new IllegalStateException();

   int result = Integer.MIN_VALUE;
   for (int i = startIndex ; i < endIndex; i++) {
      if(array[i] > result) {
         result = array[i];
      }
   }
   return result;
}

public Vector getPart(int startIndex, int endIndex) {
   if(endIndex <= startIndex || endIndex > dimension || startIndex < 0)
      throw new IllegalStateException();

   int length = endIndex - startIndex;
   int[] resultArray = new int[length];
   System.arraycopy(this.array, startIndex, resultArray, 0, length);

   return new Vector(resultArray);
}

public int getDimension() {
   return dimension;
}

public int get(int i) {
   return array[i];
}

@Override
public String toString() {
   String result = "";

   for (int i = 0; i < dimension; i++) {
      result += array[i] + "\t";
   }

   return result;
```

```
    }
}
```

Matrix.java

```
package com.vodotiiets.primitives;

import java.util.Random;

/**
 * Created by Denys Vodotiiets.
 */
public class Matrix {
    private int dimension;
    private int[][] array;

    public Matrix(int dimension) {
        this.dimension = dimension;
        array = new int[dimension][dimension];
    }

    public Matrix(Matrix other) {
        this.dimension = other.dimension;
        array = new int [this.dimension][this.dimension];
        for (int i = 0; i < this.dimension; i++) {
            for(int j = 0; j < this.dimension; j++) {
                this.array[i][j] = other.array[i][j];
            }
        }
    }

    public void generate(int maxValue) {
        Random generator = new Random();
        for (int i = 0; i < dimension; i++){
            for (int j = 0; j < dimension; j++){
                array[i][j] = generator.nextInt(maxValue);
            }
        }
    }

    public int get(int i, int j) {
        return array[i][j];
    }

    public void set(int i, int j, int value) {
        array[i][j] = value;
    }

    public int getDimension() {
        return dimension;
```

```
    }

    @Override
    public String toString() {
        String result = "";
        for (int i = 0; i < dimension; i++){
            for (int j = 0; j < dimension; j++){
                result += array[i][j] +"\t";
            }
            result += "\n";
        }
        return result;
    }
}
```

Додаток Є

Лістинг програми ПРГ2

```
#include <iostream>
#include <limits.h>
#include <time.h>
#include "mpi.h"

using namespace std;

const int N = 100;

void inputMatrix(int matrix[N][N]);
void outputMatrix(int matrix[N][N]);
void inputVector(int vector[N]);
void outputVector(int vector[N]);

void ckeckSize(int r, int s);

int maxNumber(int vector[N], int start, int end);

void sendMatrixPart(int matrix[N][N], int start, int end, int dest, int tag);
void recvMatrixPart(int matrix[N][N], int start, int end, int source, int tag, MPI_Status
status);

int main(int argc, char* argv[])
{
	long start = clock();
	MPI_Init(&argc, &argv);

	int rank, size;
	int Z[N], B[N], C[N];
	int MA[N][N], MO[N][N], MR[N][N], MK[N][N];
	int a, s;

	MPI_Status status;
	int msgTag = 0;

	MPI_Comm_size(MPI_COMM_WORLD, &size);
	MPI_Comm_rank(MPI_COMM_WORLD, &rank);


	ckeckSize(rank, size);

	int P = size;
	int H = N / P;

	//input P/2 + 1
	if (rank == P / 2)
	{
		inputVector(B);
		inputMatrix(MR);

		//send to 1
		MPI_Send(B, N, MPI_INT, 0, msgTag, MPI_COMM_WORLD);
		MPI_Send(MR, N * N, MPI_INT, 0, msgTag, MPI_COMM_WORLD);

		//send to P/2 + 2
		MPI_Send(B, N, MPI_INT, P / 2 + 1, msgTag, MPI_COMM_WORLD);
```

```
        MPI_Send(MR, N * N, MPI_INT, P / 2 + 1, msgTag, MPI_COMM_WORLD);

        //receive from P/2 + 2
        MPI_Recv(C, N, MPI_INT, P / 2 + 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(Z, N, MPI_INT, P / 2 + 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MO, N * N, MPI_INT, P / 2 + 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MK, N * N, MPI_INT, P / 2 + 1, msgTag, MPI_COMM_WORLD, &status);
}
//input P/2
else if (rank == P / 2 - 1)
{
        inputVector(C);
        inputVector(Z);
        inputMatrix(MO);
        inputMatrix(MK);

        //send to P/2 - 1
        MPI_Send(C, N, MPI_INT, P / 2 - 2, msgTag, MPI_COMM_WORLD);
        MPI_Send(Z, N, MPI_INT, P / 2 - 2, msgTag, MPI_COMM_WORLD);
        MPI_Send(MO, N * N, MPI_INT, P / 2 - 2, msgTag, MPI_COMM_WORLD);
        MPI_Send(MK, N * N, MPI_INT, P / 2 - 2, msgTag, MPI_COMM_WORLD);

        //send to P
        MPI_Send(C, N, MPI_INT, P - 1, msgTag, MPI_COMM_WORLD);
        MPI_Send(Z, N, MPI_INT, P - 1, msgTag, MPI_COMM_WORLD);
        MPI_Send(MO, N * N, MPI_INT, P - 1, msgTag, MPI_COMM_WORLD);
        MPI_Send(MK, N * N, MPI_INT, P - 1, msgTag, MPI_COMM_WORLD);

        //receive from P/2 - 1
        MPI_Recv(B, N, MPI_INT, P / 2 - 2, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MR, N * N, MPI_INT, P / 2 - 2, msgTag, MPI_COMM_WORLD, &status);
}
//input 1
else if (rank == 0)
{
        //receive from P/2 + 1
        MPI_Recv(B, N, MPI_INT, P / 2, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MR, N * N, MPI_INT, P / 2, msgTag, MPI_COMM_WORLD, &status);

        //send to 2
        MPI_Send(B, N, MPI_INT, 1, msgTag, MPI_COMM_WORLD);
        MPI_Send(MR, N * N, MPI_INT, 1, msgTag, MPI_COMM_WORLD);

        //receive from 2
        MPI_Recv(C, N, MPI_INT, 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(Z, N, MPI_INT, 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MO, N * N, MPI_INT, 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MK, N * N, MPI_INT, 1, msgTag, MPI_COMM_WORLD, &status);
}
//input P
else if (rank == P - 1)
{
        //receive from P/2
        MPI_Recv(C, N, MPI_INT, P / 2 - 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(Z, N, MPI_INT, P / 2 - 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MO, N * N, MPI_INT, P / 2 - 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MK, N * N, MPI_INT, P / 2 - 1, msgTag, MPI_COMM_WORLD, &status);

        //send to P - 1
        MPI_Send(C, N, MPI_INT, P - 2, msgTag, MPI_COMM_WORLD);
        MPI_Send(Z, N, MPI_INT, P - 2, msgTag, MPI_COMM_WORLD);
        MPI_Send(MO, N * N, MPI_INT, P - 2, msgTag, MPI_COMM_WORLD);
        MPI_Send(MK, N * N, MPI_INT, P - 2, msgTag, MPI_COMM_WORLD);
```

```
        //receive from P - 1
        MPI_Recv(B, N, MPI_INT, P - 2, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MR, N * N, MPI_INT, P - 2, msgTag, MPI_COMM_WORLD, &status);
}
else
{
        //receive from rank - 1
        MPI_Recv(B, N, MPI_INT, rank - 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MR, N * N, MPI_INT, rank - 1, msgTag, MPI_COMM_WORLD, &status);

        //send to rank + 1
        MPI_Send(B, N, MPI_INT, rank + 1, msgTag, MPI_COMM_WORLD);
        MPI_Send(MR, N * N, MPI_INT, rank + 1, msgTag, MPI_COMM_WORLD);

        //receive from rank + 1
        MPI_Recv(C, N, MPI_INT, rank + 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(Z, N, MPI_INT, rank + 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MO, N * N, MPI_INT, rank + 1, msgTag, MPI_COMM_WORLD, &status);
        MPI_Recv(MK, N * N, MPI_INT, rank + 1, msgTag, MPI_COMM_WORLD, &status);

        //send to rank - 1
        MPI_Send(C, N, MPI_INT, rank - 1, msgTag, MPI_COMM_WORLD);
        MPI_Send(Z, N, MPI_INT, rank - 1, msgTag, MPI_COMM_WORLD);
        MPI_Send(MO, N * N, MPI_INT, rank - 1, msgTag, MPI_COMM_WORLD);
        MPI_Send(MK, N * N, MPI_INT, rank - 1, msgTag, MPI_COMM_WORLD);
}

int startIndex = rank * H;
int endIndex = (rank + 1) * H;
if (rank == P - 1) {
        endIndex = N;
}

//Find max element
int a_i = maxNumber(Z, startIndex, endIndex);

MPI_Allreduce(&a_i, &a, 1, MPI_INT, MPI_MAX, MPI_COMM_WORLD);

//calc B * C

int s_i = 0;

for (int i = startIndex; i < endIndex; i++)
{
        s_i += B[i] * C[i];
}

MPI_Allreduce(&s_i, &s, 1, MPI_INT, MPI_SUM, MPI_COMM_WORLD);

//Calc MA_H
for (int i = startIndex; i < endIndex; i++)
{
        for (int j = 0; j < N; j++)
        {
                int sum = 0;

                for (int k = 0; k < N; k++)
                {
                        sum += MR[i][k] * MK[k][j];
                }

                int resultValue = MO[i][j] * s + a * sum;
                MA[i][j] = resultValue;
        }
```

```
	}

	if (rank == P / 2)
	{
		recvMatrixPart(MA, 0, rank * H, 0, msgTag, status);

		int previousStart = (P / 2 + 2) * H;

		recvMatrixPart(MA, (rank + 1) * H, N, P / 2 + 1, msgTag, status);

		long end = clock();
		cout << "Calculation ended. Time: " << end - start << endl;

		cout << "Result MA:" << endl;
		outputMatrix(MA);
	}
	else
	{

		if (rank == P - 1 || rank == P / 2 - 1)
		{
			sendMatrixPart(MA, startIndex, endIndex, rank - 1, msgTag);
		}
		else if (rank > P / 2 && rank < P - 1)
		{
			int previousStart = (rank + 1) * H;
			recvMatrixPart(MA, previousStart, N, rank + 1, msgTag, status);
			sendMatrixPart(MA, startIndex, N, rank - 1, msgTag);
		}
		else if (rank > 0 && rank < P / 2 - 1)
		{
			int previousStart = (rank + 1) * H;
			int previousEnd = (P / 2) * H;
			recvMatrixPart(MA, previousStart, previousEnd, rank + 1, msgTag, status);
			sendMatrixPart(MA, startIndex, previousEnd, rank - 1, msgTag);
		}
		else if (rank == 0)
		{
			recvMatrixPart(MA, endIndex, (P / 2) * H, rank + 1, msgTag, status);
			sendMatrixPart(MA, startIndex, (P / 2) * H, P / 2, msgTag);
		}
	}



	MPI_Finalize();
	return 0;
}

void inputMatrix(int matrix[N][N])
{
	for (int i = 0; i < N; i++)
	{
		for (int j = 0; j < N; j++)
		{
			matrix[i][j] = 1;
		}
	}
}
void outputMatrix(int matrix[N][N])
{
	for (int i = 0; i < N; i++)
	{
		for (int j = 0; j < N; j++)
```

```
			{
				printf("%10d ", matrix[i][j]);
				//cout << matrix[i][j] << " ";
			}
			cout << endl;
		}
		cout << endl;
}

void outputVector(int vector[N])
{
		for (int i = 0; i < N; i++)
		{
			printf("%10d ", vector[i]);
			//cout << vector[i] << " ";
		}
		cout << endl;
}

void inputVector(int vector[N])
{
		for (int i = 0; i < N; i++)
		{
			vector[i] = 1;
		}
}

void ckeckSize(int rank, int size)
{
		if (size < 4 )
		{
			if (rank == 0)
			{
				cout << "For correct program work the count of threads must be more than 3."
<<
					"Please make sure that you input correct data!" << endl <<
					"Your threads' size is " << size << endl;
			}
			MPI_Finalize();
			exit(-1);
		}

		if (N % 4 != 0)
		{
			if (rank == 0)
			{
				cout << "The dimension of the arrays must be a multiple of four." <<
					"Please make sure that you input correct data!" << endl <<
					"Current dimension is " << N << endl;
			}

			MPI_Finalize();
			exit(-1);
		}
}

int maxNumber(int vector[N], int start, int end)
{
		int result = INT_MIN;
		for (int i = start; i < end; i++)
		{
			if (vector[i] > result)
			{
				result = vector[i];
```

```
                }
        }

        return result;
}

void sendMatrixPart(int matrix[N][N], int start, int end, int dest, int tag)
{
        for (int i = start; i < end; i++)
        {
                MPI_Send(matrix[i], N, MPI_INT, dest, tag, MPI_COMM_WORLD);
        }
}

void recvMatrixPart(int matrix[N][N], int start, int end, int source, int tag, MPI_Status status)
{
        for (int i = start; i < end; i++)
        {
                MPI_Recv(matrix[i], N, MPI_INT, source, tag, MPI_COMM_WORLD, &status);
        }
}
```