МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ РОССИЙСКОЙ ФЕДЕРАЦИИ МОСКОВСКИЙ АВИАЦИОННЫЙ ИНСТИТУТ
(НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ)

ЛАБОРАТОРНАЯ РАБОТА №8 по курсу

объектно-ориентированное программирование I семестр, 2021/22 уч. год

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Цель работы

Целью лабораторной работы является:

- Создание сложных динамических структур данных;
- Закрепление принципа OCP.

Задание

Необходимо реализовать динамическую структуру данных – «Хранилище объектов» и алгоритм работы с ней. «Хранилище объектов» представляет собой контейнер, одного из следующих видов (Контейнер 1-го уровня):

1. Очередь
2. Динамический массив
3. Связный список
4. Бинарное дерево
5. N-Дерево (с ограничением не больше 4 элементов на одном уровне).

Каждым элемент контейнера, в свою очередь, является динамической структурой данных одного из следующих видов (Контейнер 2-го уровня):

1. Очередь
2. Динамический массив
3. Связный список
4. Бинарное дерево
5. N-Дерево (с ограничением не больше 4 элементов на одном уровне).

Таким образом у нас получается контейнер в контейнере. Т.е. для варианта (2,3) это будет массив, каждый из элементов которого – связанный список. А для варианта (1,4) – это очередь из бинарных деревьев. Элементом второго контейнера является объект-фигура, определенная вариантом задания.

При этом должно выполняться правило, что количество объектов в контейнере второго уровня не больше **5**. Если нужно хранить больше 5 объектов, то создается еще один контейнер второго уровня.
Объекты в контейнерах второго уровня должны быть отсортированы по возрастанию **площади** объекта (в том числе и для деревьев). При удалении объектов должно выполняться правило, что контейнер второго уровня не должен быть пустым. Т.е. если контейнер становится пустым, то он должен удалится.

Нельзя использовать:

- Стандартные контейнеры std.

Программа должна позволять:

- Вводить произвольное количество фигур и добавлять их в контейнер.
- Распечатывать содержимое контейнера (1-го и 2-го уровня).
- Удалять фигуры из контейнера по критериям:
  - По типу (например, все квадраты).
  - По площади (например, все объекты с площадью меньше чем заданная).

Вариант 21:

А) Контейнер 1 уровня – N-арное дерево.

Б) Контейнер 2 уровня – Вектор.

В) Фигуры – Прямоугольник, Ромб и Трапеция.

Дневник отладки

Так как работа сложная, то делалась она долго. Возникал много помарок, теперь всё вроде работает корректно.

Недочёты

Недочётов вроде нет.

Выводы

Лабораторная работа №8 – ООП внутри ООП. Элементами контейнера первого уровня являются контейнеры 2 уровня, элементами которого уже являются фигуры 3 типов. Но одна структура данных может содержать только фигуру одного типа. Эта была очень сложная работа, на которую было потрачено много времени.

Исходный код

figure.h

```
#ifndef FIGURE_H
#define FIGURE_H
#include "point.h"

class Figure
{
public:
    //virtual void Print(std::ostream& os) = 0;
    virtual double Square() = 0;
    virtual ~Figure() {};
    virtual size_t VertexesNumber() = 0;
```

```
};

#endif
```

main.cpp

```
#include <iostream>
#include "tnarytree.h"
int main()
{

    TNaryTree<Rectangle> t1(4);
    std::cout << t1 << "\n";
    t1.Update(Rectangle(std::cin), 0, "");
    t1.Update(Rectangle(std::cin), 0);
    std::cout << t1 << "\n";
    t1.Update(Rectangle(std::cin), 2, "c");
    t1.Update(Rectangle(std::cin), 0, "c");
    t1.Update(Rectangle(std::cin), 1, "c");
    t1.Update(Rectangle(std::cin), 2, "c");
    std::cout << t1 << "\n";
    t1.Update(Rectangle(std::cin), 4, "c");
    t1.Update(Rectangle(std::cin), 3, "c");
    std::cout << t1.getItem("c");
    std::cout << t1 << "\n";
    t1.Update(Rectangle(std::cin), 0, "cb");
    t1.Update(Rectangle(std::cin), 1, "cb");
    t1.Update(Rectangle(std::cin), 2, "cb");
    t1.Update(Rectangle(std::cin), 3, "cb");
    std::cout << t1 << "\n";
    t1.Update(Rectangle(std::cin), 0, "cbc");
    t1.Update(Rectangle(std::cin), 1, "cbc");
    t1.Update(Rectangle(std::cin), 2, "cbc");
    t1.Update(Rectangle(std::cin), 2, "cbc");
    t1.Update(Rectangle(std::cin), 3, "cbc");
    std::cout << t1 << "\n";
    t1.Update(Rectangle(std::cin), 0, "cbb");
    t1.Update(Rectangle(std::cin), 1, "cbb");
    t1.Update(Rectangle(std::cin), 2, "cbb");
    t1.Update(Rectangle(std::cin), 3, "cbb");
    std::cout << t1 << "\n";
    t1.Update(Rectangle(std::cin), 4, "cbb");
    t1.Update(Rectangle(std::cin), 5, "cbb");
    t1.Update(Rectangle(std::cin), 7, "cbb");
    t1.Update(Rectangle(std::cin), 6, "cbb");
    std::cout << t1 << "\n";
    t1.Update(Rectangle(std::cin), 0, "cbbb");

    t1.Remove(false, "cbb", 6);
    t1.Remove(false, "cb", 2);
    std::cout << t1 << "\n";

    t1.Remove(false, "c", 2);
    t1.Remove(false, "cbb", 3);
    t1.Remove(false, "cb", 0);
    std::cout << t1 << "\n";
```

```
    t1.Remove(true, "cb");
    std::cout << t1 << "\n";
    t1.Remove(true);
    std::cout << t1 << "\n";
    system("pause");
    return 0;
}
```

rectangle.cpp

```
#include "rectangle.h"

Rectangle::Rectangle() : a(0.0, 0.0), b(0.0, 0.0), c(0.0, 0.0), d(0.0, 0.0), len1(0),
len2(0), square(0.0)
{
};

Rectangle::Rectangle(std::istream& is)
{
	is >> a >> b >> c >> d;
	len1 = dist(a, b);
	len2 = dist(b, c);
	square = len1 * len2;
}

Rectangle& Rectangle::operator= (Rectangle rectangle)
{
	a = rectangle.a;
	b = rectangle.b;
	c = rectangle.c;
	d = rectangle.d;
	len1 = rectangle.len1;
	len2 = rectangle.len2;
	square = rectangle.square;
	return rectangle;
};

bool Rectangle::operator< (Rectangle rectangle)
{
	if (square != rectangle.Square())
	{
		return square < rectangle.Square();
	}
	if (a != rectangle.a)
	{
		return a < rectangle.a;
	}
	if (b != rectangle.b)
	{
		return b < rectangle.b;
	}
	if (c != rectangle.c)
	{
		return c < rectangle.c;
	}
```

```
	return d < rectangle.d;
};


bool Rectangle::operator== (Rectangle rectangle)
{
	if ((a == rectangle.a) && (b == rectangle.b) && (c == rectangle.c) && (d == rectangle.d))
	{
		return true;
	}
	return false;
};

void Rectangle::Print(std::ostream& os)
{
	os << "Rectangle: " << a << " " << b << " " << c << " " << d << std::endl;
}

std::istream& operator >>(std::istream& is, Rectangle& rectangle)
{
	is >> rectangle.a >> rectangle.b >> rectangle.c >> rectangle.d;
	return is;
};

std::ostream& operator <<(std::ostream& os, const Rectangle& rectangle)
{
	os << rectangle.a << " " << rectangle.b << " " << rectangle.c << " " << rectangle.d;
	return os;
};

size_t Rectangle::VertexesNumber()
{
	return 4;
}

double Rectangle::Square()
{
	return square;
}

Rectangle::~Rectangle()
{

}
```

rectangle.h

```
#ifndef RECTANGLE_H
#define RECTANGLE_H
#include "figure.h"

class Rectangle : public Figure
{
public:
	Rectangle();
	Rectangle(std::istream& is);
```

```
        void Print(std::ostream& os);
        double Square();
        friend std::istream& operator >>(std::istream& is, Rectangle& rectangle);
        friend std::ostream& operator <<(std::ostream& os, const Rectangle& rectangle);
        Rectangle& operator= (Rectangle rectangle);
        bool operator== (Rectangle rectangle);
        bool operator< (Rectangle rectangle);
        size_t VertexesNumber();
        virtual ~Rectangle();

private:
        Point a, b, c, d;
        double len1, len2;
        double square;
};

#endif
```

rhombus.cpp

```
#include "rhombus.h"

Rhombus::Rhombus() : a(0.0, 0.0), b(0.0, 0.0), c(0.0, 0.0), d(0.0, 0.0), square(0.0),
diag1(0.0), diag2(0.0)
{

};

Rhombus::Rhombus(std::istream& is)
{
        is >> a >> b >> c >> d;
        diag1 = dist(a, c);
        diag2 = dist(b, d);
        square = (diag1 * diag2) / 2.;
}

Rhombus& Rhombus::operator= (Rhombus rhombus)
{
        a = rhombus.a;
        b = rhombus.b;
        c = rhombus.c;
        d = rhombus.d;
        diag1 = rhombus.diag1;
        diag2 = rhombus.diag2;
        square = rhombus.square;
        return rhombus;
};

bool Rhombus::operator< (Rhombus rhombus)
{
        if (square != rhombus.Square())
        {
                return square < rhombus.Square();
        }
        if (a != rhombus.a)
        {
```

```
		return a < rhombus.a;
	}
	if (b != rhombus.b)
	{
		return b < rhombus.b;
	}
	if (c != rhombus.c)
	{
		return c < rhombus.c;
	}
	return d < rhombus.d;
}


bool Rhombus::operator== (Rhombus rhombus)
{
	if ((a == rhombus.a) && (b == rhombus.b) && (c == rhombus.c) && (d == rhombus.d))
	{
		return true;
	}
	return false;
};

void Rhombus::Print(std::ostream& os)
{
	os << "Rhombus: " << a << " " << b << " " << c << " " << d << std::endl;
}

std::istream& operator >>(std::istream& is, Rhombus& rhombus)
{
	is >> rhombus.a >> rhombus.b >> rhombus.c >> rhombus.d;
	return is;
};

std::ostream& operator <<(std::ostream& os, const Rhombus& rhombus)
{
	os << rhombus.a << " " << rhombus.b << " " << rhombus.c << " " << rhombus.d;
	return os;
};

size_t Rhombus::VertexesNumber()
{
	return 4;
}

double Rhombus::Square()
{
	return square;
}

Rhombus::~Rhombus()
{

}
```

rhombus.h

```
#ifndef RHOMBUS_H
#define RHOMBUS_H
#include "figure.h"

class Rhombus : public Figure
{
public:
	Rhombus();
	Rhombus(std::istream& is);
	void Print(std::ostream& os);
	double Square();
	friend std::istream& operator >>(std::istream& is, Rhombus& rhombus);
	friend std::ostream& operator <<(std::ostream& os, const Rhombus& rhombus);
	Rhombus& operator= (Rhombus rhombus);
	bool operator== (Rhombus rhombus);
	bool operator< (Rhombus rhombus);
	size_t VertexesNumber();
	virtual ~Rhombus();


private:
	Point a, b, c, d;
	double diag1, diag2;
	double square;
};

#endif
```

trapezoid.cpp

```
#include "trapezoid.h"

Trapezoid::Trapezoid() : a(0.0, 0.0), b(0.0, 0.0), c(0.0, 0.0), d(0.0, 0.0), square(0.0),
lena(0.0), lenb(0.0), lenc(0.0), lend(0.0)
{

};

Trapezoid::Trapezoid(std::istream& is)
{
	is >> a >> b >> c >> d;
	lena = dist(b, c);
	lenb = dist(a, d);
	lenc = dist(c, d);
	lend = dist(a, b);
	/*if (lena > lenb)
	{
		std::swap(lena, lenb);
		std::swap(lenc, lend);
	}*/
	square = ((lena + lenb) / 2.) * sqrt(pow(lenc, 2) - pow(((pow(lenb - lena, 2) +
pow(lenc, 2) - pow(lend, 2)) / (2. * (lenb - lena))), 2));
}
```

```
Trapezoid& Trapezoid::operator= (Trapezoid trapezoid)
{
	a = trapezoid.a;
	b = trapezoid.b;
	c = trapezoid.c;
	d = trapezoid.d;
	lena = trapezoid.lena;
	lenb = trapezoid.lenb;
	lenc = trapezoid.lenc;
	lend = trapezoid.lend;
	square = trapezoid.square;
	return trapezoid;
};

bool Trapezoid::operator< (Trapezoid trapezoid)
{
	if (square != trapezoid.Square())
	{
		return square < trapezoid.Square();
	}
	if (a != trapezoid.a)
	{
		return a < trapezoid.a;
	}
	if (b != trapezoid.b)
	{
		return b < trapezoid.b;
	}
	if (c != trapezoid.c)
	{
		return c < trapezoid.c;
	}
	return d < trapezoid.d;
};

bool Trapezoid::operator== (Trapezoid trapezoid)
{
	if ((a == trapezoid.a) && (b == trapezoid.b) && (c == trapezoid.c) && (d ==
trapezoid.d))
	{
		return true;
	}
	return false;
};

void Trapezoid::Print(std::ostream& os)
{
	os << "Trapezoid: " << a << " " << b << " " << c << " " << d << std::endl;
}

std::istream& operator >>(std::istream& is, Trapezoid& trapezoid)
{
	is >> trapezoid.a >> trapezoid.b >> trapezoid.c >> trapezoid.d;
	return is;
};

std::ostream& operator <<(std::ostream& os, const Trapezoid& trapezoid)
{
	os << trapezoid.a << " " << trapezoid.b << " " << trapezoid.c << " " << trapezoid.d;
```

```
	return os;
};

size_t Trapezoid::VertexesNumber()
{
	return 4;
}

double Trapezoid::Square()
{
	return square;
}

Trapezoid::~Trapezoid()
{

}
```

trapezoid.h

```
#ifndef TRAPEZOID_H
#define TRAPEZOID_H
#include "figure.h"
#include <algorithm>
class Trapezoid : public Figure
{
public:
	Trapezoid();
	Trapezoid(std::istream& is);
	void Print(std::ostream& os);
	double Square();
	friend std::istream& operator >>(std::istream& is, Trapezoid& trapezoid);
	friend std::ostream& operator <<(std::ostream& os, const Trapezoid& trapezoid);
	Trapezoid& operator= (Trapezoid trapezoid);
	bool operator== (Trapezoid trapezoid);
	bool operator< (Trapezoid trapezoid);
	size_t VertexesNumber();
	virtual ~Trapezoid();

private:
	Point a, b, c, d;
	double lena, lenb, lenc, lend;
	double square;
};

#endif
```

point.cpp

```
#include "point.h"

Point::Point() : x_(0.0), y_(0.0) {}

Point::Point(double x, double y) : x_(x), y_(y) {}
```

```
Point::Point(std::istream& is)
{
	is >> x_ >> y_;
}

double dist(Point& p1, Point& p2)
{
	double dx = (p1.x_ - p2.x_);
	double dy = (p1.y_ - p2.y_);
	return std::sqrt(dx * dx + dy * dy);
}

std::istream& operator >> (std::istream& is, Point& p)
{
	is >> p.x_ >> p.y_;
	return is;
}

std::ostream& operator << (std::ostream& os, const Point& p)
{
	os << "(" << p.x_ << ", " << p.y_ << ")";
	return os;
}

bool Point::operator == (Point point)
{
	return (x_ == point.x_) && (y_ == point.y_);
}

bool Point::operator!= (Point point)
{
	return (x_ != point.x_) || (y_ != point.y_);
}

bool Point::operator< (Point point)
{
	if (x_ != point.x_)
	{
		return x_ < point.x_;
	}
	return y_ < point.y_;
}

Point::~Point()
{

}
```

point.h

```
#ifndef POINT_H
#define POINT_H

#include <iostream>
```

```
class Point {
public:
  Point();
  Point(std::istream &is);
  Point(double x, double y);
  friend bool operator == (Point& p1, Point& p2);
  friend class Pentagon;
  double X();
  double Y();
  friend std::istream& operator>>(std::istream& is, Point& p);
  friend std::ostream& operator<<(std::ostream& os, Point& p);

private:
  double x;
  double y;
};

#endif
```

point.cpp

```
#include "point.h"

Point::Point() : x_(0.0), y_(0.0) {}

Point::Point(double x, double y) : x_(x), y_(y) {}

Point::Point(std::istream& is)
{
	is >> x_ >> y_;
}

double dist(Point& p1, Point& p2)
{
	double dx = (p1.x_ - p2.x_);
	double dy = (p1.y_ - p2.y_);
	return std::sqrt(dx * dx + dy * dy);
}

std::istream& operator >> (std::istream& is, Point& p)
{
	is >> p.x_ >> p.y_;
	return is;
}

std::ostream& operator << (std::ostream& os, const Point& p)
{
	os << "(" << p.x_ << ", " << p.y_ << ")";
	return os;
}
```

```
bool Point::operator == (Point point)
{
	return (x_ == point.x_) && (y_ == point.y_);
}

bool Point::operator!= (Point point)
{
	return (x_ != point.x_) || (y_ != point.y_);
}

bool Point::operator< (Point point)
{
	if (x_ != point.x_)
	{
		return x_ < point.x_;
	}
	return y_ < point.y_;
}

Point::~Point()
{

}
```

tnarytree.cpp

```
#include "tnarytree.h"

template TNaryTree<Rectangle>;
template TNaryTree<Rhombus>;
template TNaryTree<Trapezoid>;

template <class T> TNaryTree<T>::TNaryTree()
{
	this->N = 2;
	this->amount = 1;
	root = std::make_shared<Node<T>>(Node<T>(TVector<T>(), 0, nullptr, nullptr));
}
template <class T> TNaryTree<T>::TNaryTree(int N)
{
	try
	{
		if (N > 4)
		{
			throw std::invalid_argument("Number of sons must be lesser than 5\n");
		}
		this->N = N;
		this->amount = 1;
		root = std::make_shared<Node<T>>(Node<T>(TVector<T>(), 0, nullptr,
```

```
nullptr));
	}
	catch (std::invalid_argument& error)
	{
		std::cout << error.what();
		return;
	}
}

template <class T> TNaryTree<T>::TNaryTree(TNaryTree& other)
{
	N = other.N;
	if (other.Empty())
	{
		root = nullptr;
		return;
	}
	root = std::make_shared<Node<T>>(Node<T>(other.root->vector, 0, nullptr, nullptr));
	BuildTree(root, other.root);
}

template <class T> void TNaryTree<T>::BuildTree(std::shared_ptr<Node<T>>&
current_node, std::shared_ptr<Node<T>> other_node)
{
	if (!other_node->child)
	{
		return;
	}
	current_node->child = std::make_shared<Node<T>>(Node<T>(other_node->child-
>vector, other_node->child->remainder, current_node, nullptr));
	std::shared_ptr<Node<T>>copy = current_node->child, other_copy = other_node-
>child;
	while (other_copy)
	{
		BuildTree(copy, other_copy);
		if (other_copy->right_brother)
		{
			copy->right_brother =
std::make_shared<Node<T>>(Node<T>(other_copy->right_brother->vector, other_copy-
>right_brother->remainder, current_node, copy));
		}
		else
		{
			copy->right_brother = nullptr;
		}
		copy = copy->right_brother;
		other_copy = other_copy->right_brother;
	}
}
```

```
template <class T> bool TNaryTree<T>::Empty()
{
	if (root)
	{
		return false;
	}
	return true;
}


template<class T> TVector<T> TNaryTree<T>::getItem(std::string&& tree_path)
{
	try
	{
		if (!tree_path.length())
		{
			if (Empty())
			{
				throw std::invalid_argument("There's no root\n");
			}
			else
			{
				return root->vector;
			}
		}
		std::shared_ptr<Node<T>> current_node = root;
		while (tree_path.length())
		{
			switch (tree_path[0])
			{
				case 'b':
				{
					if (!current_node)
					{
						throw std::invalid_argument("There's no such
element in tree\n");
					}
					current_node = current_node->right_brother;
					break;
				}
				case 'c':
				{
					if (!current_node)
					{
						throw std::invalid_argument("There's no such
element in tree\n");
					}
					current_node = current_node->child;
```

```
                                        break;
                                }
                                default:
                                {
                                        throw std::invalid_argument("String must contain only 'b'
or 'c' characters\n");
                                }
                        }
                        tree_path.erase(tree_path.begin());
                }
                if (!current_node)
                {
                        throw std::invalid_argument("There's no such element in tree\n");
                }
                return current_node->vector;
        }
        catch (std::invalid_argument& error)
        {
                std::cout << error.what() << "Default vector will be displayed\n";
                return TVector<T>();
        }
        catch (std::out_of_range& error)
        {
                std::cout << error.what() << "Default vector will be displayed\n";
                return TVector<T>();
        }
}

template <class T> void TNaryTree<T>::Update(T&& t, int index, std::string&& tree_path)
{
        try
        {
                if (index < 0)
                {
                        throw std::invalid_argument("Index must be whole non-negative
number\n");
                }
                if (!tree_path.length())
                {
                        if (Empty())
                        {
                                root = std::make_shared<Node<T>>(Node<T>(TVector<T>(t), 0,
nullptr, nullptr));
                                ++amount;
                        }
                        else
                        {
                                if (!root->vector.arr)
                                {
```

```
                                        if (index)
                                        {
                                                throw std::out_of_range("There's no such element
in vector\n");
                                        }
                                        else
                                        {
                                                root->vector = TVector<T>(t);
                                        }
                                }
                                else
                                {
                                        if (index < root->vector.real_size)
                                        {
                                                root->vector.Update(t, index);
                                        }
                                        else if ((!root->vector.real_size) && (!index))
                                        {
                                                root->vector.Update(t, index);
                                        }
                                        else if (index == root->vector.real_size)
                                        {
                                                root->vector.AppendElement(t);
                                        }
                                        else
                                        {
                                                throw std::out_of_range("There's no such element
in vector\n");
                                        }
                                }
                        }
                        return;
                }
                std::shared_ptr<Node<T>> current_node = root;
                while (tree_path.length() > 1)
                {
                        switch (tree_path[0])
                        {
                                case 'b':
                                {
                                        if (!current_node)
                                        {
                                                throw std::invalid_argument("There's no such
element in tree\n");
                                        }
                                        current_node = current_node->right_brother;
                                        break;
                                }
                                case 'c':
```

```
                                {
                                        if (!current_node)
                                        {
                                                throw std::invalid_argument("There's no such
element in tree\n");
                                        }
                                        current_node = current_node->child;
                                        break;
                                }
                                default:
                                {
                                        throw std::invalid_argument("String must contain only 'b'
or 'c' characters\n");
                                }
                        }
                        tree_path.erase(tree_path.begin());
                }
                switch (tree_path[0])
                {
                        case 'b':
                        {
                                if ((!current_node) || (!current_node->remainder))
                                {
                                        throw std::out_of_range("Node already has " +
std::to_string(N) + " sons, so it's imposible to add another one\n");
                                }
                                if (!current_node->right_brother)
                                {
                                        if ((++amount) == 6)
                                        {
                                                --amount;
                                                throw std::invalid_argument("Number of elements
in tree must be lesser than 5\n");
                                        }
                                        if (index)
                                        {
                                                --amount;
                                                throw std::out_of_range("There's no such element
in vector\n");
                                        }
                                        current_node->right_brother =
std::make_shared<Node<T>>(Node<T>(TVector<T>(t), current_node->remainder - 1,
current_node->parent, current_node));
                                }
                                else
                                {
                                        if (!current_node->right_brother->vector.arr)
                                        {
                                                if (index)
```

```
                                        {
                                                throw std::out_of_range("There's no such
element in vector\n");
                                        }
                                        else
                                        {
                                                current_node->right_brother->vector =
TVector<T>(t);
                                        }
                                }
                                else
                                {
                                        if (index < current_node->right_brother-
>vector.real_size)
                                        {
                                                current_node->right_brother-
>vector.Update(t, index);
                                        }
                                        else if (index == current_node->right_brother-
>vector.real_size)
                                        {
                                                current_node->right_brother-
>vector.AppendElement(t);
                                        }
                                        else
                                        {
                                                throw std::out_of_range("There's no such
element in vector\n");
                                        }
                                }
                        }
                        break;
                }
                case 'c':
                {
                        if (!current_node)
                        {
                                throw std::invalid_argument("There's no such element in
tree\n");
                        }
                        if (!current_node->child)
                        {
                                if ((++amount) == 5)
                                {
                                        throw std::invalid_argument("Number of elements
in tree must be lesser than 5\n");
                                }
                                if (index)
                                {
```

```
                                        --amount;
                                        throw std::out_of_range("There's no such element
in vector\n");
                                }
                                current_node->child =
std::make_shared<Node<T>>(Node<T>(TVector<T>(t), N - 1, current_node, nullptr));
                        }
                        else
                        {
                                if (!current_node->child->vector.arr)
                                {
                                        if (index)
                                        {
                                                throw std::out_of_range("There's no such
element in vector\n");
                                        }
                                        else
                                        {
                                                current_node->child->vector =
TVector<T>(t);
                                        }
                                }
                                else
                                {
                                        if (index < current_node->child->vector.real_size)
                                        {
                                                current_node->child->vector.Update(t,
index);
                                        }
                                        else if (index == current_node->child-
>vector.real_size)
                                        {
                                                current_node->child-
>vector.AppendElement(t);
                                        }
                                        else
                                        {
                                                throw std::out_of_range("There's no such
element in vector\n");
                                        }
                                }
                        }
                        break;
                }
                default:
                {
                        throw std::invalid_argument("String must contain only 'b' or 'c'
characters\n");
                }
```

```
                }
                tree_path.erase(tree_path.begin());
        }
        catch (std::invalid_argument& error)
        {
                std::cout << error.what();
                return;
        }
        catch (std::out_of_range& error)
        {
                std::cout << error.what();
                return;
        }
}

template <class T> void TNaryTree<T>::DeleteSons(std::shared_ptr<Node<T>>& node)
{
        std::shared_ptr<Node<T>> copy = node->child, previous = copy;
        while (copy)
        {
                if (copy->child)
                {
                        DeleteSons(copy);
                }
                previous = copy;
                copy = copy->right_brother;
        }
        while (previous)
        {
                if ((previous->right_brother) && (previous->right_brother->vector.arr))
                {
                        previous->right_brother->vector.Delete();
                }
                --amount;
                previous->right_brother = nullptr;
                previous = previous->left_brother;
        }
        node->child->vector.Delete();
        --amount;
        node->child = nullptr;
}

template <class T> void TNaryTree<T>::Remove(bool v, std::string&& tree_path, int index)
{
        try
        {
                if (index < 0)
                {
                        throw std::invalid_argument("Index must be whole non-negative
```

```
number\n");
		}
		if (!tree_path.length())
		{
			if (Empty())
			{
				throw std::invalid_argument("The root is empty\n");
			}
			else
			{
				if (v)
				{
					DeleteSons(root);
					root->vector.Delete();
					--amount;
					root = nullptr;
					return;
				}
				if (index >= root->vector.real_size)
				{
					throw std::invalid_argument("There's no such element in
vector\n");
				}
				else
				{
					root->vector.DeleteElement(index);
				}
			}
		}
		std::shared_ptr<Node<T>> current_node = root;
		while (tree_path.length())
		{
			switch (tree_path[0])
			{
				case 'b':
				{
					if (!current_node)
					{
						throw std::invalid_argument("There's no such
element in tree\n");
					}
					current_node = current_node->right_brother;
					break;
				}
				case 'c':
				{
					if (!current_node)
					{
						throw std::invalid_argument("There's no such
```

```
element in tree\n");
                                        }
                                        current_node = current_node->child;
                                        break;
                                }
                                default:
                                {
                                        throw std::invalid_argument("String must contain only 'b'
or 'c' characters\n");
                                }
                        }
                        tree_path.erase(tree_path.begin());
                }
                if (!current_node)
                {
                        throw std::invalid_argument("There's no such element in tree\n");
                }
                if ((v) || (current_node->vector.real_size == 1))
                {
                        if (current_node->vector.real_size == 1)
                        {
                                current_node->vector.Delete();
                        }
                        DeleteSons(current_node);
                        std::shared_ptr<Node<T>> clone = current_node->right_brother;
                        current_node->vector.Delete();
                        if (current_node->left_brother)
                        {
                                if (current_node->right_brother)
                                {
                                        current_node->right_brother->left_brother =
current_node->left_brother;
                                }
                                current_node->left_brother->right_brother = current_node-
>right_brother;
                        }
                        else
                        {
                                current_node->parent->child = current_node->right_brother;
                        }
                        current_node = nullptr;
                        while (clone)
                        {
                                ++(clone->remainder);
                                clone = clone->right_brother;
                        }
                }
                else
                {
```

```
                        if (index >= current_node->vector.real_size)
                        {
                                throw std::out_of_range("There's no such element in vector\n");
                        }
                        else
                        {
                                current_node->vector.DeleteElement(index);
                        }
                }
        }
        catch (std::invalid_argument& error)
        {
                std::cout << error.what();
                return;
        }
        catch (std::out_of_range& error)
        {
                std::cout << error.what();
                return;
        }
}
/*
template <class T> double TNaryTree<T>::AreaOfSubtree(std::shared_ptr<Node<T>> node)
{
        double S = node->t.Square();
        std::shared_ptr<Node<T>> current_node = node->child;
        while (current_node)
        {
                S += AreaOfSubtree(current_node);
                current_node = current_node->right_brother;
        }
        return S;
}

template <class T> double TNaryTree<T>::Area(std::string&& tree_path)
{
        try
        {
                if (Empty())
                {
                        throw std::invalid_argument("The root is empty\n");
                }
                if (!tree_path.length())
                {
                        return AreaOfSubtree(root);
                }
                std::shared_ptr<Node<T>> current_node = root;
                while (tree_path.length())
                {
```

```
                        switch (tree_path[0])
                        {
                        case 'b':
                        {
                                if (!current_node)
                                {
                                        throw std::invalid_argument("There is no such element in
tree\n");
                                }
                                current_node = current_node->right_brother;
                                tree_path.erase(tree_path.begin());
                                break;
                        }
                        case 'c':
                        {
                                if (!current_node)
                                {
                                        throw std::invalid_argument("There is no such element in
tree\n");
                                }
                                current_node = current_node->child;
                                tree_path.erase(tree_path.begin());
                                break;
                        }
                        default:
                        {
                                throw std::invalid_argument("String must contain only 'b' or 'c'
characters\n");
                        }
                        }
                        tree_path.erase(tree_path.begin());
                }
                if (!current_node)
                {
                        throw std::invalid_argument("There's no such element in tree\n");
                }
                return AreaOfSubtree(current_node);
        }
        catch (std::invalid_argument& error)
        {
                std::cout << error.what();
                return -1.;
        }
        catch (std::out_of_range& error)
        {
                std::cout << error.what();
                return -1.;
        }
}*/
```

```
template std::ostream& operator<<(std::ostream& os, TNaryTree<Rectangle>& tree);
template std::ostream& operator<<(std::ostream& os, TNaryTree<Rhombus>& tree);
template std::ostream& operator<<(std::ostream& os, TNaryTree<Trapezoid>& tree);

template <typename T> std::ostream& operator<<(std::ostream& os, TNaryTree<T>& tree)
{
	try
	{
		if (tree.Empty())
		{
			throw std::invalid_argument("The root is empty");
		}
		std::shared_ptr<Node<T>> current_node = tree.root;
		tree.root->PrintSubTree(os);
	}
	catch (std::invalid_argument& error)
	{
		os << error.what();
	}
	return os;
};

template <class T> TNaryTree<T>::~TNaryTree()
{
	if (!Empty())
	{
		DeleteSons(root);
		root = nullptr;
	}
}
```

tnarytree.h

```
#ifndef TNARYTREE_H
#define TNARYTREE_H
#include"tnarytreeitem.h"
#include <exception>
#include <string>

template<class T>
class TNaryTree
{
private:
	std::shared_ptr<Node<T>> root;
	int N;
	int amount;
public:
	TNaryTree();
```

```
        TNaryTree(int);
        TNaryTree(TNaryTree<T>&);
        void BuildTree(std::shared_ptr<Node<T>>&, std::shared_ptr<Node<T>>);
        void Update(T&&, int, std::string && = "");
        void Remove(bool, std::string && = "", int index = 0);
        void DeleteSons(std::shared_ptr<Node<T>>&);
        TVector<T> getItem(std::string && = "");
        bool Empty();
        /*
        double Area(std::string && = "");
        double AreaOfSubtree(std::shared_ptr<Node<T>>);*/
        template <typename A>
        friend std::ostream& operator<<(std::ostream&, TNaryTree<A>&);
        virtual ~TNaryTree();
};
#endif
```

tnarytreeitem.cpp

```
#include "tnarytreeitem.h"
template Node<Rectangle>;
template Node<Rhombus>;
template Node<Trapezoid>;

template <class T> Node<T>::Node(T t, int remainder, std::shared_ptr<Node<T>> parent,
std::shared_ptr<Node<T>> left_brother)
{
        vector = TVector<T>(t);
        this->remainder = remainder;
        this->parent = parent;
        this->child = child;
        this->left_brother = left_brother;
        this->right_brother = right_brother;
}

template <class T> Node<T>::Node(TVector<T> tvector, int remainder,
std::shared_ptr<Node<T>> parent, std::shared_ptr<Node<T>> left_brother)
{
        vector = tvector;
        this->remainder = remainder;
        this->parent = parent;
        this->child = child;
        this->left_brother = left_brother;
        this->right_brother = right_brother;
}

template <typename T> std::shared_ptr<Node<T>> Node<T>::getChild()
{
        return this->child;
}

template <typename T> std::shared_ptr<Node<T>> Node<T>::getBrother()
{
        return this->right_brother;
}
```

```
template <typename T> std::shared_ptr<Node<T>> Node<T>::getParent()
{
	return this->parent;
}

template <class T> void Node<T>::PrintSubTree(std::ostream& os)
{
	os << *this;
	if (!this->child)
	{
		return;
	}
	std::shared_ptr<Node<T>> current_node = this->getChild();
	os << ": [";
	while (current_node)
	{
		current_node->PrintSubTree(os);
		if (current_node->getBrother())
		{
			os << ", ";
		}
		current_node = current_node->getBrother();
	}
	os << "]";
}

template std::ostream& operator<<(std::ostream& os, const Node<Rectangle>& node);
template std::ostream& operator<<(std::ostream& os, const Node<Rhombus>& node);
template std::ostream& operator<<(std::ostream& os, const Node<Trapezoid>& node);

template <typename T> std::ostream& operator<< (std::ostream& os, const Node<T>& node)
{
	os << node.vector;
	return os;
}

template<class T> Node<T>::~Node()
{

}
```

tnarytreeitem.h

```
#ifndef TNARY_TREE_ITEM_H
#define TNARY_TREE_ITEM_H

#include "tvector.h"

template <class T>
class Node
{
public:
	Node(T, int, std::shared_ptr<Node<T>>, std::shared_ptr<Node<T>>);
	Node(TVector<T>, int, std::shared_ptr<Node<T>>, std::shared_ptr<Node<T>>);
```

```
	TVector<T> vector;
	int remainder;
	std::shared_ptr<Node> parent;
	std::shared_ptr<Node> child;
	std::shared_ptr<Node> left_brother;
	std::shared_ptr<Node> right_brother;
	void PrintSubTree(std::ostream& os);
	template <typename A>
	friend std::ostream& operator<<(std::ostream&, const Node<A>&);
	virtual ~Node();
	std::shared_ptr<Node<T>> getChild();
	std::shared_ptr<Node<T>> getBrother();
	std::shared_ptr<Node<T>> getParent();
};
#endif
```

tvector.cpp

```
#include "tvector.h"

template TVector<Rectangle>;
template TVector<Rhombus>;
template TVector<Trapezoid>;

template <class T> TVector<T>::TVector()
{
	real_size = 0;
	size_of_memory = 1;
	arr = new T[size_of_memory];
}

template<class T> TVector<T>::TVector(T t)
{
	real_size = size_of_memory = 1;
	arr = new T[size_of_memory];
	arr[0] = t;
}

template <class T> void TVector<T>::Realloc(bool increase)
{
	double value;
	if (increase)
	{
		value = 2;
	}
	else
	{
		value = 0.5;
	}
	T* aux_arr = new T[int(size_of_memory * value)];
	for (int i = 0; i < real_size; i++)
	{
		aux_arr[i] = this->arr[i];
	}
	delete[] arr;
	this->arr = new T[int(size_of_memory * value)];
```

```
	for (int i = 0; i < real_size; i++)
	{
		this->arr[i] = aux_arr[i];
	}
	size_of_memory = int(size_of_memory * value);
	delete[] aux_arr;
}

template <class T> void TVector<T>::Move(int index, bool forward, int stop, bool updating,
T t)
{
	if (forward)
	{
		if (real_size == size_of_memory)
		{
			Realloc(forward);
		}
		for (int i = stop; i > index; i--)
		{
			arr[i] = arr[i - 1];
		}
		if (!updating)
		{
			++real_size;
		}
		arr[index] = t;
	}
	else
	{
		for (int i = index; i < stop - 1; i++)
		{
			arr[i] = arr[i + 1];
		}
		if (!updating)
		{
			--real_size;
		}
		if ((real_size * 2) == size_of_memory)
		{
			Realloc(forward);
		}
	}
}

template <class T> int TVector<T>::LowerBound(T t)
{
	int l = 0, r = real_size, m;
	while (l < r)
	{
		m = l + (r - l) / 2;
		if (!(arr[m] < t))
		{
			r = m;
		}
		else
		{
			l = m + 1;
		}
	}
```

```
	return l;
}

template <class T> void TVector<T>::AppendElement(T t)
{
	if (!real_size)
	{
		if (!size_of_memory)
		{
			arr = new T[++size_of_memory];
		}
		arr[0] = t;
		++real_size;
	}
	else
	{
		//double square = t.Square();
		int index = LowerBound(t);
		Move(index, true, real_size, false, t);
	}
}

/*
template <class T> int TVector<T>::BinarySearch(T t)
{
	int l = -1, r = real_size, m
	while (l < r - 1)
	{
		m = (l + r) / 2;
		if (arr[m] < t)
		{
			l = m;
		}
		else
		{
			r = m;
		}
	}
	return ((r < real_size) && (arr[r] == t)) ? r : -1;
}
*/
template <class T> void TVector<T>::DeleteElement(int index)
{
	if (index >= real_size)
	{
		std::cout << "There's no such element in vector\n";
		return;
	}
	if (real_size == 1)
	{
		real_size = size_of_memory = 0;
		delete[] arr;
		arr = nullptr;
		return;
	}
	Move(index, false, real_size, false);
}

template <class T> void TVector<T>::Delete()
```

```
{
	if (arr)
	{
		delete[] arr;
		arr = nullptr;
	}
	real_size = size_of_memory = 0;
}

template <class T> void TVector<T>::Update(T t, int index)
{
	if ((!index) && (!real_size))
	{
		++real_size;
		arr[index] = t;
		return;
	}
	if (index >= real_size)
	{
		std::cout << "There's no such element in vector\n";
		return;
	}
	else
	{
		int new_index = LowerBound(t);
		if ((new_index >= index) && (index + 1 >= new_index))
		{
			arr[index] = t;
			return;
		}
		else if (new_index < index)
		{
			Move(new_index, true, index, true, t);
		}
		else
		{
			Move(index, false, new_index, true);
			arr[new_index - 1] = t;
		}
	}
}


template <typename T> void TVector<T>::operator= (const TVector<T>& tvector)
{
	if (arr)
	{
		delete[] arr;
	}
	real_size = tvector.real_size;
	size_of_memory = tvector.size_of_memory;
	arr = new T[size_of_memory];
	for (int i = 0; i < real_size; i++)
	{
		arr[i] = tvector.arr[i];
	}
}

template std::ostream& operator<<(std::ostream& os, const TVector<Rectangle>& tvector);
```

```
template std::ostream& operator<<(std::ostream& os, const TVector<Rhombus>& tvector);
template std::ostream& operator<<(std::ostream& os, const TVector<Trapezoid>& tvector);

template <typename T> std::ostream& operator<< (std::ostream& os, const TVector<T>&
tvector)
{
	os << "{";
	for (int i = 0; i < tvector.real_size - 1; i++)
	{
		os << tvector.arr[i] << "; ";
	}
	if (tvector.real_size)
	{
		os << tvector.arr[tvector.real_size - 1];
	}
	os << "}";
	return os;
}

template <class T> TVector<T>::~TVector()
{

}
```

tvector.h

```
#ifndef TVECTOR_H
#define TVECTOR_H

#include "rhombus.h"
#include "rectangle.h"
#include "trapezoid.h"

template <class T>
class TVector
{
public:
	TVector();
	TVector(T);
	int real_size, size_of_memory;
	T* arr = nullptr;
	void AppendElement(T);
	//int BinarySearch(T);
	void Delete();
	void DeleteElement(int);
	int LowerBound(T);
	void Move(int, bool, int, bool, T = T());
	void Realloc(bool);
	void Update(T, int);
	void operator= (const TVector<T>&);
	template <typename A>
	friend std::ostream& operator<<(std::ostream&, const TVector<A>&);
	~TVector();
};
#endif
```