Design using UML diagrams of an educational informatics system for the study of computational geometry elements

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Abstract: - This paper presents the necessary stages in implementing an informatics system used for the study of computational geometry elements, such as determining the parallel and perpendicular to a given line through a point, to verify the property that a point lies within a triangle, verification of the convex or concave property of a polygon, the determination of the convex hull of a set of points. The modeling of the system is achieved through specific UML diagrams representing the stages of analysis, design and implementation, the system thus being described in a clear and concise manner.

Key-Words: - Educational Software, Computational Geometry, Java, Distance Education.

1 Introduction

The multimedia technologies transformed the computer into a valuable interlocutor and allowed the students, without going out of the class, to assist the lessons of different emeriti scientists and professors, to communicate with persons located in different countries, to have access to different information [1,3]. By a single click of the mouse, the student can visit an artistic gallery, read the originals for writing a history paper or visualize information for a narrow profile, which couldn't be found five-ten years ago.

One of the main aspects of using computer for lessons is the development of the student's creative thinking. An optimal mean in this case is the introduction in the computational training means of the interactivity elements [2,4,5]. The „interactivity" term means „to interact, to influence one-to-another". This property of the computational technologies is absolutely unique compared with television, lectures, books, instructive movies etc.

2 Development stages of the educa-tional informatics system

2.1 System's analysis

Using the UML modeling language, the analysis of an informatics system consists in drawing the use case and activity diagrams [6]. The software utility ArgoUML [7] was used to construct the diagrams.

The informatics system will be described in a clear and concise manner by representation of the use-cases. Each case describes the interaction between the user and the system. The use case diagram is represented in figure 1.

The presented diagram defines the system's domain, allowing visualization of the size and scope of the whole developing process. It contains:

- an actor - the user who represents the external entity with which the system interacts;
- six use cases describing the functionality of the system;
- relationships between the user and use cases (association relationships) and the relationships between use cases (generalization relationships).

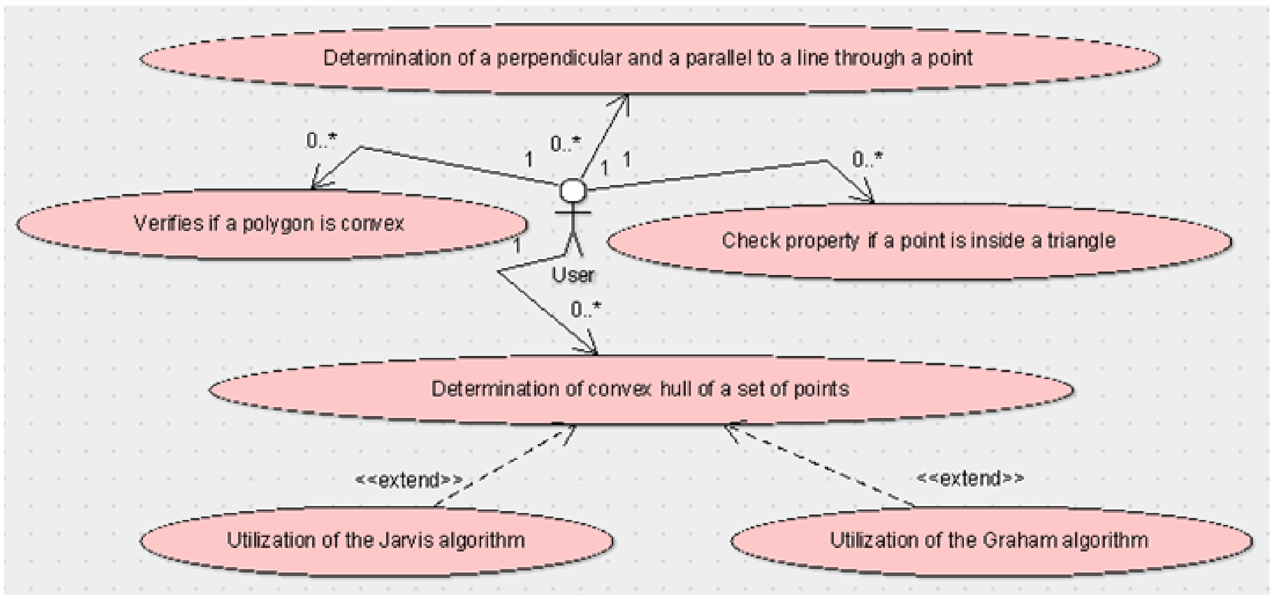
For each use-case in the diagram presented earlier an activity diagram is constructed. Each diagram will specify the processes and algorithms that are behind the use cases studied.

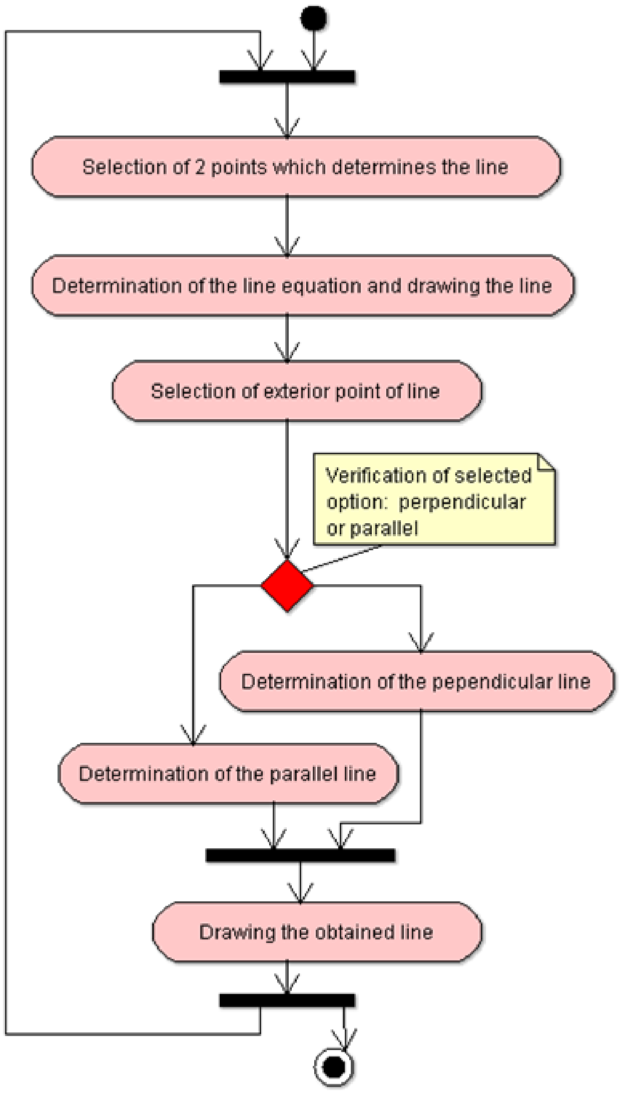
Activity diagrams [8] are represented by nodes (with partitions and branches) or conditional blocks (with decisions).

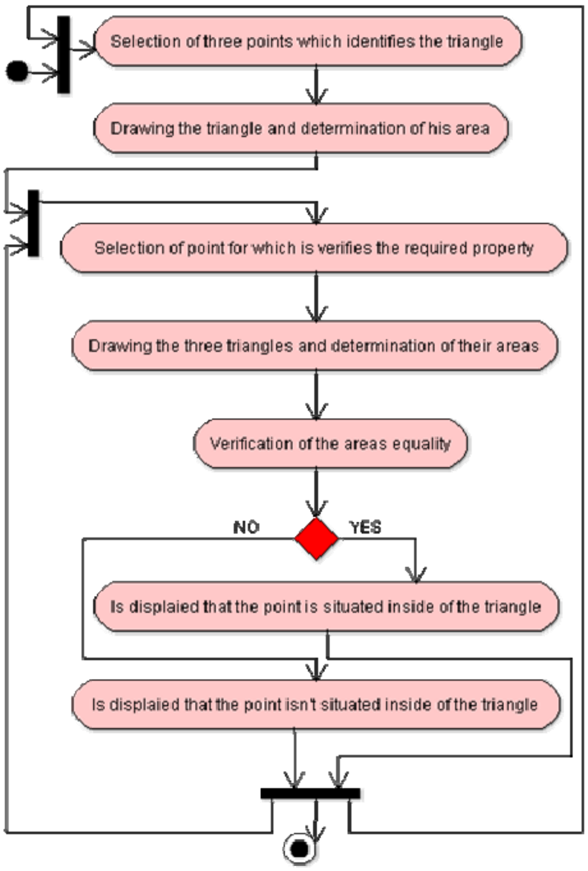
The activity diagrams are used to visualize, specify, build and document dynamic issues related to the informatics system processes. They focus on flow control seeking the transition, in a certain order, from one activity to another.

Figure 2 present the activity diagram corresponsive to the use-case "Determination of a perpendicular and a parallel to a line through a point".

Figure 3 present the activity diagram corresponsive to the use-case "Check property if a point is inside a triangle" and figure 4 present the activity diagram corresponsive to the use-case "Verifies if a polygon is convex".


Determination of a perpendicular and a parallel to a line through a point
Verifies if a polygon is convex
Check property if a point is inside a triangle
User
Determination of convex hull of a set of points
<<extend>>
<<extend>>
Utilization of the Jarvis algorithm
Utilization of the Graham algorithm
0..*
1
0..*
1
1
0..*
1
0..*
Fig.1 Use-cases diagram


Selection of 2 points which determines the line
Determination of the line equation and drawing the line
Selection of exterior point of line
Verification of selected option: perpendicular or parallel
Determination of the pependicular line
Determination of the parallel line
Drawing the obtained line
Fig. 2 Activity diagram for the use-case "Determination of a perpendicular and a parallel to a line through a point"


Selection of three points which identifies the triangle
Drawing the triangle and determination of his area
Selection of point for which is verifies the required property
Drawing the three triangles and determination of their areas
Verification of the areas equality
NO
YES
Is displaied that the point is situated inside of the triangle
Is displaied that the point isn't situated inside of the triangle
Fig. 3 Activity diagram for the use-case "Check property if a point is inside a triangle"

2.2 System's designing

2.2.1 Class Diagrams

Conceptual modeling [9] allows the identification of the most important concepts for the system.

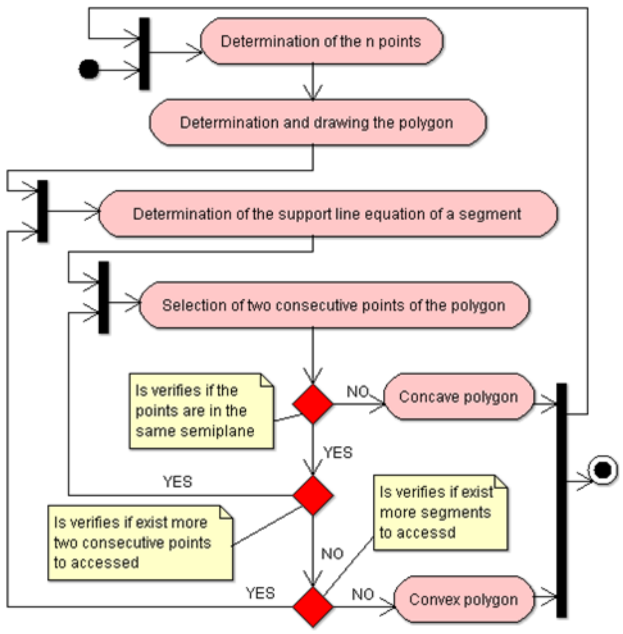

Determination of the n points
Determination and drawing the polygon
Determination of the support line equation of a segment
Selection of two consecutive points of the polygon
Is verifies if the points are in the same semiplane
NO
Concave polygon
YES
YES
Is verifies if exist more segments to accessd
Is verifies if exist more two consecutive points to accessed
NO
YES
NO
Convex polygon

Fig. 4 Activity diagram for the use-case "Verifies if a polygon is convex"

Since classes are concepts, the following two diagrams present the classes that will be used in the project.

Figure 5 presents the inheritance and achievement relationships used. It may be noted that all attributes and methods of the *JPanel* class will apply to the derived class *Desen*, which implements two interfaces, *Runnable* and *MouseInputListener*.

The composition and aggregation relationships that exist between instances of the classes in the architecture are shown in figure 5.

Aggregation relationship is a partnership where the whole and the part are specified. By analyzing figure 6, it is apparent that an object of type *Dreapta* or type *Graham* is part of an object of type *Proiect*.

The difference of the composition relationship, with respect to aggregation, is that the instance of the whole could not exist without part objects.

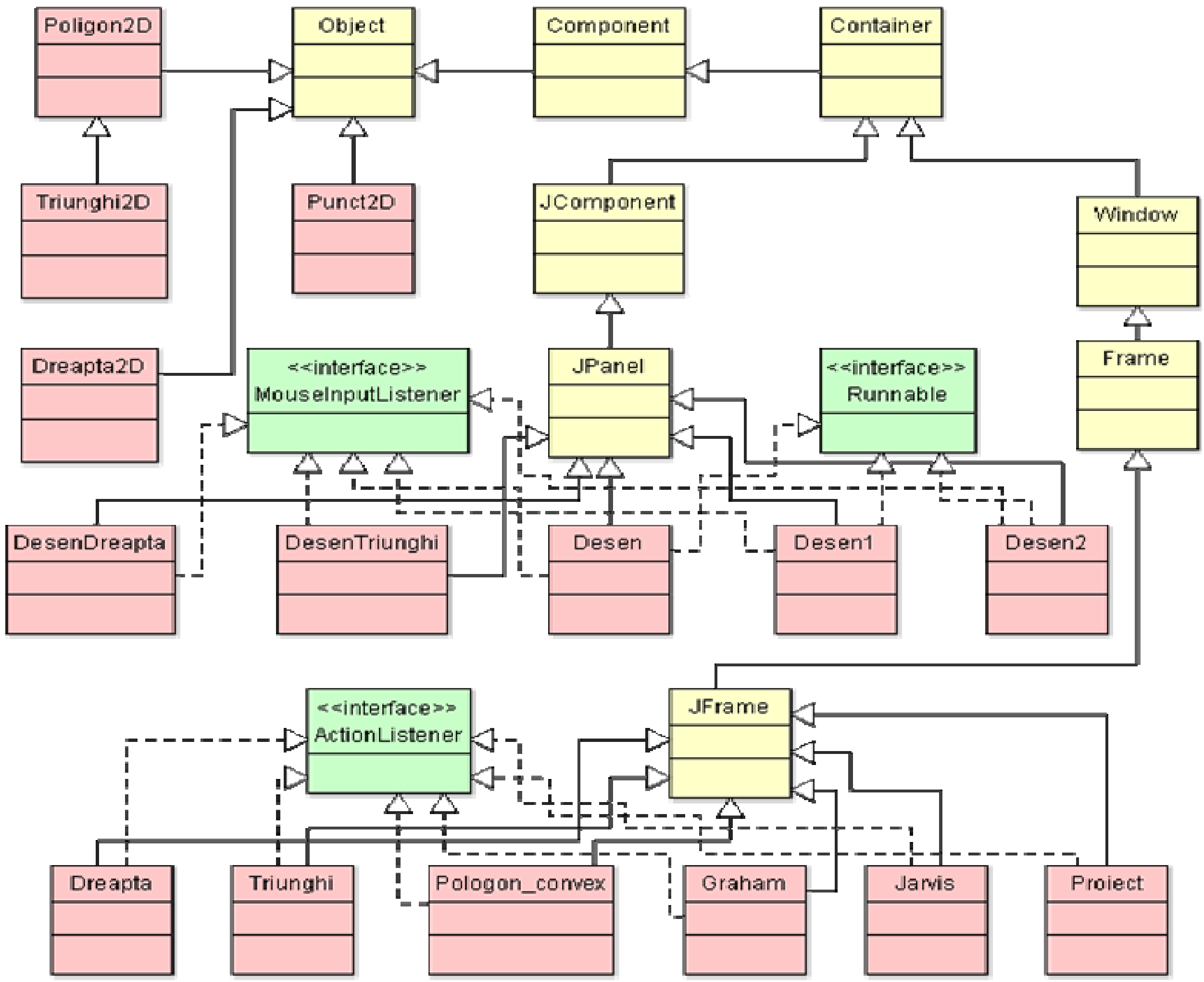


Fig.5 Class diagram

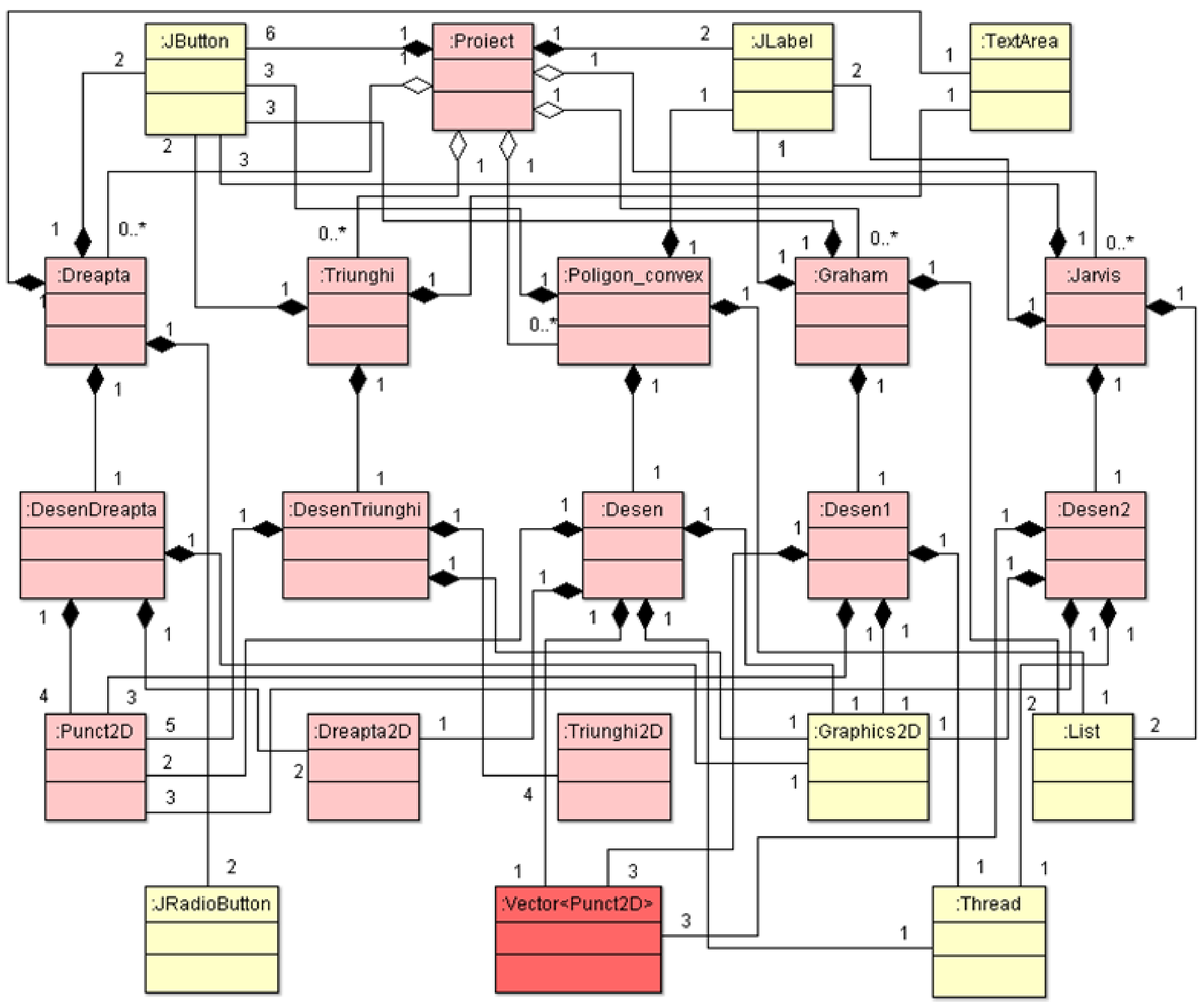


Fig.6 Class diagram

When looking at figure 6 one can see that a type *DesenTriunghi* instance consists of five *Punct2D* type items, one *Triunghi2D* object type and one *Graphics2D* object type.

In such a relationship it is possible for an object to belong to several instances of a whole. For example object type *Punct2D* belongs to *DesenTriunghi, DesenDreapta, Desen, Desen1* and *Desen2* type instances.

Both class diagrams shown contain specific classes to the application as well as existing classes and interfaces from Java.

2.2.2 Sequence Diagrams

Sequence diagrams [10] describe the behavior of a set of objects in a certain context, emphasizing the temporal aspect.

The diagram shown in figure 7 reflects the interactions between objects, the purpose of which is drawing a triangle with specified points.

Note that there are interactions between 11 objects, from which the object type *Triunghi* is already created and object types *DesenTriunghi, TextArea, Graphics2D, Punct2D, String* and *Triunghi* will be instantiated during interactions.

These objects are represented on the Ox axis and the messages sorted ascending by time are represented on the Oy axis. At first, execution control is acquired by the object type *Triunghi* which creates instances of classes *DesenTriunghi, TextArea* and *Graphics2D.*

Now control is acquired by the newly created instance *DesenTriunghi* which will allow the creation of the triangle endpoints through interactions with *Punct2D, String, Graphics2D* and *TextArea* object types.

Thereafter control is passed to the object of type *DesenTriunghi* which that will instantiate the object type *Triunghi2D*. The last post will lead to the redesign of the geometrical construction which will now include the previously created triangle.

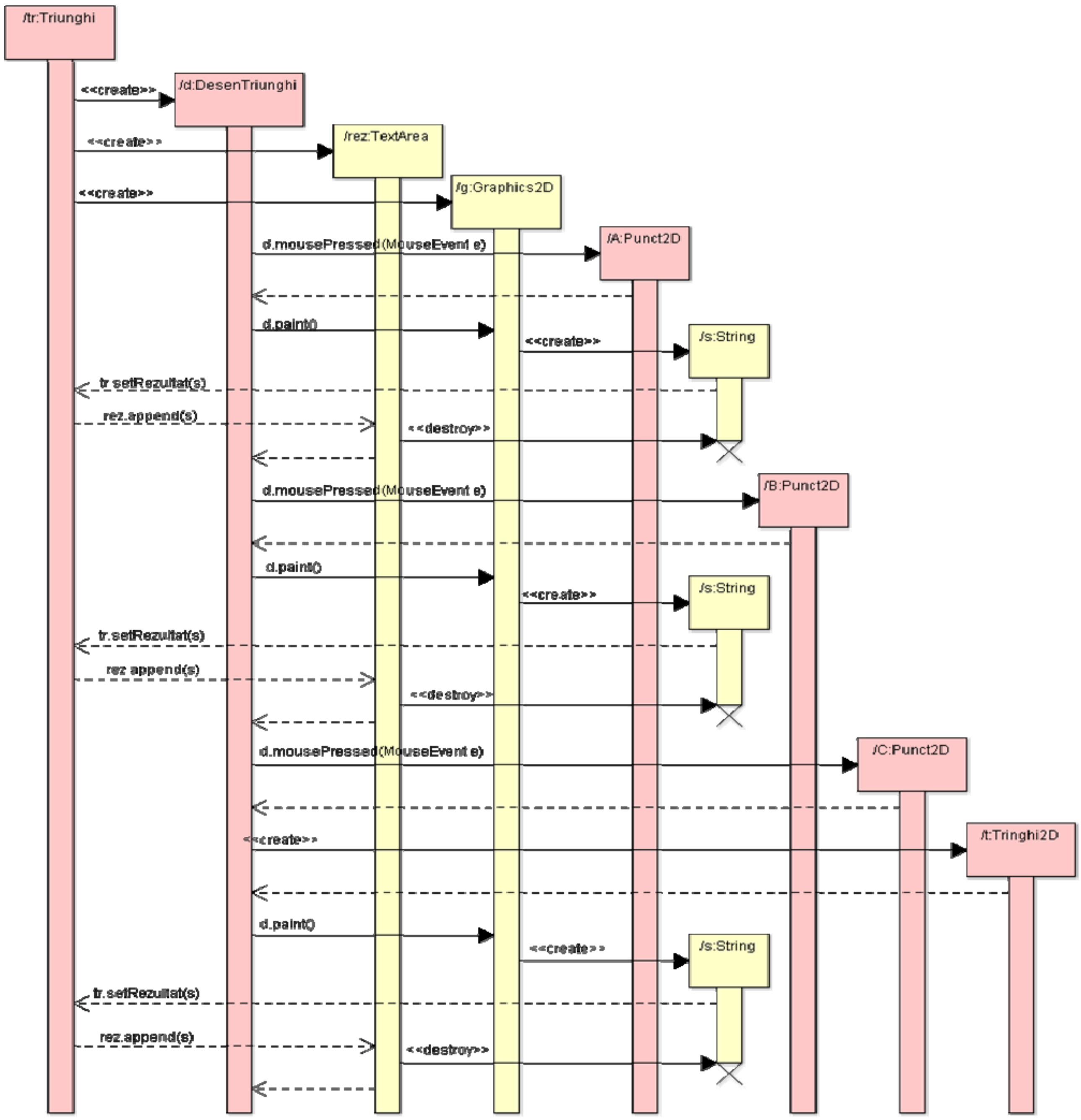


Fig.7 Sequence diagram

2.2.3 State chart diagrams

The objects corresponding to the classes presented posses both behavior and internal state, in other words, they fulfill certain actions and posses information.

State chart diagrams can be developed in order to understand them. UML state chart diagrams [11] describe the different states an object can be found in and the transitions between these states.

Figure 8 illustrates, the state chart diagram corresponding to an instance of the class *Desen*, class which implements the *Runnable* interface corresponding to threads.

2.2.4. Collaboration diagrams

Collaboration diagrams describe [12], same as sequence diagrams, the conduct of a set of objects in a certain context, focusing on organizing objects participating in an interaction.

These diagrams are graphs, their peaks are objects participating in the interaction and the arcs represent the links between instances.The diagram shown in figure 9 reflects the interactions between objects aimed at drawing a triangle. Note that the following interactions between objects types exist: *Triunghi, DesenTriunghi, Punct2D, Triunghi2D, TextArea, String* and *Graphics2D*.

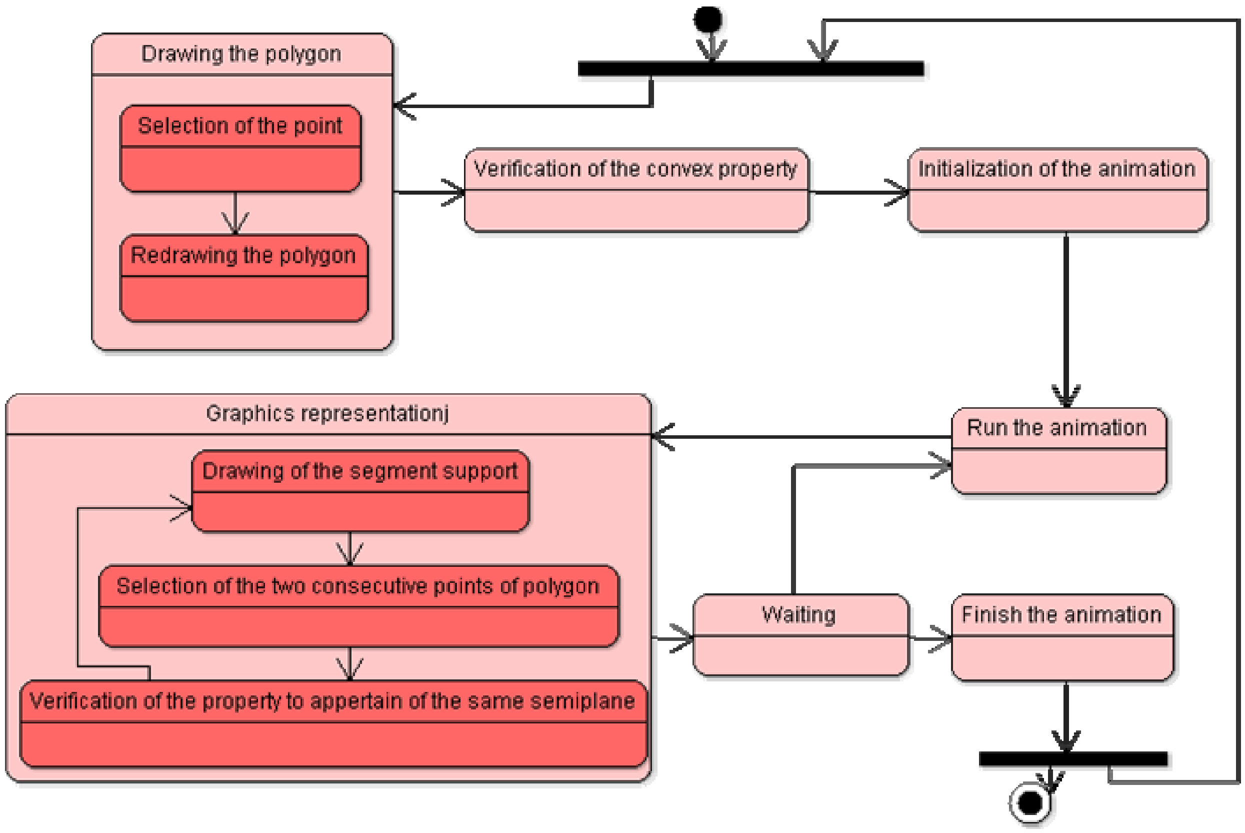

Drawing the polygon
Selection of the point
Redrawing the polygon
Verification of the convex property
Initialization of the animation
Graphics representationj
Drawing of the segment support
Selection of the two consecutive points of polygon
Verification of the property to appertain of the same semiplane
Run the animation
Waiting
Finish the animation

Fig.8 State chart diagram

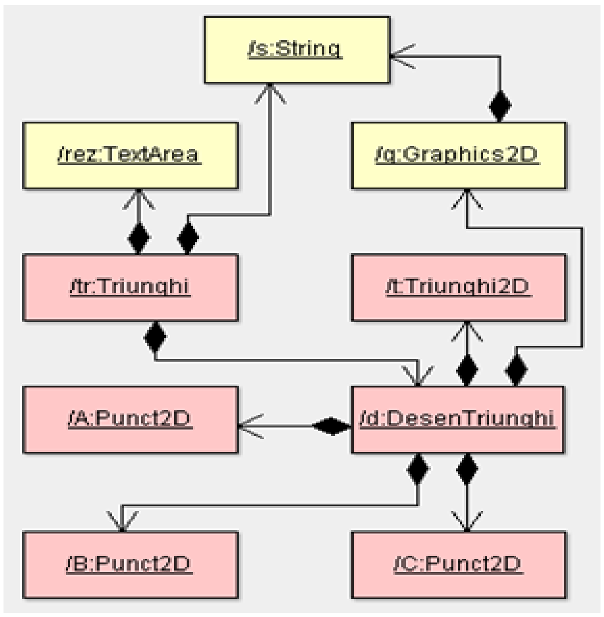


Fig. 9 Collaboration diagram

2.3 System's implementation

The component diagram [13] allows the visualization of the module in which the system is broken into and the dependencies between modules. The component diagram emphasis on physical software components (files, libraries, executables) and not on logic components, such as packages.

The diagram in figure 10 describes the collection of components that all together provide functionality for the educational informatics system that allows geometric constructions in the plan.

The central component of the diagram *Proiect.class* is obtained by transforming the component *Proiect.java* into executable code by the Java compiler. It can be noted that this component interacts directly only with components *Dreapta.class*, *Triunghi.class*, *Graham.class*, *Poligon_convex..class* and *Jarvis.class*.

3 User interface

The application "Computational Geometry Elements" is accomplished using the Java programming language [14, 15]. The main page of the application contains buttons for selecting the following options: perpendicular and parallel to a line through a point inside a triangle, the verification of the convexity of a polygon, the determination of the convex hull using *Graham* and *Jarvis* methods.

By selecting *"Parallel and perpendicular to a line through a point"*, a new window is opened containing the drawing area, an image containing formulas used to calculate the parallel and perpendicular to a line, a text component containing the equations of the lines and two radio buttons to select the type of line (perpendicular or parallel).

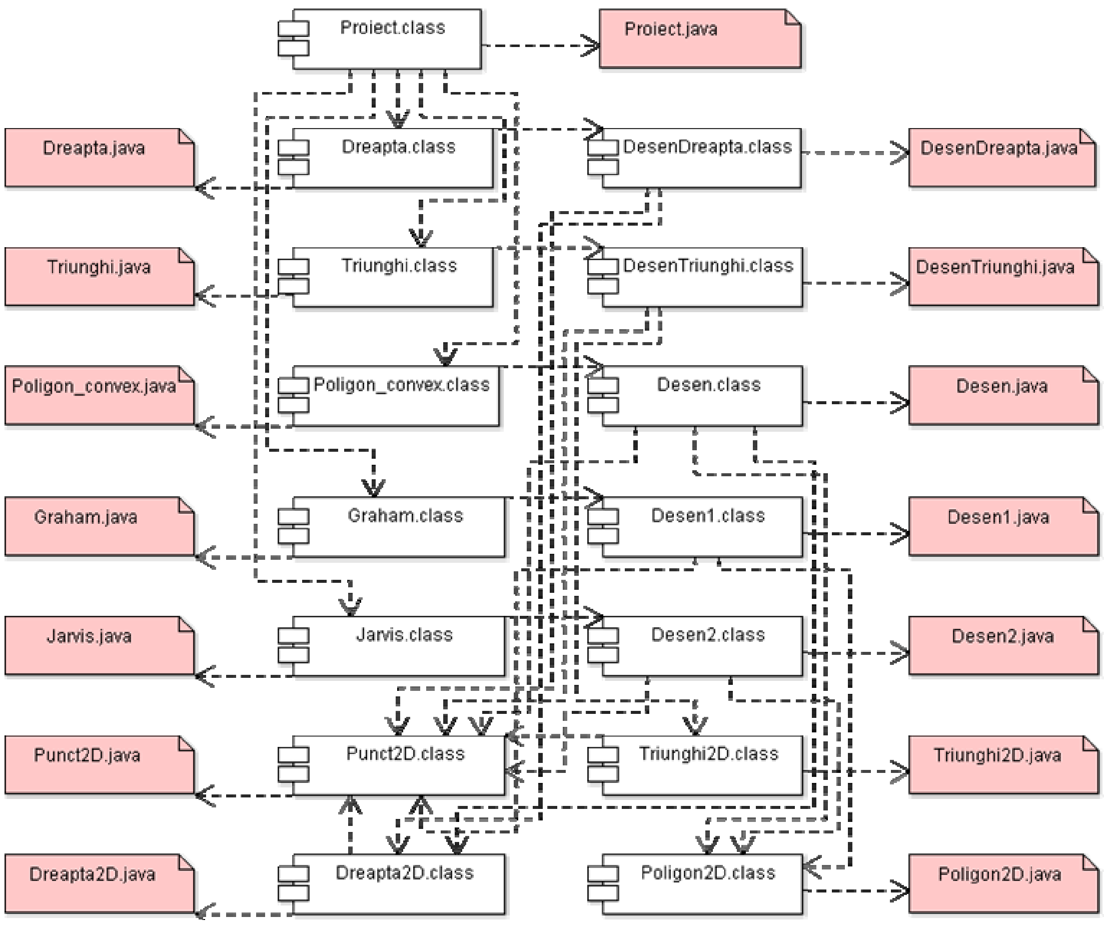


Fig.10 Component diagram

The second option of the main window opens another window (Fig. 11) to check if a point is inside a triangle drawn by the user. This window contains a drawing area, an image that contains the formula for calculating area of a triangle, a text component containing the coordinates of peak triangles and their areas, and result verification.

The triangles are drawing by the following method of the class *DesenTriunghi*:

```
public void paint(Graphics g1) {
  g=(Graphics2D) g1;
  g.clearRect(0,0,this.getWidth(),this.getHeight());
  g.setColor(Color.yellow);
  g.fillRect(0,0,this.getWidth(),this.getHeight());
  String s;
  A.setCuloare(Color.red);
  A.desenare(g,this.getWidth(),this.getHeight());
  B.setCuloare(Color.red);
  B.desenare(g,this.getWidth(),this.getHeight());
  C.setCuloare(Color.red);
  C.desenare(g,this.getWidth(),this.getHeight());
  M.setCuloare(Color.blue);
  M.desenare(g,this.getWidth(),this.getHeight());
  f.stergRezultat(); s=new String("Punct  A(";
  s+=String.format("%.1f",A.getX())+",";
s+=String.format("%.1f",A.getY())+")");
f.setRezultat(s); s=new String("\nPunct  B(";
s+=String.format("%.1f",B.getX())+",";
s+=String.format("%.1f",B.getY())+")");
f.setRezultat(s);
s=new String("\nPunct  C(";
s+=String.format("%.1f",C.getX())+",";
s+=String.format("%.1f",C.getY())+")");
f.setRezultat(s); s=new String("\nPunct  M(";
s+=String.format("%.1f",M.getX())+",";
s+=String.format("%.1f",M.getY())+")");
f.setRezultat(s); g.setColor(Color.red);
t.desenare(g,this.getWidth(),this.getHeight());
t1.desenare1(g,this.getWidth(),this.getHeight(),new
Color(155,65,30,100));
t2.desenare1(g,this.getWidth(),this.getHeight(),new
Color(0,255,0,80));
t3.desenare1(g,this.getWidth(),this.getHeight(),new
Color(155,55,150,120));
s=new String("\nAria triunghiului ABC este ";
s+=String.format("%.2f",a));
f.setRezultat(s);
s=new String("\nAria triunghiului MAB este ";
s+=String.format("%.2f",a1));
f.setRezultat(s);
```

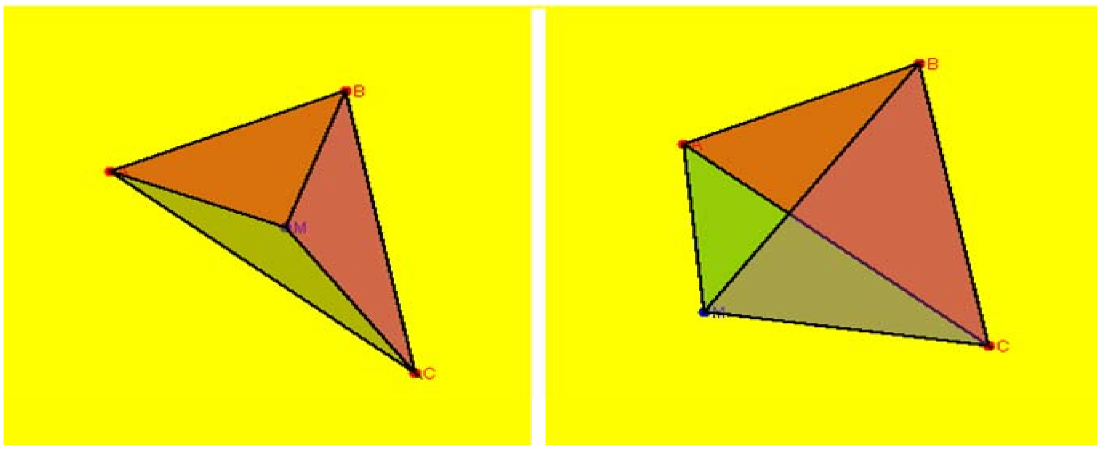


Fig.11 Point inside of a triangle

```
s=new String("\nAria triunghiului MAC este ";
s+=String.format("%.2f",a2));
    f.setRezultat(s);
    s=new String("\nAria triunghiului MBC este ";
    s+=String.format("%.2f",a3));
    f.setRezultat(s);
   if (cod)
    s=new String("\nPunctul M este in interiorul
triunghiului ABC");
   else s=new String("\nPunctul M nu apartine
interiorului triunghiului ABC");
   f.setRezultat(s);
   }}
```

The next option allows the user to open a window (Fig. 12) where it can be verified whether or not a polygon is convex. This window contains a drawing surface on which the points that will form the polygon are selected, an image containing the algorithm used to verify the property, three buttons, a label that displays the number of points and a text component that will display the coordinates of the polygon endpoints.

The method of the class *Poligon2D* which draw the polygon is presented forwards:

```
public void desenare(Graphics2D g) {
  figura=new GeneralPath();
  int xe,ye,a,b;
  a=(int)(latime/2);
  b=(int)(inaltime/2);
  xe=Desen.xecran(latime,a,V[0].getX());
  ye=Desen.yecran(inaltime,b,V[0].getY());
  figura.moveTo(xe,ye);
  for (int i=1;i<nr;i++) {
     xe=Desen.xecran(latime,a,V[i].getX());
     ye=Desen.yecran(inaltime,b,V[i].getY());
     figura.lineTo(xe,ye);}
  xe=Desen.xecran(latime,a,V[0].getX());
  ye=Desen.yecran(inaltime,b,V[0].getY());
  figura.lineTo(xe,ye);
  g.setColor(new Color(255,0,0,110));
  g.fill(figura);
  g.setColor(culoare);
  g.setStroke(stil);
  g.draw(figura);}
```

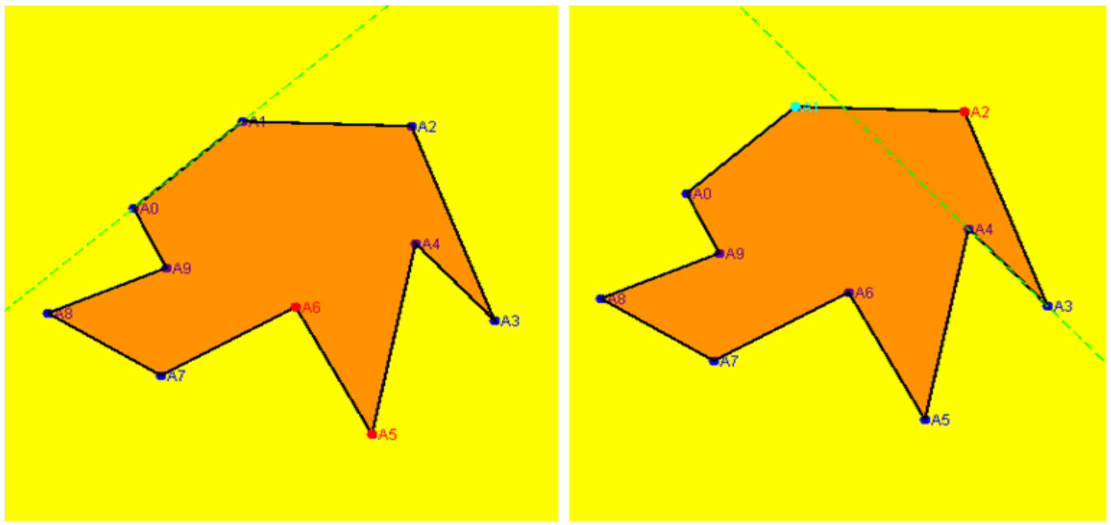


Fig.12 Concave Polygon

Selecting "*Graham Method*" opens a window (Fig. 13) with a program that determines the convex hull of a set of points.

This window contains a drawing surface, an image that contains the algorithm used, three buttons, two labels and two text components containing the initial points and those points which are in the list determined by the hull.

After selecting the points on the drawing area by clicking the button *Animație* a thread, that will allow the simulation of the algorithm for determining the convex hull, is instantiated. At first the nearest point to the origin is determined.

The points' vector is then scanned and sorted according to the polar angle. After the points' vector was sorted the points' list will appear sorted by the polar angles to the minimum point determined during the algorithm's first stage.

Further, the first three points are added to the chosen list. They will be displayed in the appropriate text component and on the drawing surface they will be colored in red so they can stand out. Further, for every three points, a check is performed to determine whether the angle formed by these points cancels the polygon's convexity.

If so, the second point is then removed from the stack and will be colored black. If the angle formed by the three points does not cancel the polygon's convexity, then the three points are inserted into the stack and will be colored red.

The method of the class *Desen1* which presents step-by-step the Graham algorithm is presented forwards:

```
public void run() {
   repaint(); pauza(500); sortare(); pas=2;
   f.stergereLista(); f.setLista(P0,1);
   for (int poz=1;poz<puncte.size();poz++) {
      Q=new Punct2D((Punct2D)puncte.get(poz));
      f.setLista(Q,1);  repaint(); pauza(500);  }
   pas=3; infasuratoare=new Vector();
   infasuratoare.add(P0); f.setLista(P0,2);
   infasuratoare.add((Punct2D)puncte.get(1));
   f.setLista((Punct2D)puncte.get(1),2);
   infasuratoare.add((Punct2D)puncte.get(2));
   f.setLista((Punct2D)puncte.get(2),2);
   parcurse=new Vector();
   repaint(); pauza(500); pas=4;
   for (int i=3;i<puncte.size();i++) {
      cod=false;
      while (!cod && infasuratoare.size()>=2) {
        P=new Punct2D((Punct2D)infasuratoare.
get(infasuratoare.size()-2));
        Q=new Punct2D((Punct2D)infasuratoare.
get(infasuratoare.size()-1));
        R=new Punct2D((Punct2D)puncte.get(i));
        triunghi=true; repaint();
        pauza(1000); triunghi=false;
        if (P.determinant(Q,R)>=0) {
           infasuratoare.add(R); f.setLista(R,2);
           repaint(); pauza(1000); cod=true;
        }
        else {
           f.stergLista();
           parcurse.add((Punct2D)infasuratoare.
get(infasuratoare.size()-1));
        infasuratoare.remove(infasuratoare.size()-1);
           repaint(); pauza(1000);  }
   } while (!cod && infasuratoare.size()>=2);  }
   repaint(); pauza(1000); }
```

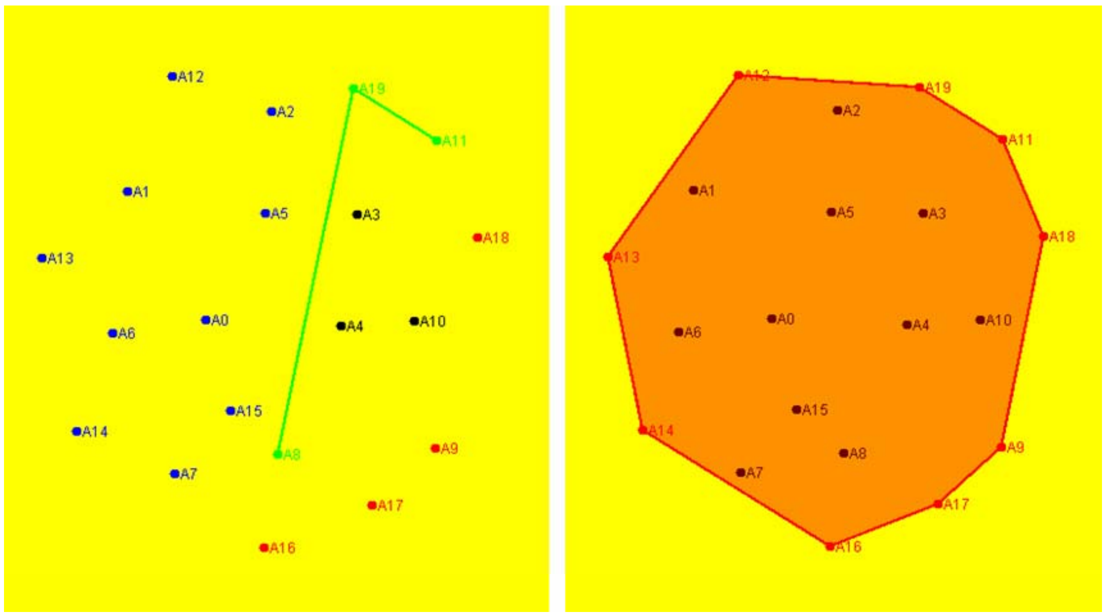


Fig. 13 Graham Algorithm

The last option of the application allows the user to open another window where the convex hull of a set of points using *Jarvis's match* algorithm (Fig. 14). This window has the same elements as the *Graham Scan*.

The application was created to facilitate the understanding of some basic concepts in computational geometry. With the help of the "Graphics2D" class, offered by the Java language, it was possible to achieve an application which simulates very realistically the necessary algorithms' steps needed to determine the requirements of each option.

The method of the class *Desen2* which presents step-by-step the Jarvis algorithm is presented forwards:

```
public void run() {
  infasuratoare=new Vector();
  infasuratoare.add(P0);
  f.setLista(P0,2);
  repaint();
  pauza(1000);
  crt=new Punct2D(P0);
  pozCrt=0;
  pas=2;
  do {
   crt=new Punct2D((Punct2D)sortare(pozCrt+1));
   infasuratoare.add(crt);
   f.setLista(crt,2);
   pozCrt=pozitie(crt);
   repaint();
   pauza(1000);
 }while(!(crt.getX()==Q.getX()&&
crt.getY()==Q.getY()));
  pas=3;
  do {
    crt=new Punct2D((Punct2D)sortare1(pozCrt-1));
    infasuratoare.add(crt);
    f.setLista(crt,2);
     pozCrt=pozitie(crt);
     repaint();
     pauza(1000);
  } while(!(crt.getX()==P0.getX()&&
crt.getY()==P0.getY()));
   pas=4;
   repaint();
   pauza(1000);
 }
```

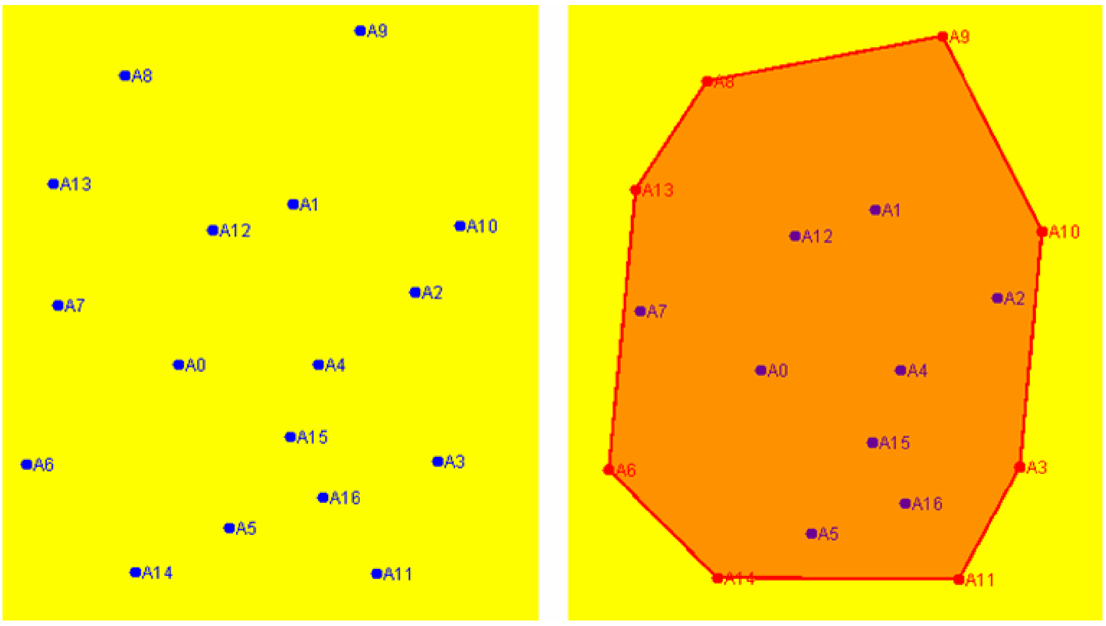


Fig. 14 Jarvis Algorithm

The convex hull of a set of points obtains with Jarvis algorithm is draw by the following method of class *Desen2*:

```
public void paint(Graphics g1) {
   g=(Graphics2D) g1;
   g.clearRect(0,0,this.getWidth(),this.getHeight());
   g.setColor(Color.yellow);
   g.fillRect(0,0,this.getWidth(),this.getHeight());
   Punct2D x;
   for (int i=0;i<puncte.size();i++)
    { x=(Punct2D)puncte.get(i);
      x.setCuloare(Color.blue);
      x.desenare(g,this.getWidth(),this.getHeight());
    }
   if (pas>=1) {
     for (int i=0;i<infasuratoare.size();i++){
        x=(Punct2D)infasuratoare.get(i);
        x.setCuloare(Color.red);
      x.desenare(g,this.getWidth(),this.getHeight());
     }
     if (pas==2||pas==3) {
        int xe1,ye1,xe2,ye2;
        Punct2D B;
        g.setColor(Color.red);
        g.setStroke(new BasicStroke(2.2f));
        for (int i=1;i<infasuratoare.size();i++) {
  B=new Punct2D((Punct2D)infasuratoare.get(i-1));
        xe1=Desen.xecran(this.getWidth(),(int)(this.
getWidth()/2),B.getX());
        ye1=Desen.yecran(this.getHeight(),(int)(this.
getHeight()/2),B.getY());
    B=new Punct2D((Punct2D)infasuratoare.get(i));
        xe2=Desen.xecran(this.getWidth(),(int)(this.
getWidth()/2),B.getX());
        ye2=Desen.yecran(this.getHeight(),(int)(this.
getHeight()/2),B.getY());
        g.drawLine(xe1,ye1,xe2,ye2);
     }
    }
    if (pas==4){
     Punct2D[] V=new Punct2D[infasuratoare.size()];
    for (int i=0;i<infasuratoare.size();i++)
V[i]=new Punct2D((Punct2D)(infasuratoare.get(i)));
     Poligon2D poligon;
     poligon=new Poligon2D(infasuratoare.size(),V);
     poligon.setCuloare(Color.red);
     poligon.desenare(g,this.getWidth(),
this.getHeight());
    }
   }}
```

4 Conclusion

Through the diagram representation all three phases: analysis, design and implementation, the educational informatics system has been described in a clear and concise manner. The use of the UML modeling language for the creation of the diagrams is characterized by rigorous syntactic, rich semantic and visual modeling support.

The diagrams were made using a new approach, multidisciplinary of the informatics application, encompassing both modern pedagogy methods and discipline-specific components. The link between teaching activities and scientific goals and objectives was established through the development of the new methods and the assimilation of new ways, capable of enhancing school performance, enabling students to acquire the knowledge and techniques required and apply them in optimum conditions.

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