

### Some claims concerning a tetrahedron ABCP based on an acute triangle ABC

Scale and position the tetrahedron so that the coordinates of A, B and C are  $(x_1, y_1, 0)$ ,  $(x_2, y_2, 0)$ ,  $(x_3, y_3, 0)$ , respectively, with  $x_j = \cos \phi_j, y_j = \sin \phi_j$  ( $j = 1, 2, 3$ ) and  $\phi_1 + \phi_2 + \phi_3 = 0$ .

Define the following:

$$\angle A = \angle CAB, \angle B = \angle ABC, \angle C = \angle BCA, \alpha = \angle BPC, \beta = \angle CPA, \gamma = \angle APB,$$

$$C_0 = \cos \alpha \cos \beta \cos \gamma, C_1 = \cos^2 \alpha, C_2 = \cos^2 \beta, C_3 = \cos^2 \gamma,$$

$$L = 2 [(y_1 + y_2 + y_3)(1 - C_0) + (1 - x_1)y_1(C_1 - 1) + (1 - x_2)y_2(C_2 - 1) + (1 - x_3)y_3(C_3 - 1)],$$

$$R = 2 [(1 + x_1 + x_2 + x_3)(1 - C_0) + (1 + x_1)x_1(C_1 - 1) + (1 + x_2)x_2(C_2 - 1) + (1 + x_3)x_3(C_3 - 1)],$$

$$H = 1 + 2C_0 - C_1 - C_2 - C_3, \quad E = L^2 + (R+H)^2,$$

$$D = E^2 + 18EH^2 + 8(R+H)H[(R+H)^2 - 3L^2] - 27H^4.$$

The following (proven) constraints hold:

1.  $H > 0$  (which is equivalent to  $\alpha + \beta + \gamma < 2\pi$ ,  $\alpha < \beta + \gamma$ ,  $\beta < \alpha + \gamma$ ,  $\gamma < \alpha + \beta$ );
2.  $\angle A + \beta + \gamma < 2\pi$ ,  $\alpha + \angle B + \gamma < 2\pi$ ,  $\alpha + \beta + \angle C < 2\pi$ ;
3.  $\beta + \gamma - \alpha < 2(\angle B + \angle C)$ ,  $\gamma + \alpha - \beta < 2(\angle C + \angle A)$ ,  $\alpha + \beta - \gamma < 2(\angle A + \angle B)$ ;
4.  $\alpha < \angle A \rightarrow [\beta < \max\{\angle B, \angle C + \alpha\} \wedge \gamma < \max\{\angle C, \angle B + \alpha\}]$ ,  
 $\beta < \angle B \rightarrow [\gamma < \max\{\angle C, \angle A + \beta\} \wedge \alpha < \max\{\angle A, \angle C + \beta\}]$ ,  
 $\gamma < \angle C \rightarrow [\alpha < \max\{\angle A, \angle B + \gamma\} \wedge \beta < \max\{\angle B, \angle A + \gamma\}]$ ;
5.  $\alpha < \angle A \rightarrow \cos \angle C \cos \beta + \cos \angle B \cos \gamma > 0$ ,  
 $\beta < \angle B \rightarrow \cos \angle A \cos \gamma + \cos \angle C \cos \alpha > 0$ ,  
 $\gamma < \angle C \rightarrow \cos \angle B \cos \alpha + \cos \angle A \cos \beta > 0$ ;
6.  $(D > 0 \wedge \alpha < \angle A) \rightarrow (\beta < \angle B \vee \gamma < \angle C)$ ,  
 $(D > 0 \wedge \beta < \angle B) \rightarrow (\gamma < \angle C \vee \alpha < \angle A)$ ,  
 $(D > 0 \wedge \gamma < \angle C) \rightarrow (\alpha < \angle A \vee \beta < \angle B)$ ;
7.  $D > 0 \rightarrow [\alpha < \angle A \vee \alpha > \pi - \angle A \vee \beta < \angle B \vee \beta > \pi - \angle B \vee \gamma < \angle C \vee \gamma > \pi - \angle C]$ .

Also, experimental evidence strongly suggests that this collection of constraints is necessary and sufficient for a suitable tetrahedron ABCP to exist for a given acute triangle ABC. At present though, the sufficiency claim is only a conjecture. (Note: the right arrows mean logical implication here.)