

# OK Geometry

## Automated observation of dynamic constructions

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You can download OK Geometry at

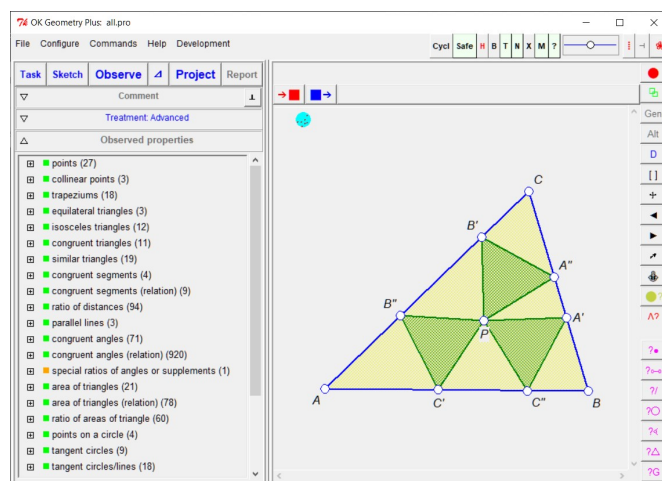
[www.ok-geometry.com](http://www.ok-geometry.com)

Please download the version **19.4.4** .

Unzip and launch OKGeometry\_19\_4.exe

Hereby shown examples are in the  
section **Adg2023examples**.

## OKG - A tool for observing dynamic constructions



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**OKG - A tool for observing dynamic constructions**

**3 working modes**

- **Easy** (lower secondary level)
- **Basic** (upper secondary level)
- **Plus**

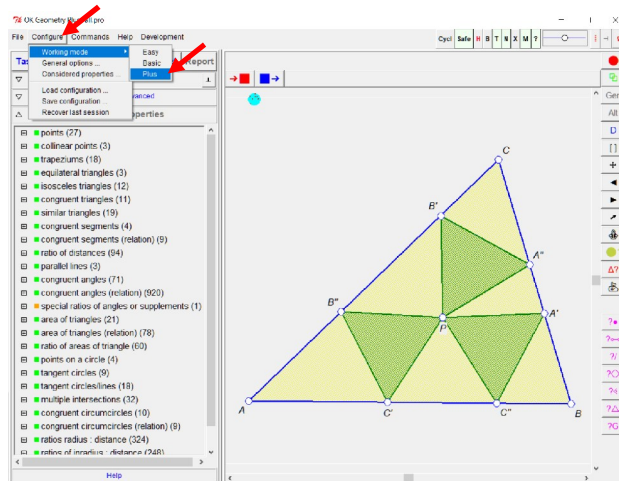
**Easy and Basic level available in**

- English
- German
- Italian
- Czech
- Slovenian

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## OKG - A tool for observing dynamic constructions



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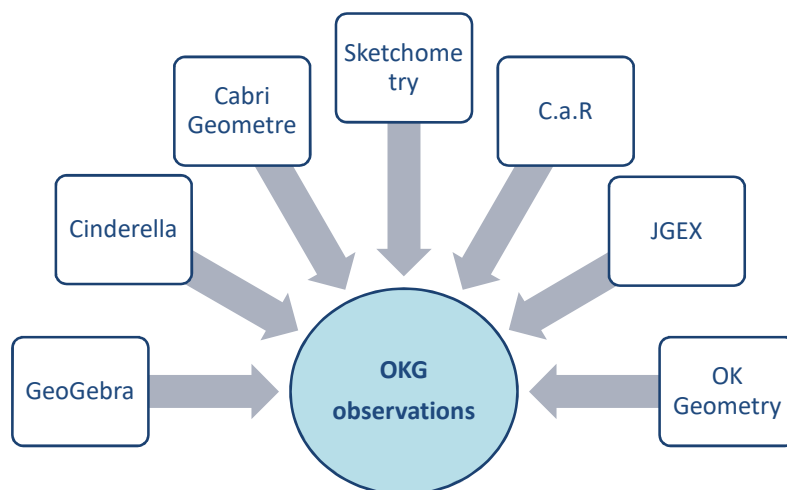
## Simple observation

- Observe properties of a dynamic construction
  - Make sense of properties and observations
  - A rationale for observing dynamic constructions
- Using observations for constructions
- Observing algebraic relations

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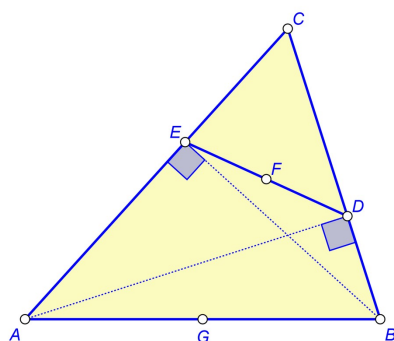
## Importing constructions from DGS



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## Observing imported constructions



Adg01.ggb  
Adg01a

- $ABC$  - a triangle
- $D$  – base of  $A$ -altitude
- $E$  – base of  $B$ -altitude
- $F$  – midpoint of  $DE$
- $G$  – midpoint of  $AB$

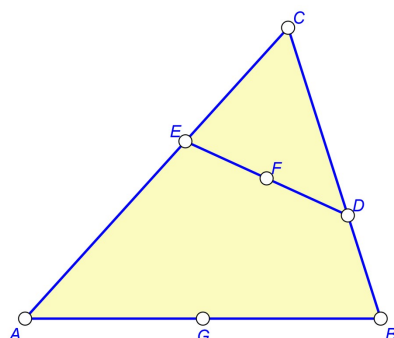
*Observe the properties of this configuration.*

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## Observing imported constructions



Adg01.ggb  
Adg01a

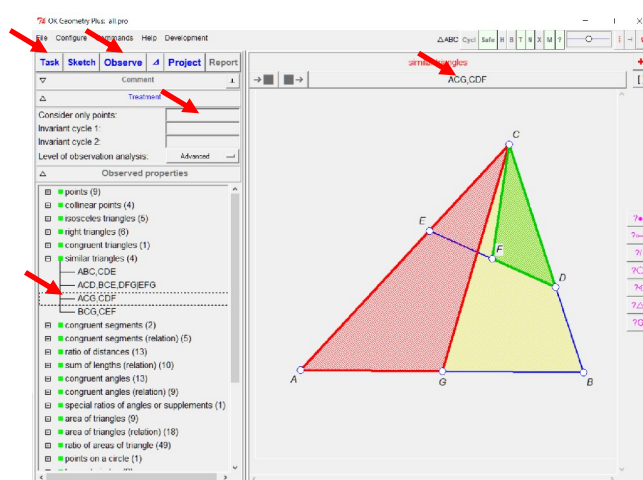
- ABC a triangle
- D – base of A-altitude
- E – base of B-altitude
- F – midpoint of DE
- G – midpoint of AB

*Observe the properties of this configuration.*

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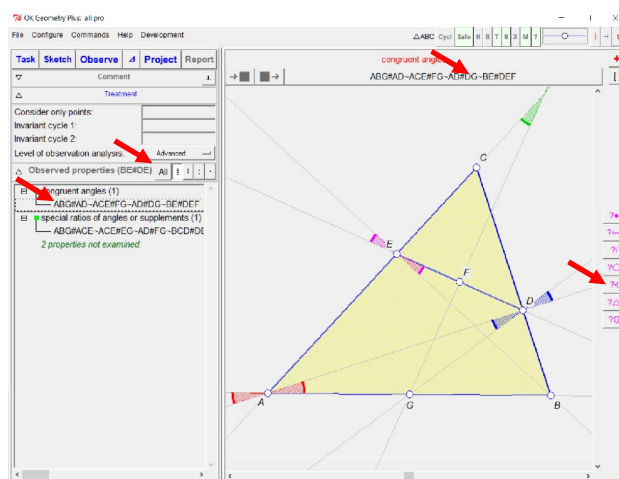
## Observing imported constructions



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## Observing imported constructions

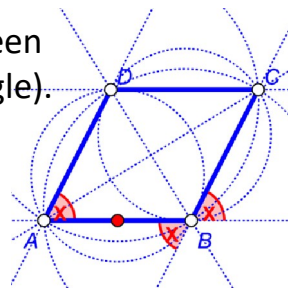


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## Understanding properties

- OKG considers the displayed objects and objects passing through **labelled points**.
- Advice: label 3-12 relevant points.
- OKG considers only angles between lines (angle  $\equiv$  supplementary angle).
- OKG ignores trivial congruences of angles between lines.



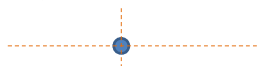
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## Models of geometry

### Static model

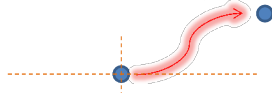
Free point  $A(3,5)$



### Dynamic model

Free point

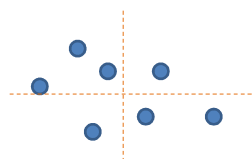
$A(3,5) \rightarrow A(x,y)$



### Stochastic dynamic model

Free point  $A(3,5) \rightarrow$

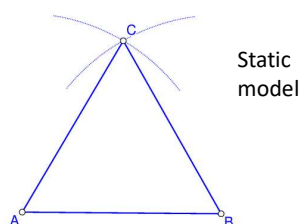
$\{(x_1, y_1), (x_2, y_2), \dots, (x_k, y_k)\}$



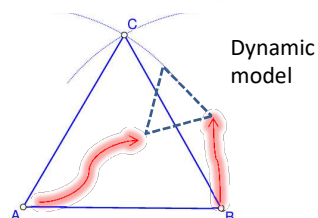
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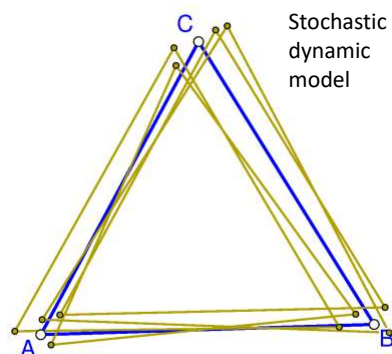
## Models of geometry



Static  
model



Dynamic  
model



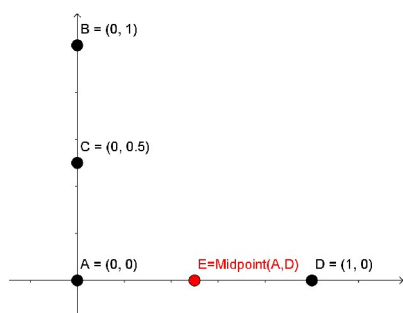
Stochastic  
dynamic  
model

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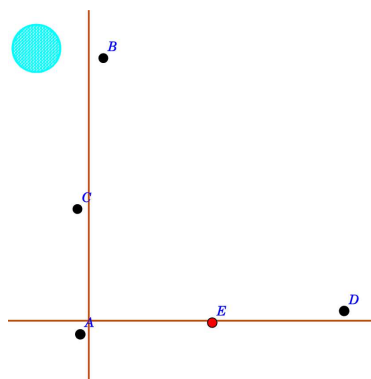
# Randomisation of constructions

## GeoGebra



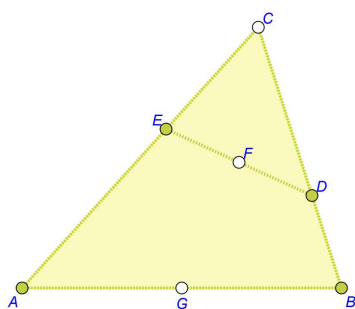
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## Instance of construction



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# Advanced observation



Adg01b

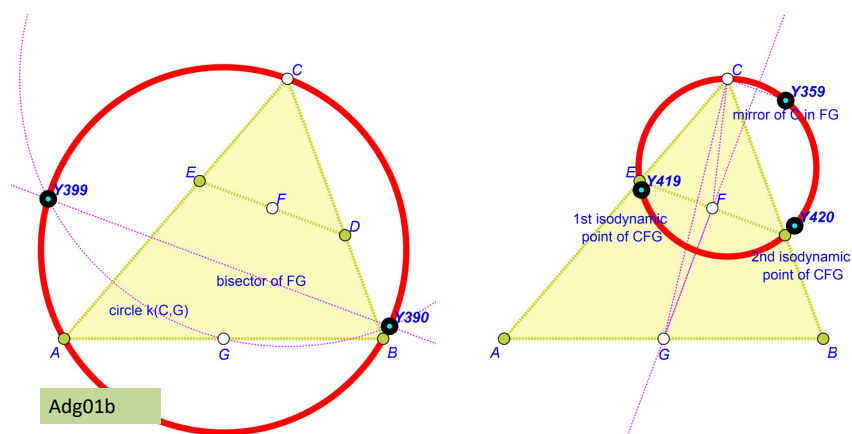
- How to **construct** the triangle  $ABC$  from known positions of points  $C$ ,  $F$ ,  $G$ .



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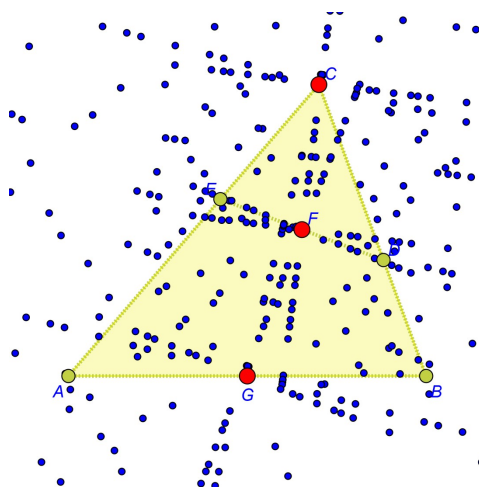
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# Advanced observation



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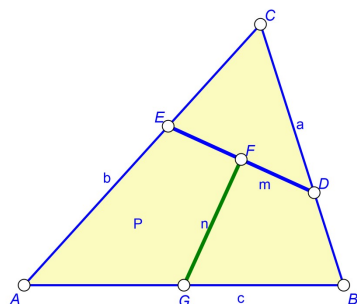
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## Observing algebraic relations



Adg01.ggb  
Adg01c

$P = \text{Area}(A,B,C)$   
 $a = \text{Distance}(B,C)$   
 $b = \text{Distance}(C,A)$   
 $c = \text{Distance}(A,B)$

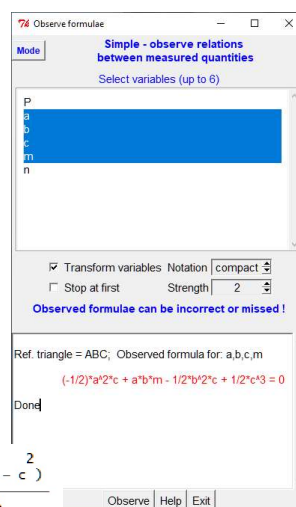
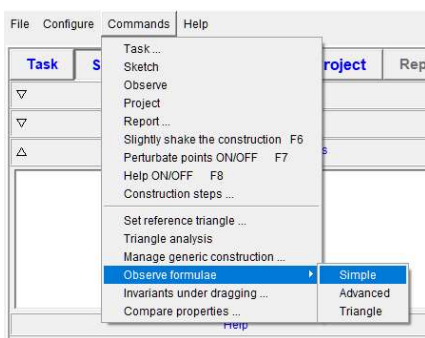
$m = \text{Distance}(D,E)$   
 $n = \text{Distance}(F,G)$

**Note.** Use explicit measurements.

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## Observing algebraic relations



$$m = \frac{c \cdot (a^2 + b^2 - c^2)}{2 \cdot a \cdot b}$$

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## Observing algebraic relations

- Consider several instances of a construction to obtain several instances of parameters ( $x_1, x_2, \dots, x_k$ ).
- Solve the a system of linear equations

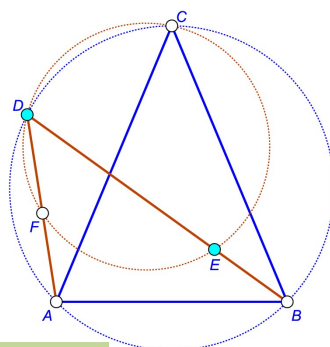
$$\sum_{n_1+n_2+\dots+n_k \leq r} \alpha_{n_1, n_2, \dots, n_k} x_1^{n_1} x_2^{n_2} \dots x_k^{n_k} = 0$$

- Technical problems...

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## Observing imported constructions (example)



Adg02

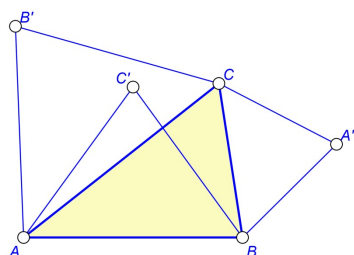
- ABC isosceles
- $D - k(A,B,C)$
- E – point on BD
- $F - AD \cap k(D,E,C)$

*Observe the  
properties.*

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## Observing imported constructions (example)



Adg03

- $ABC$  – a triangle
- $A'CB, B'AC$  – outward equilateral triangles
- $C'AB$  – inward equilateral triangle

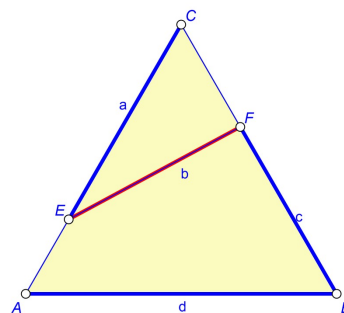
*Observe the properties.  
Construct  $ABC$  for given  
points  $A', B', C'$ .*

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## Observing formulae (example)

- $ABC$  – equilateral triangle
- Find the length  $b$  in terms of  $a, c, d$ .
- Find the Area of  $CEF$  in terms of  $a, b, d$ .



Adg04

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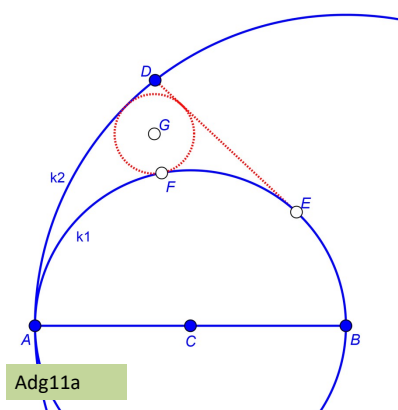
## OKG Sketch Editor

- Configuration vs. construction
- OKG observation requires (several) 'exact' configurations.
- Sketch Editor creates
  - Constructions
  - Difficult objects
  - Implicit constructions (configurations)
  - Configurations by optimisation

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## Difficult objects

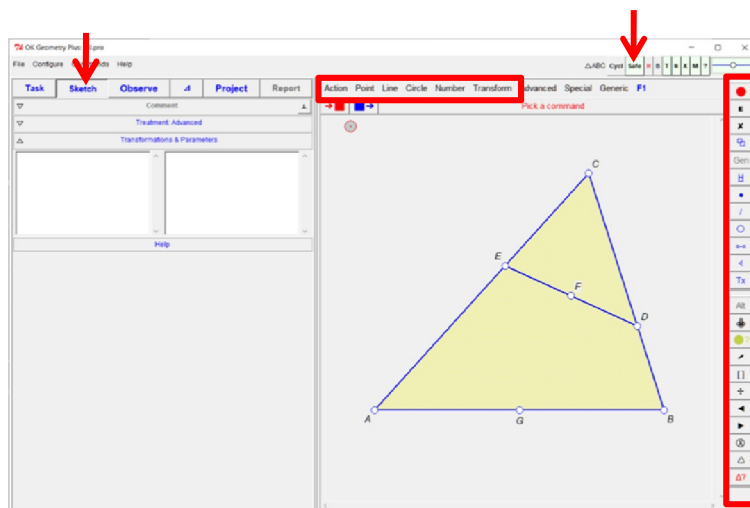


- A, B points
- C – midpoint of AB
- $k1 = k(C,A)$ ,  $k2 = k(B,A)$
- D – a point on  $k2$
- E – on  $k1$  so that DE is tangent to  $k1$  at E
- $k(G,F)$  - tangent to  $k1$  at F, DE,  $k2$

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## OKG Sketch Editor



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## OKG Sketch Editor – common buttons





	Shape objects		Safe objects
	Hide objects		Alternative objects
	Delete objects		Anchor
	(Scenes,...)		(Mark Unknown)
	(Generic view)		Drag point
	Label points		Zoom view ...
	Point, Intersection, Midpoint		Move view
	Line, <b>Line 2 obj</b>		Undo
	Circle, <b>Circle 3 obj, ...</b>		Redo
	Segment, Perp.seg., Polyline		Redefine
	Angle, Various decorations		(Declare cyclic)
	Text		(Triangle analysis)

**F8 – Help  
ON/OFF**

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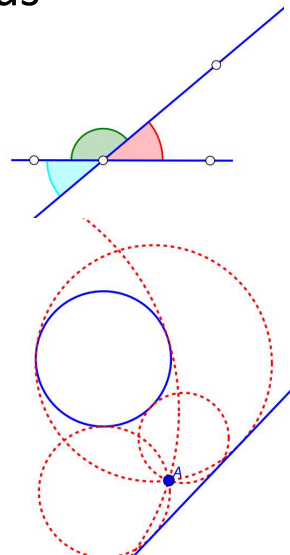
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## OKG Sketch Editor – special commands

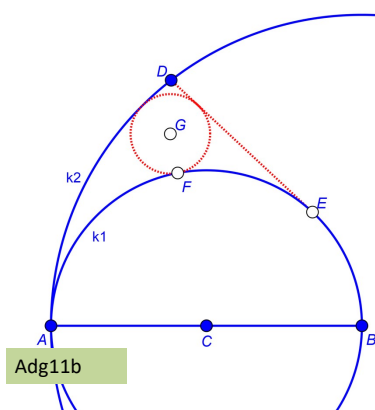
	<b>Safe ON</b>	When necessary, segments are treated as lines, arcs as circles.
	<b>Alt</b> (try mouse scroll)	Press repeatedly for alternative solutions.
	<b>Anchor</b> (otrymouse scroll)	Press repeatedly for different ways of representation of objects,
	<b>Line 2 objects</b> + <b>Alt</b> (try mouse scroll)	Line defined by 2 objects in terms of 'passing through', 'is parallel', 'is tangent', 'is radical axis'.
	<b>Circle 3 objects</b> + <b>Alt</b> (try mouse scroll)	Circle defined with 3 objects in terms of 'passing through', 'is tangent'.

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## Difficilt objects

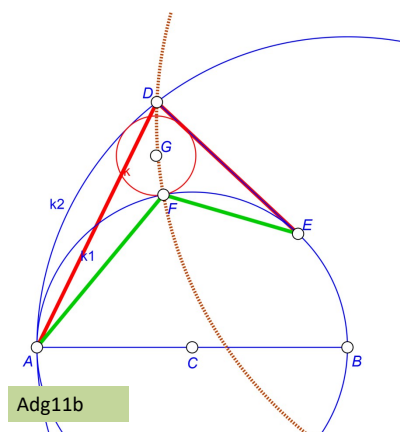


Adg11b

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- A, B points
- C – midpoint of AB
- $k_1 = k(C,A)$ ,  $k_2 = k(B,A)$
- D – a point on  $k_2$
- E – on  $k_1$  so that DE is tangent to  $k(C,A)$
- $k(G,F)$  - tangent to  $k_1$  at F, DE,  $k_2$

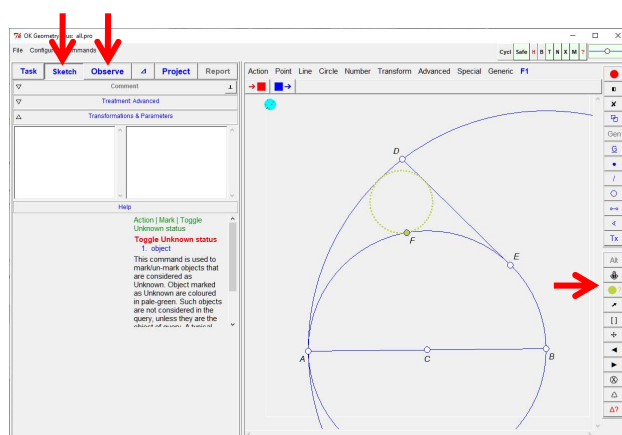



$$|AF| : |EF| = \\ = |AD| : |ED| = \sqrt{2} : 1$$

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## Advanced observation

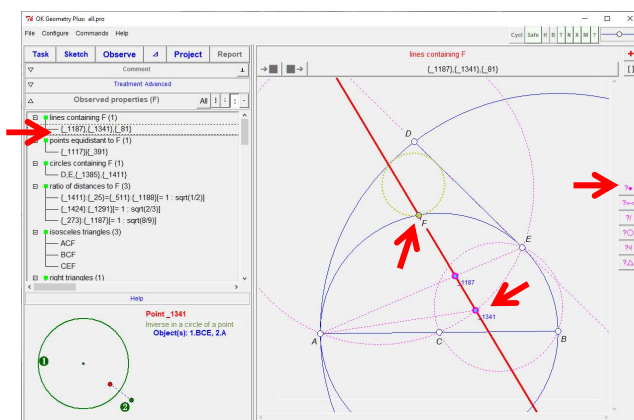



Use  to mark objects you don't know how to construct. Then Observe.

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## Advanced observation



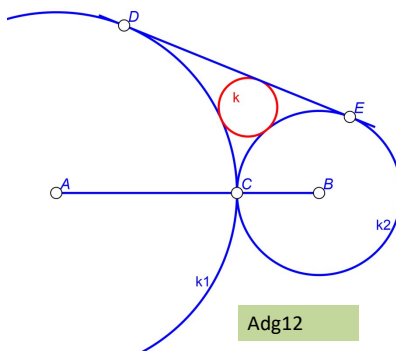
Query   
 point F.  
 Select a  
 property.  
 Show \_points  
 (e.g. \_1341  
 is the  
 inverse of  
 A in  
 $k(B,E,C)$  ).

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## Observing formulae (example)

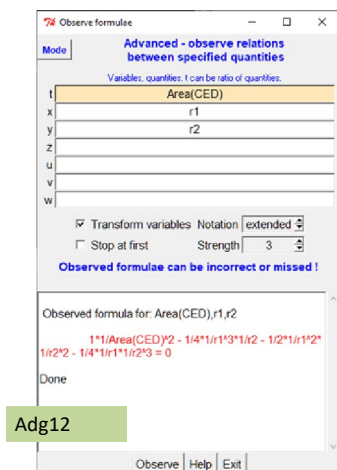
- Circles  $k_1(A,C)$  and  $k_2(B,C)$  touch externally at C.
- $D \in k_1$ ,  $E \in k_2$ , so that the line DE is tangent to  $k_1$  and  $k_2$ .
- Circle  $k$  is tangent to DE,  $k_1$  and  $k_2$ .
- Let  $r_1, r_2$  be the radii of  $k_1, k_2$ . Find
  - $|DE|$
  - the radius  $r$  of the circle  $k$
  - the area of triangle CDE.



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## Observing formulae (example)

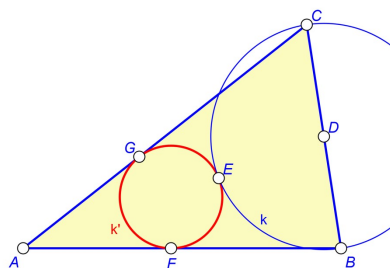


- In the advanced and triangle mode of Formulae observation you can specify quantities directly (see Help).
- To amplify the range of formulae, apply Transformation of variables and/or increase strength.

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## Create and analyse configuration (example)



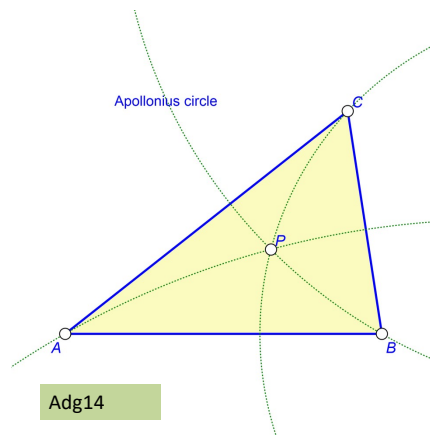
Adg13

- ABC – an acute triangle
- $k = k(D, B)$  – circle with diameter BC
- $k'$  – a circle inscribed in the 'triangle' bound by AB,  $k$  and CB.
- How to construct the points E, F, G and the circle  $k'$ ?
- Find the radius of  $k'$ .

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## Create and analyse configurations (example)



Find alternative constructions for the 1st isodynamic point of a triangle.

Adg14

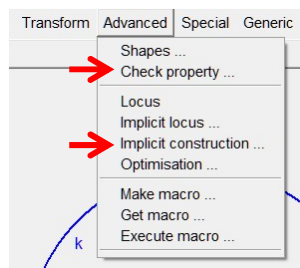
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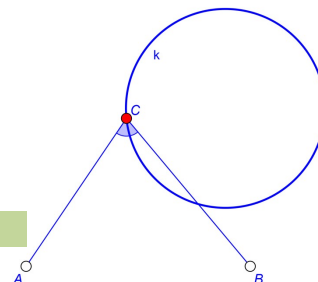
## Implicit constructions

Obtain a configuration by dragging one or more objects in order to satisfy **additional conditions**.

- A, B points
- $k$  circle
- C a point on  $k$
- $\angle ACB$  is right

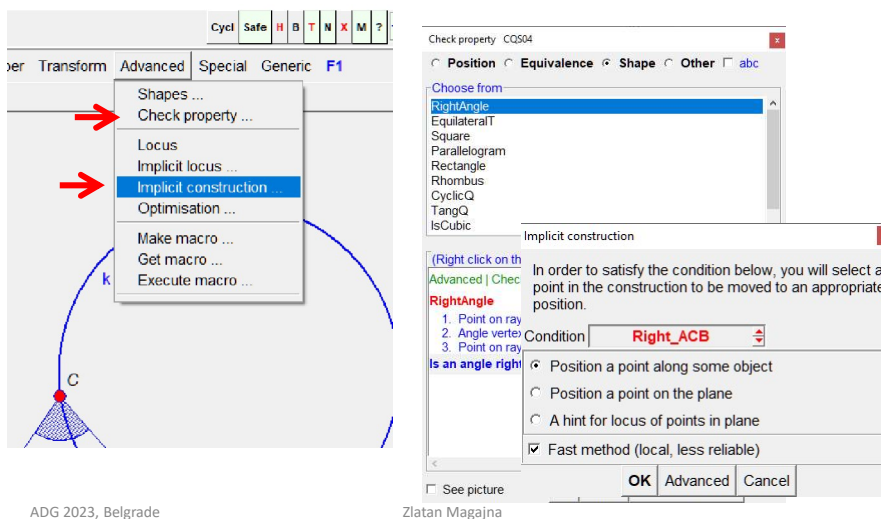


Adg21



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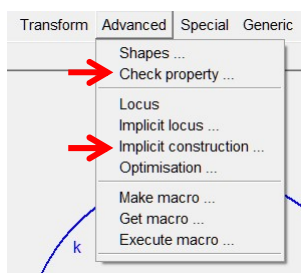
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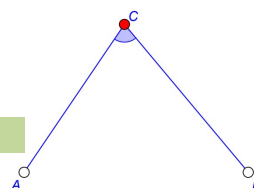
## A hint for locus

Obtain a hint for locus of points on a plane satisfying a condition.

- A, B points
- C point
- $\angle ACB$  is right



Adg22



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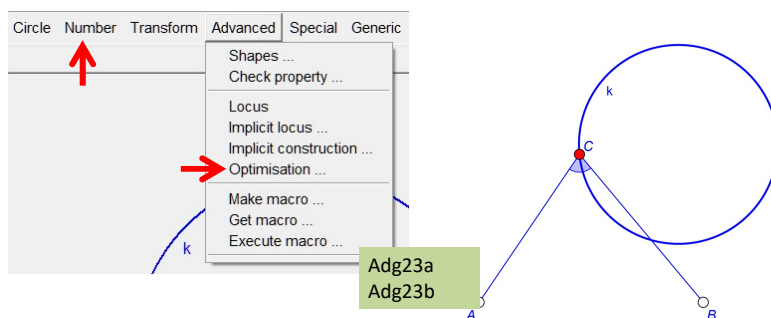
Zlatan M



## Constructions by optimisation

Drag one or more objects in order to optimise a parameter.

- A, B points
- k circle
- C a point on k
- $\angle ACB$  is maximal



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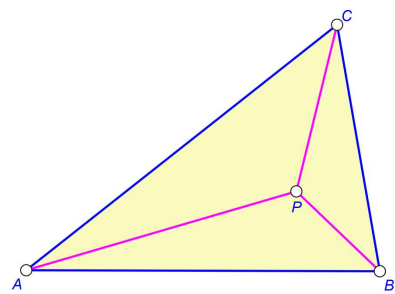
## Triangle geometry

- Observe objects wrt. reference triangle
- Drawing triangle objects
- Glossary of triangle objects
- Observing algebraic relations in a triangle

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# Triangle observation



Adg26

ABC – **reference triangle**

P – point on plane that  
minimises

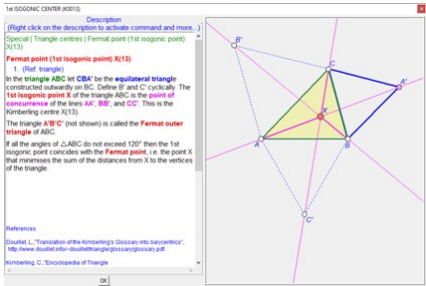
$|AP| + |BP| + |CP|$ .

Analyse Δ? P wrt. the  
**reference triangle** ABC.

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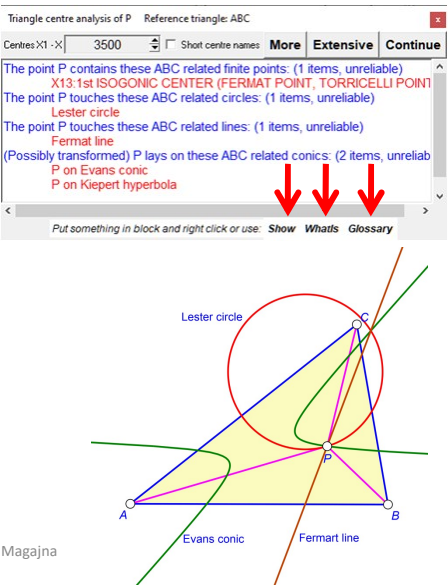
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# Triangle observation



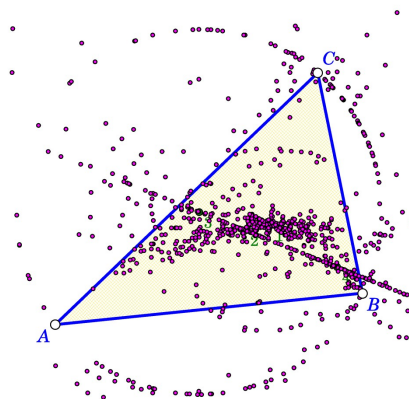
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## Triangle centres and transformations

- >50.000 centres
- >30 transformations
- ~500.000 transformed centres
- millions of lines connecting the centres

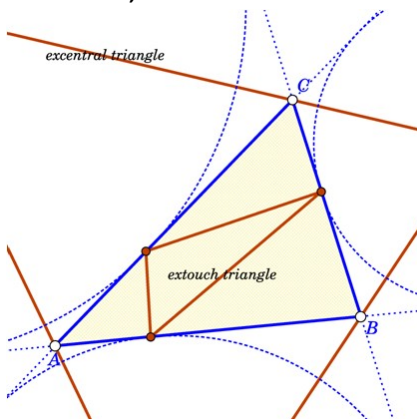


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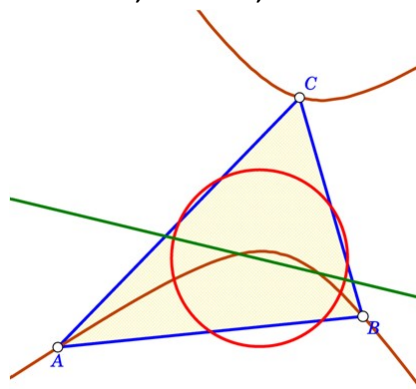
## Triangle objects

~ 230 considered triangles →  
 >2000 lines, >6000 circles



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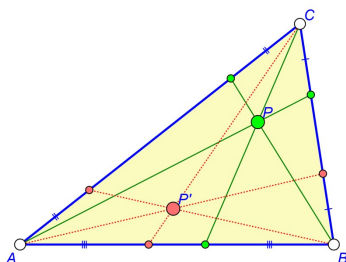
~ 30 considered lines  
 ~100 circles, ~40 conics, ~1300 cubics



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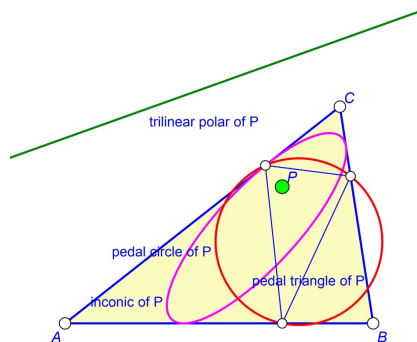
# Triangle centres and transformations

Triangle transformations  
(e.g. isotomic conjugation)



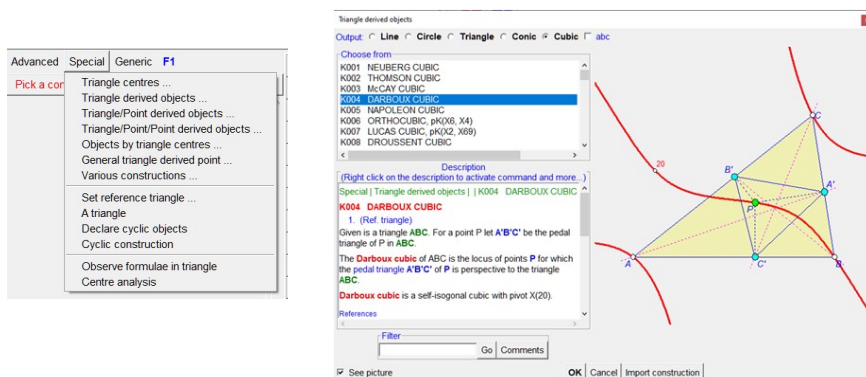
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Triangle-Point objects



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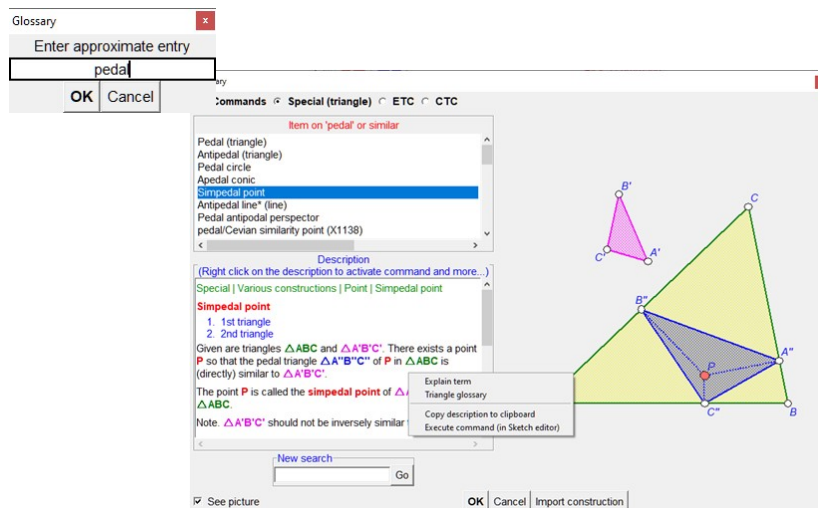
## Triangle objects



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# Glossary

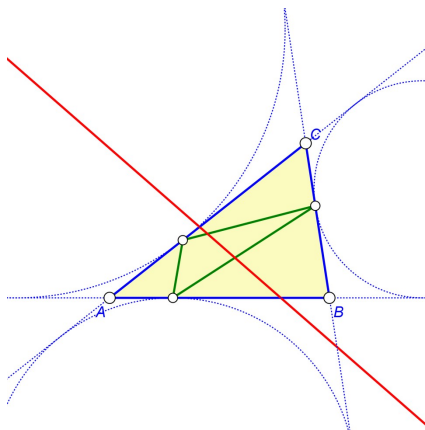


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## Triangle objects

- Given is a triangle ABC.
- Draw the Euler line of the extouch triangle of ABC.

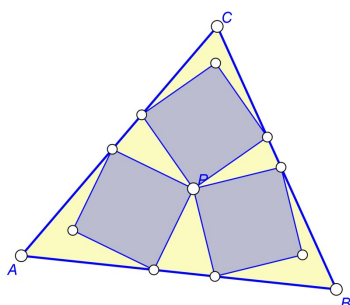


Adg32a  
Adg32b

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## A nice point



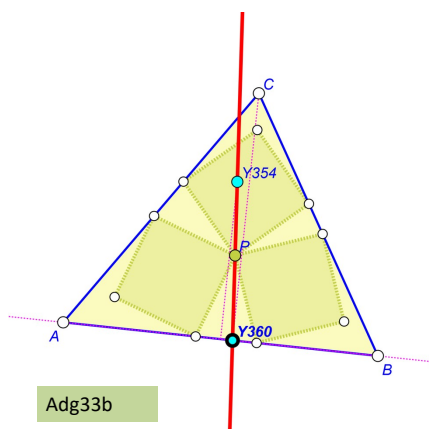
Adg33a

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- How to inscribe 3 congruent squares into a given triangle ABC as shown on the left?
- To obtain a configuration, draw first P and the 3 squares, then 'circumscribe' a triangle.
- Analyse the point P in the reference triangle ABC.

## A nice point



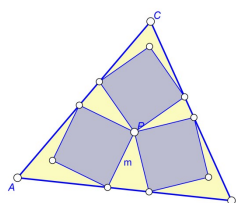
Adg33b

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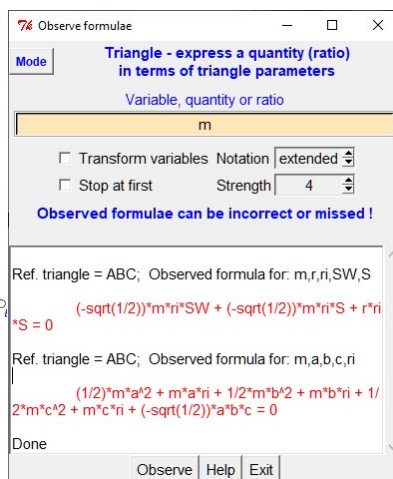
- Y354 = Local coordinates  $x = 1/2$ ,  $y = 1/2$ ; Object(s): A,B
- Y360 = Projection onto line of point; Object(s): AB,C

## A nice point



Adg33c

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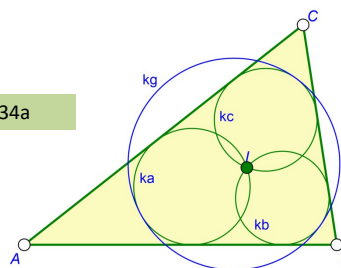


Hypothesise the size  $m$  of squares in terms of common triangle quantities.

## Create and observe triangle objects (example)

- ABC – triangle
- I – incentre of ABC
- $ka$  – circle through I and touching AB and CA;  $kb$ ,  $kc$  are defined cyclically
- $kg$  touches internally  $ka$ ,  $kb$  and  $kc$  in  $A'$ ,  $B'$ ,  $C'$ .
- **Observe** the radii of  $ka$ ,  $kb$ ,  $kc$ .
- Observe the relation between radii of  $ka$ ,  $kb$ ,  $kc$ ,  $kg$ .

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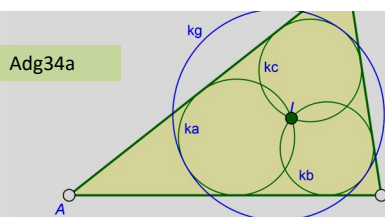
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## Create and observe triangle objects (example)

- $ABC$  – triangle
- $I$  – incentre of  $ABC$
- $ka$  – circle through  $I$  and touching  $AB$  and  $CA$ ;  $kb$ ,  $kc$  are defined cyclically
- $kg$  touches internally  $ka$ ,  $kb$  and  $kc$  in  $A'$ ,  $B'$ ,  $C'$ .
- **Observe** the radii of  $ka$ ,  $kb$ ,  $kc$ .
- Observe the relation between radii of  $ka$ ,  $kb$ ,  $kc$ ,  $kg$ .

$$\frac{1}{r_g} = \frac{2 \cdot \left( \left( \frac{1}{r_a} \right)^2 \cdot \left( s - \frac{1}{r_a} \right) + \left( \frac{1}{r_b} \right)^2 \cdot \left( s - \frac{1}{r_b} \right) + \left( \frac{1}{r_c} \right)^2 \cdot \left( s - \frac{1}{r_c} \right) \right)}{2 \cdot s \cdot \left( s - \frac{1}{r_c} \right) \cdot \left( s - \frac{1}{r_a} \right) \cdot \left( s - \frac{1}{r_b} \right)}$$

$$s = \frac{\frac{1}{r_a} + \frac{1}{r_b} + \frac{1}{r_c}}{2}$$

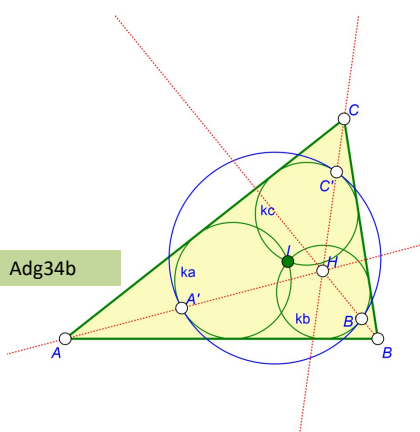


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## Create and observe triangle objects (example)

- $ABC$  – triangle
- $I$  – incentre of  $ABC$
- $ka$  – circle through  $I$  and touching  $AB$  and  $CA$ ;  $kb$ ,  $kc$  are defined cyclically
- $kg$  touches internally  $ka$ ,  $kb$  and  $kc$  in  $A'$ ,  $B'$ ,  $C'$ .
- **Observe:**  $AA'$ ,  $BB'$ ,  $CC'$  concur at  $H$ . Analyse  $H$  in  $ABC$ .



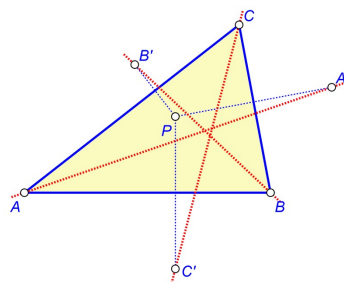
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## Example of a triangle locus

- $A', B', C'$  are the mirror images of a point  $P$  in the sides of triangle  $ABC$ .
- For what points  $P$  are the lines  $AA', BB', CC'$  concurrent?



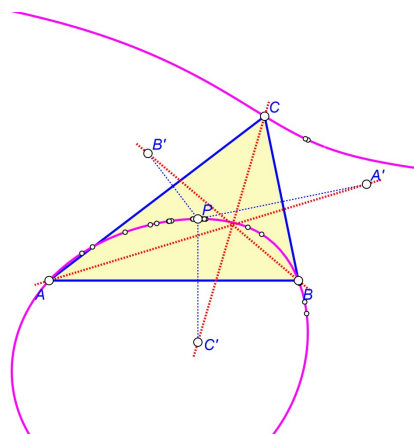
Adg35a

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## Example of a triangle locus

- $A', B', C'$  are the mirror images of a point  $P$  in the sides of triangle  $ABC$ .
- For what points  $P$  are the lines  $AA', BB', CC'$  concurrent?



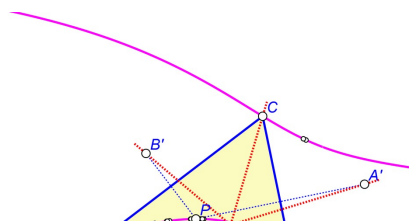
Adg35b

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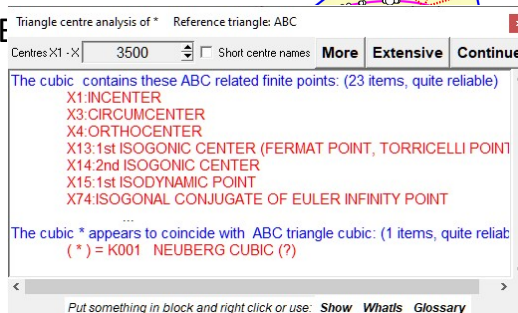
## Example of a triangle locus

- $A', B', C'$  are the mirror images of a point  $P$  in the sides of triangle  $ABC$ .
- For what points  $P$  are the lines  $AA', B'$  concurrent?



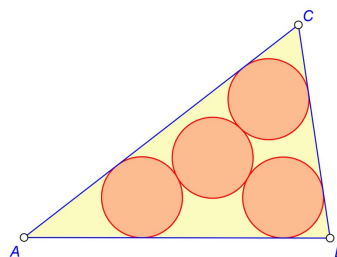
Adg35b

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## 4 congruent circles (example)

- Inscribe 4 congruent circles into a given acute triangle  $ABC$  as shown in the figure.

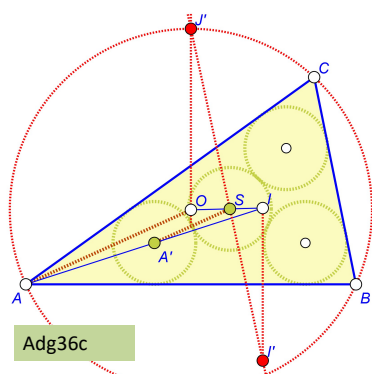


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## 4 congruent circles (example)



### Solution

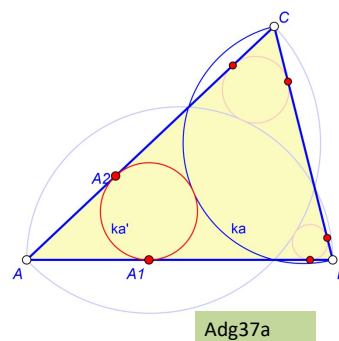
- $O$  - circumcentre of  $ABC$
- $I$  - incentre of  $ABC$
- $I'$  – mirror image of  $I$  in  $AB$
- $J'$  – intersection of circumcircle of  $ABC$  and bisector of  $AB$
- $S$  – intersection of  $OI$  and  $I'J'$
- $A'$  – lays on  $AI$
- $A'S \parallel AO$
- Can be proved with JGEX.
- The observed radii of the circles are  $R \cdot r / (R + 2r)$ , which is easy to prove.

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## Cyclic constructions

- $ABC$  – an acute triangle
- $ka$  – the inwards semicircle on  $BC$
- $ka'$  – the smallest of circles touching  $AB$ ,  $AC$ , and (externally)  $ka$
- $kb'$ ,  $kc'$  – defined cyclically
- Investigate the points of contact of  $ka'$ ,  $kb'$ ,  $kc'$  with the sidelines of  $ABC$ .

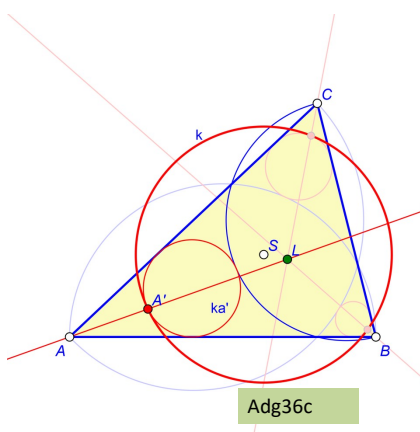


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## Cyclic constructions

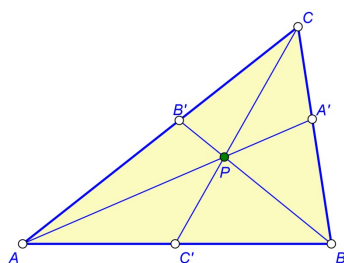
- $k$  – circle that touches internally  $ka'$ ,  $kb'$ ,  $kc'$
- $A'$  – point of contact of  $ka'$  and  $k$
- $B'$ ,  $C'$  – defined cyclically
- Investigate the circle  $k$  (its centre  $S$ , the radius)
- Analyse the observed point of concurrence  $L$  of  $AA'$ ,  $BB'$ ,  $CC'$ .



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## Equal Cevians (example)



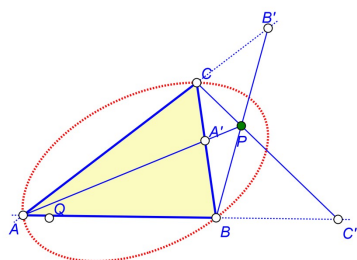
Adg38a

- $ABC$  – a triangle
- $P$  – a point
- $AA'$ ,  $BB'$ ,  $CC'$  – Cevian lines of  $P$  in  $ABC$ .
- Is there a point  $P$  for which the Cevian lines  $AA'$ ,  $BB'$ ,  $CC'$  are congruent? Investigate!

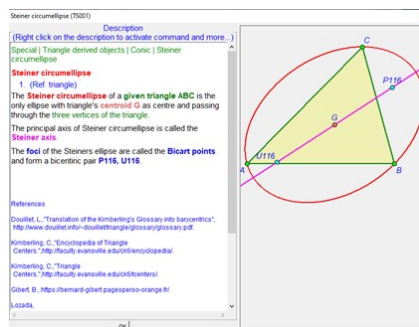
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## Equal Cevians (example)



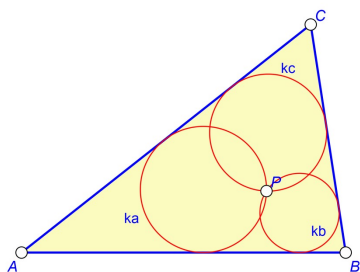
Adg38b



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## 3 circles (example)

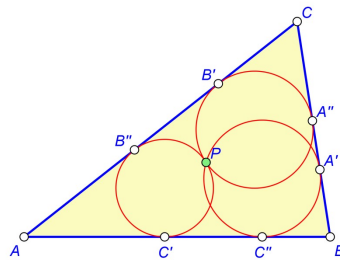
Adg39a  
Adg39b

- ABC - a triangle
- P - a point
- $ka$  – circle through P and touching the sides CA and AB.
- $kb, kc$  – defined cyclically.
- Analyse the case when  $ka, kb, kc$  are congruent.

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## 3 circles (example)



Adg39c  
Adg39d

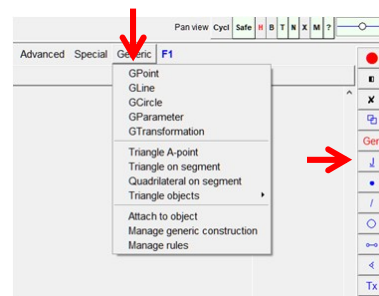
- ABC - a triangle
- P - a point
- $ka$  – circle through P touching the sides CA and AB.
- $kb, kc$  – defined cyclically.
- For what P are  $A'B'C'A''B''C''$  cocircular/coconical?

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## Generic constructions

- Generic constructions are constructionally isomorphic families of dynamic constructions.
- Generic constructions appear and behave like ordinary constructions, where some construction steps consist of rules (i.e. groups of isomorphic operations).

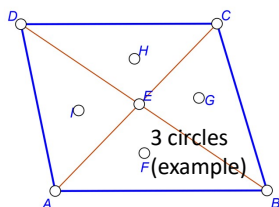


All resulting constructions can be visualised, analysed, checked for properties, etc. at the same time.

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## Generic constructions – constructionally isomorphic configurations



1. ABCD – a **trapezium**
2.  $E = AC \cap BD$
3. F, G, H, I **incentres** of the 4 triangles (ABE, BCE, CDE, DAE)

**1. Quadrilateral** →  
Random,  
bicentric, cyclic,  
equidiagonal, ...)

Adg41

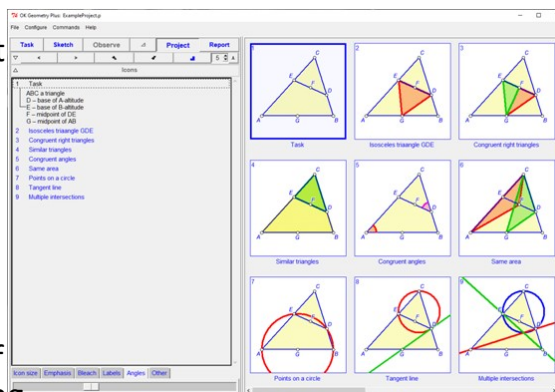
**3. incentres** →  
incentre, centroid,  
circumcentre,  
orthocentre, ...

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## Projects

- You can collect constructions, part of constructions, results, etc. into a project.
- A project may contain related constructions, observed properties, a proof of a claim, a proving task, etc.

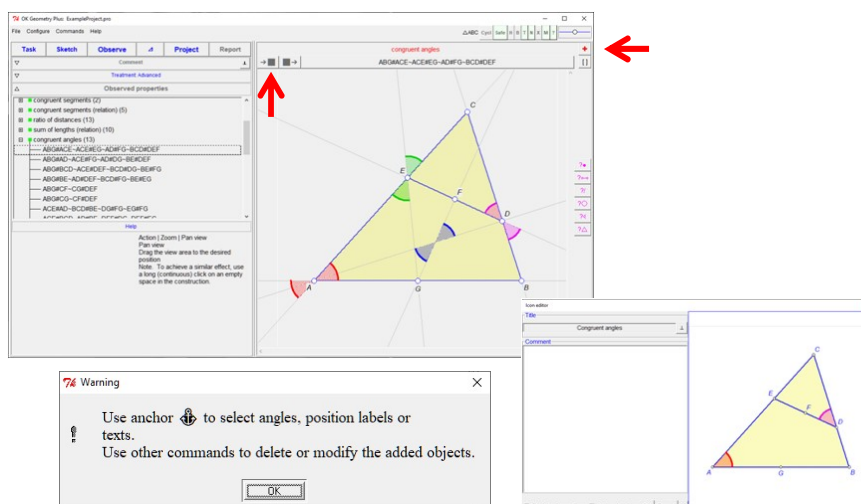


AdgProperties.pro

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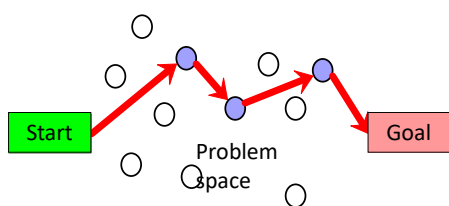
## Saving properties



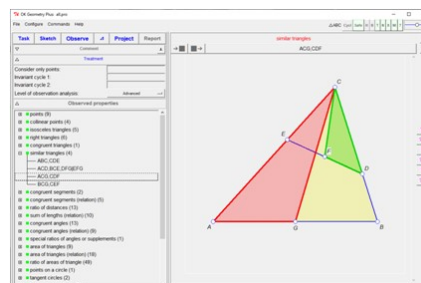
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## Proving tasks



- Observe properties
- Select relevant properties
- Organise the properties
- Provide deductive argumentation

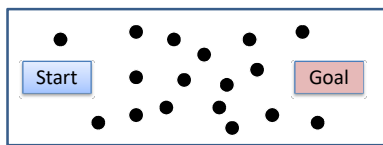
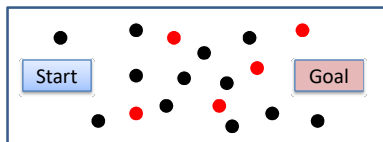
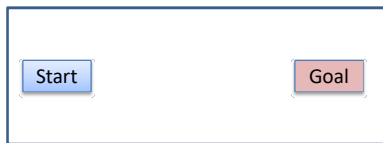


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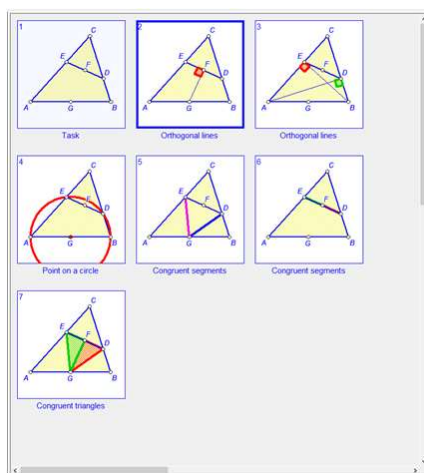
Does a given  
problem space  
help?



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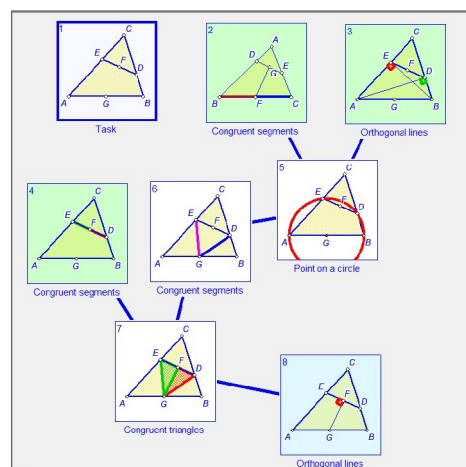
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## Proving

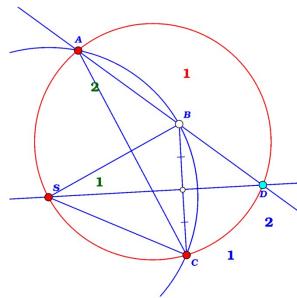


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AdgProofTask.pro



Task

1 Task

Given is a circle with centre S and three points, A, B, C on its circumference. Let D be the intersection of the line AB and the bisector of the chord BC. Prove that S, C, D, and A are cocyclic.

Comment:

2 Proof

**Definition** Let E be the midpoint of BC.

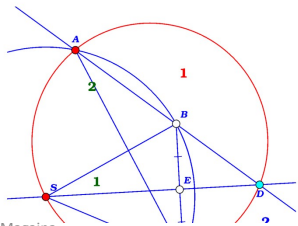
**Claim 1**  $\angle CSB = 2 \cdot \angle CSD$

**Argument 1** First, note that S lies on the bisector of segment BC (since  $|SB| = |SC|$ ). Let E be the midpoint of BC. The triangles AEB and SEC are congruent by sss. Thus  $\angle CSE = \angle ESB$

and consequently  $\angle CSB = 2 \cdot \angle CSD$ .

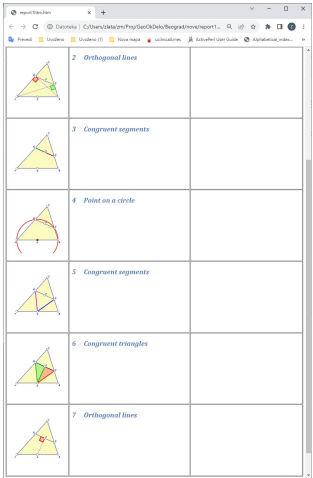
**Claim 2**  $\angle CAB = \angle CSD$

**Argument 2** The arc BC of the circle  $k(S, A)$  spans an inscribed angle  $\angle CAB$  and the central angle  $\angle CSB$ . By a known theorem

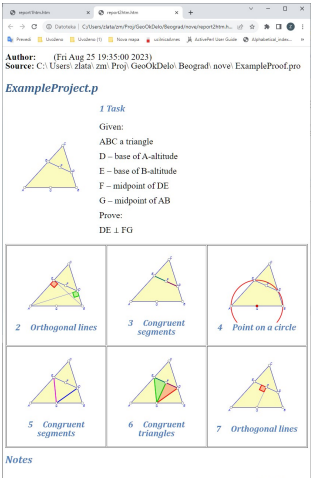


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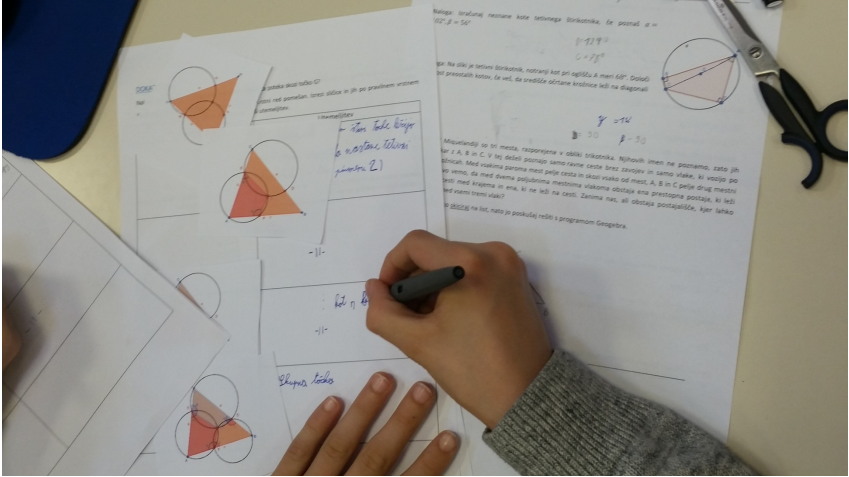
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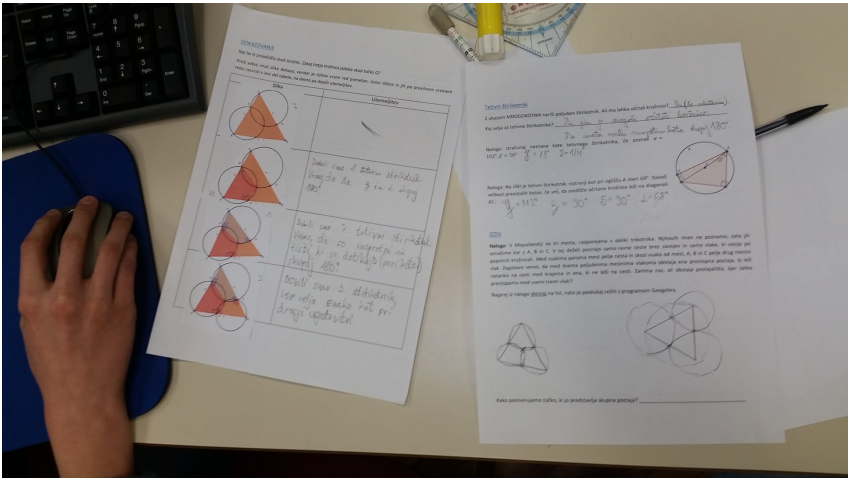


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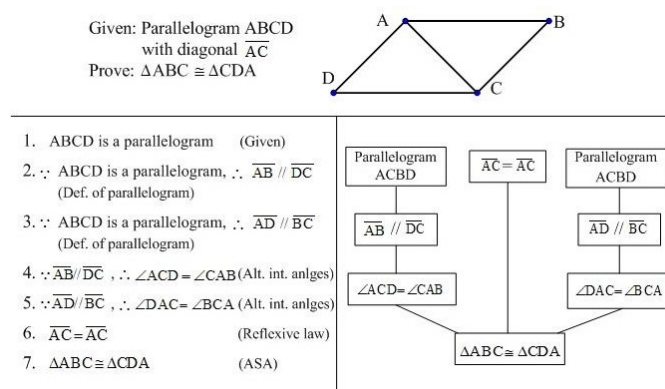
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## Multiple representations – Mr Geo (Wong, Yin, Yang, Cheng, 2011)



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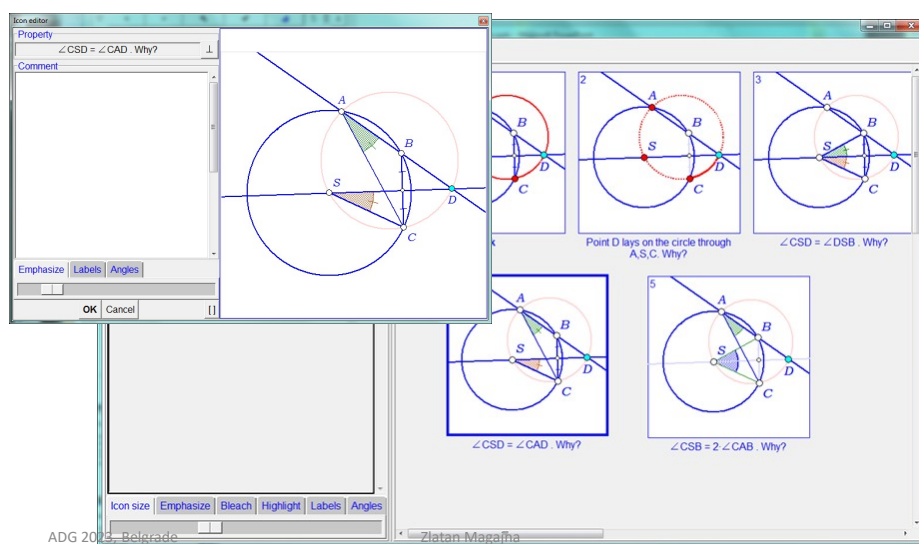
## Technology and writing up proofs

- Various dimensions of comprehending proofs (Weber, Selden,...)
- Various levels of comprehending proofs (Lin)
- Various presentation modes (Herbst, Wong,...)
- Various specific tools
- Meaning of terms and statements
- Justification of claims
- Logical structure (proof framework)
- High level ideas (structure of proof)
- General method
- Application of proof

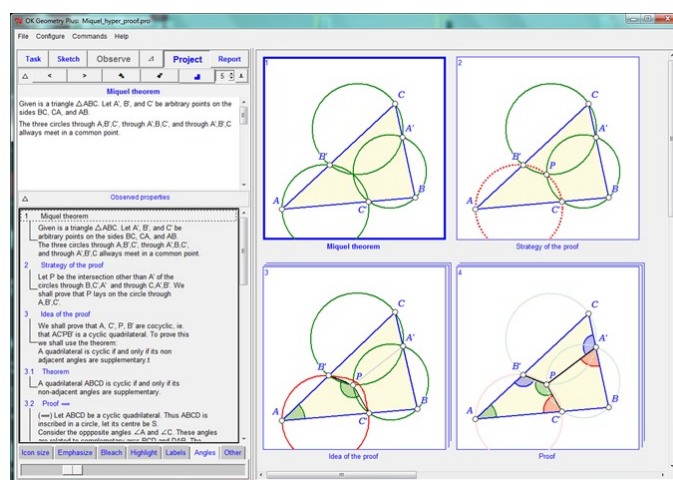
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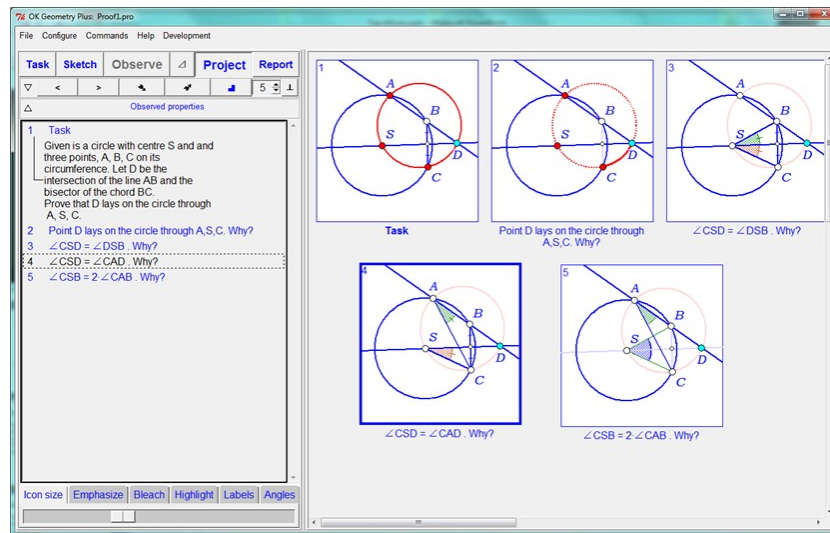
## Justification of claims



## High-level ideas



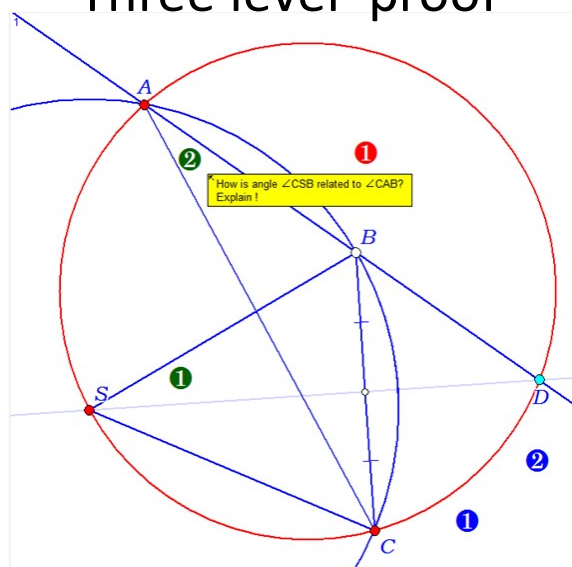
# Chaining elements



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## 'Three level' proof



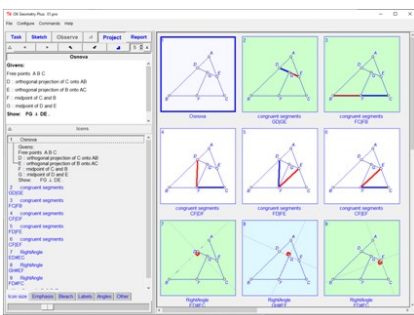
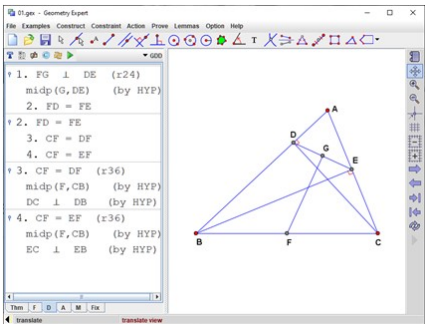
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# Importing proofs JGEX → OKG

JGEX

OKG

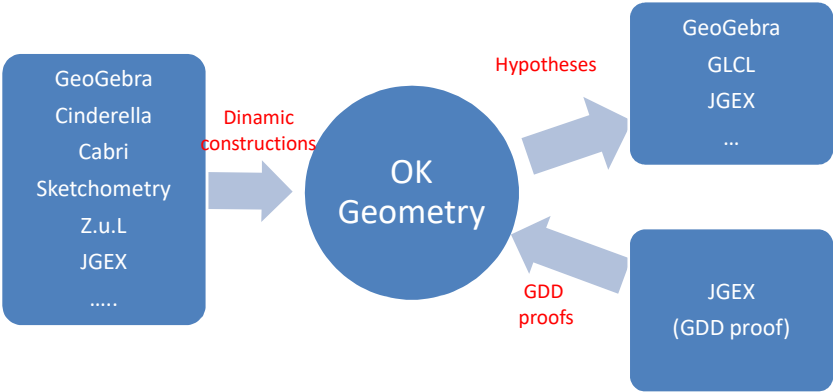


AdgJGEXTask.pro

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## OKG and DG tools



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