بسم الله الرحمن الرحيم

AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region

طاقة الشمال
North Lebanon Alternative Power
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برنامج رقمي هدفه حساب و محاكاة عملية الحرق و ديناميكية الموائع الحسابية (CFD)
Framework + Graphical User Interface (GUI), CFD + Numerical combustion

مدخل: استجابة لحاجة المستخدم الكبيرة والتطورات الأخيرة في مجالات ديناميكية السوائل العددية (CFD) ونمذجة عملية الاحتراق (numerical combustion) التي تشتمل على عدد من العمليات الفيزيائية والكيميائية المعقدة والمرتبطة بشكل وثيق تقرر برمجة كود لديه القدرة على حساب مثل هذه التدفقات في المحارق.. وتشمل ديناميكيات عابرة ثلاثية الأبعاد لتبخير بخاخ الوقود تتفاعل مع تدفق الغازات المتعددة المكونات التي تمر بالاختلاط ، الاشتعال ، التفاعلات الكيميائية ، ونقل الحرارة.

Main equations used in our program:

1. Continuity equation (mass conservation)

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho u_i}{\partial x_i} = 0$$

2. Momentum equation

$$\frac{\partial}{\partial t}\rho u_j + \frac{\partial}{\partial x_i}\rho u_i u_j = -\frac{\partial p}{\partial x_j} + \frac{\partial \tau_{ij}}{\partial x_i} + \rho \sum_{k=1}^{N} Y_k f_{kj}$$

3. Energy Conservation

$$\frac{\partial \rho E}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i E) = \dot{\omega}_T - \frac{\partial q_i}{\partial x_i} + \frac{\partial}{\partial x_j}(\sigma_{ij} u_i) + \dot{Q} + \rho \sum_{k=1}^{N} Y_k f_{k,i}(u_i + V_{k,i})$$

4. Chemical equations

$$\dot{\omega}_k = \sum_{j=1}^{M} \dot{\omega}_{kj} = W_k \sum_{j=1}^{M} \nu_{kj} Q_j$$

$$Q_j = K_{fj} \Pi_{k=1}^{N} \left(\frac{\rho Y_k}{W_k}\right)^{\nu'_{kj}} - K_{rj} \Pi_{k=1}^{N} \left(\frac{\rho Y_k}{W_k}\right)^{\nu''_{kj}}$$

$$K_{fj} = A_{fj} T^{\beta_j} \exp\left(-\frac{E_j}{RT}\right) = A_{fj} T^{\beta_j} \exp\left(-\frac{T_{aj}}{T}\right)$$

$$K_{rj} = \frac{K_{fj}}{\left(\frac{p_a}{RT}\right)^{\sum_{k=1}^{N} \nu_{kj}} \exp\left(\frac{\Delta S_j^0}{R} - \frac{\Delta H_j^0}{RT}\right)}$$

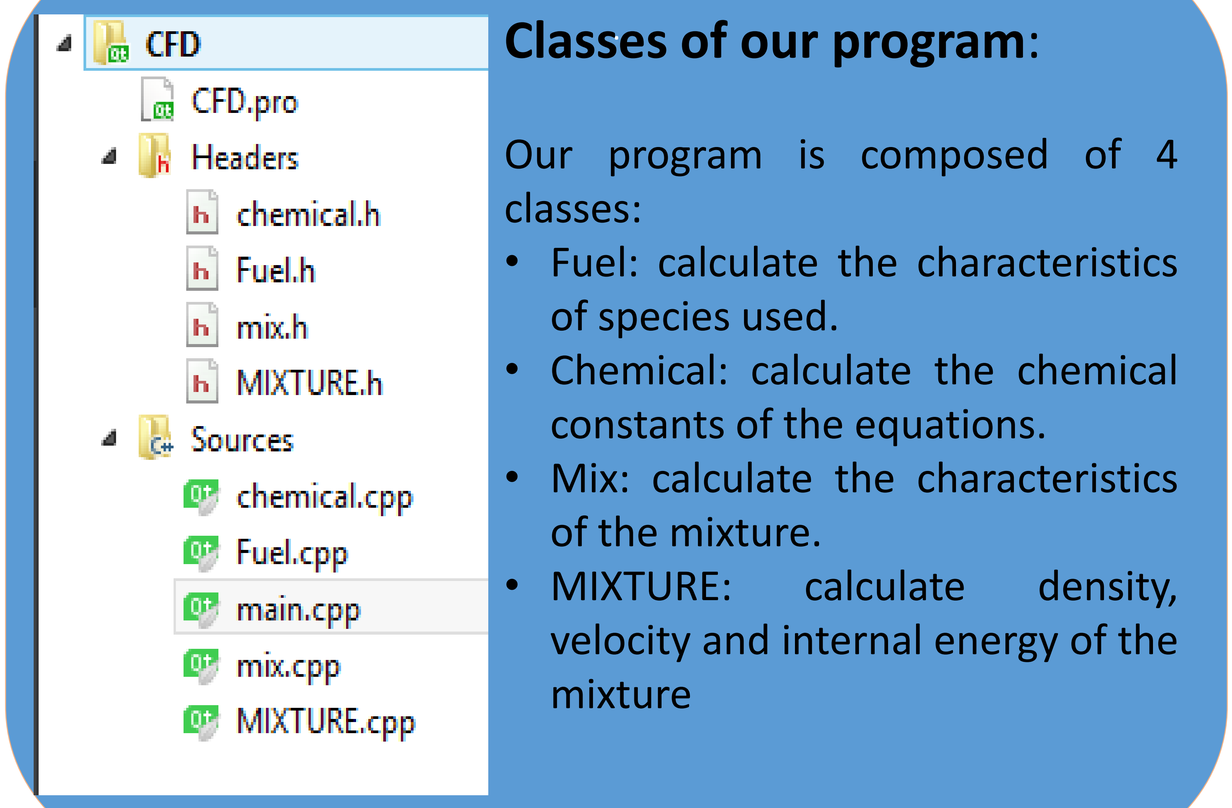
5. Mixture characteristics

$$\rho_m = (\rho_1 v_1 + \rho_2 v_2 + .. + \rho_n v_n) / (v_1 + v_2 + .. + v_n)$$

$$\mu_{ga} = \frac{\sum_{i=1}^{N} y_i \mu_i \sqrt{M_{gi}}}{\sum_{i=1}^{N} y_i \sqrt{M_{gi}}}$$

The equation below are then discretized by the finite differential method and implemented in our C++ program. The values at t+Δt are obtained from a Taylor's series expansion in time as:

$$g_i^{t+\Delta t} = g_i^t + \left(\frac{\partial g^t}{\partial t}_i\right)\Delta t + \left(\frac{\partial^2 g}{\partial t^2}\right)_i^t \frac{(\Delta t)}{2} + \cdots$$



Classes of our program:

Our program is composed of 4 classes:

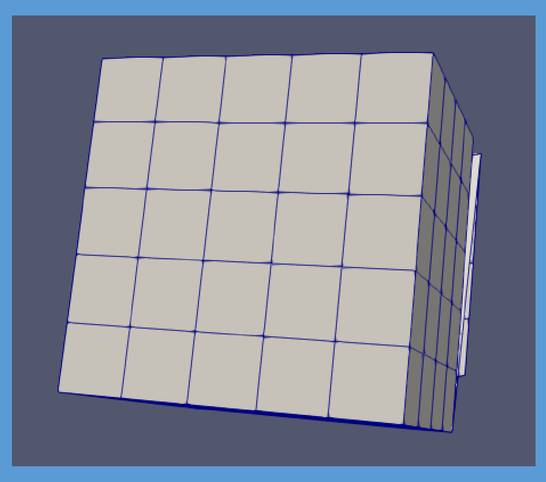
- Fuel: calculate the characteristics of species used.
- Chemical: calculate the chemical constants of the equations.
- Mix: calculate the characteristics of the mixture.
- MIXTURE: calculate density, velocity and internal energy of the mixture

Application : Hydrogen Combustion

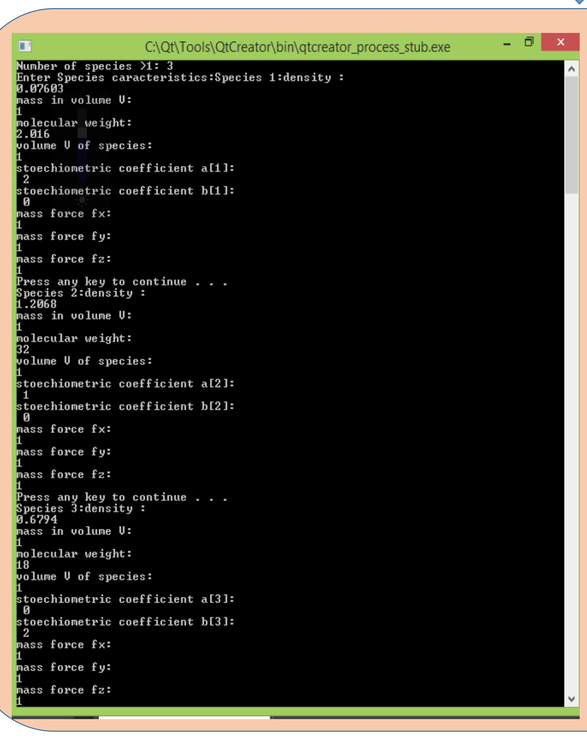
$$2H_2 + O_2 \rightarrow 2H_2O$$

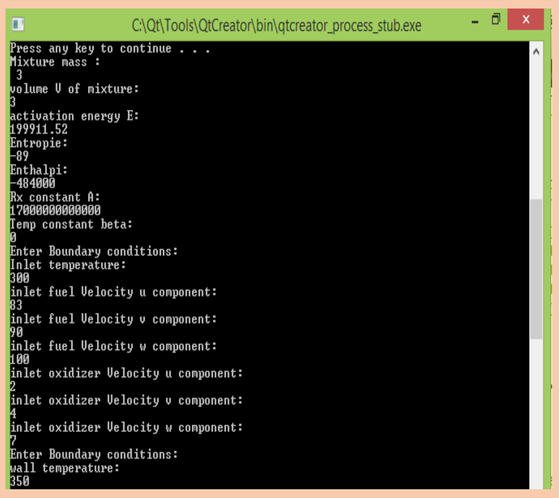
Meshing

The geometry sustainable in our program is a cube. Each side is divided to 5 parts (X, Y and Z) so it's a total of 125 points to be calculated. The fuel entrance is a square fixed at (2;0;1), (2;0;2), (3;0;1), (3;0;2) and the oxidizer entrances are the rest of the points with y=0.
The points are shown in the figure beside.



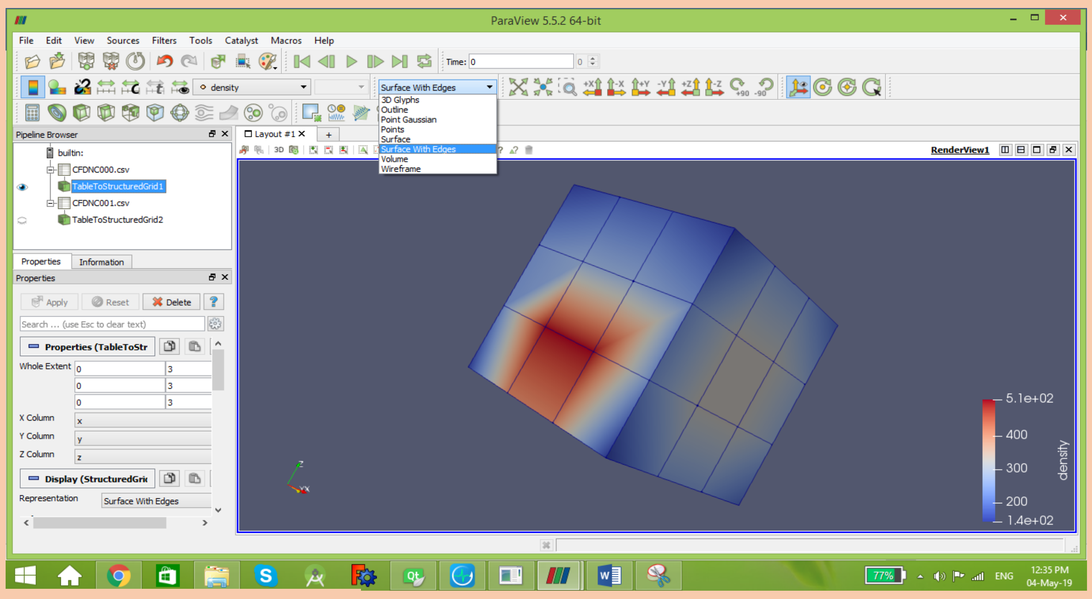
Program Input: (Characteristics)



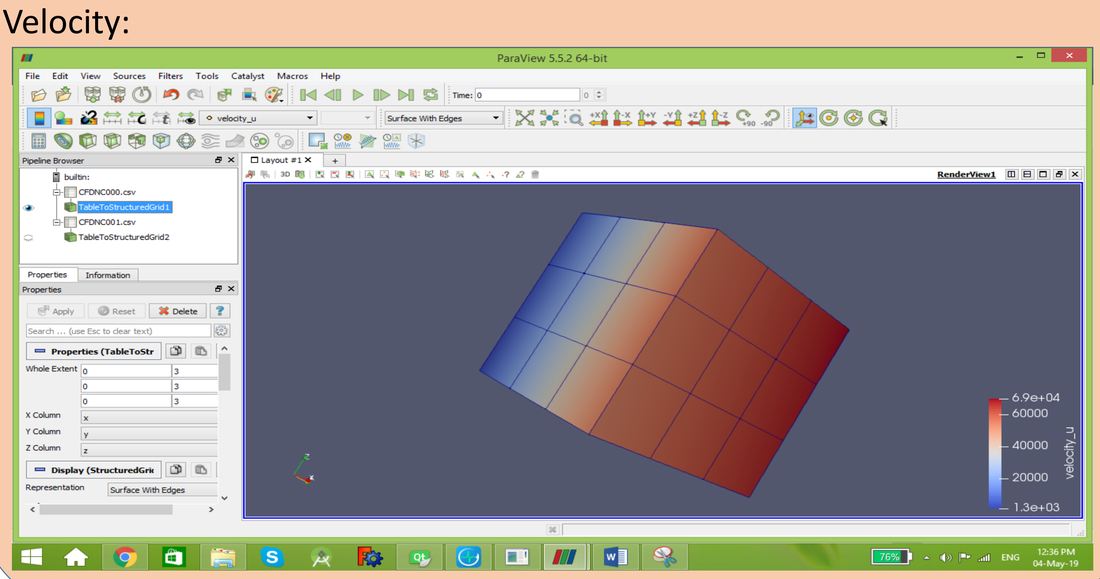


Results presented on Paraview

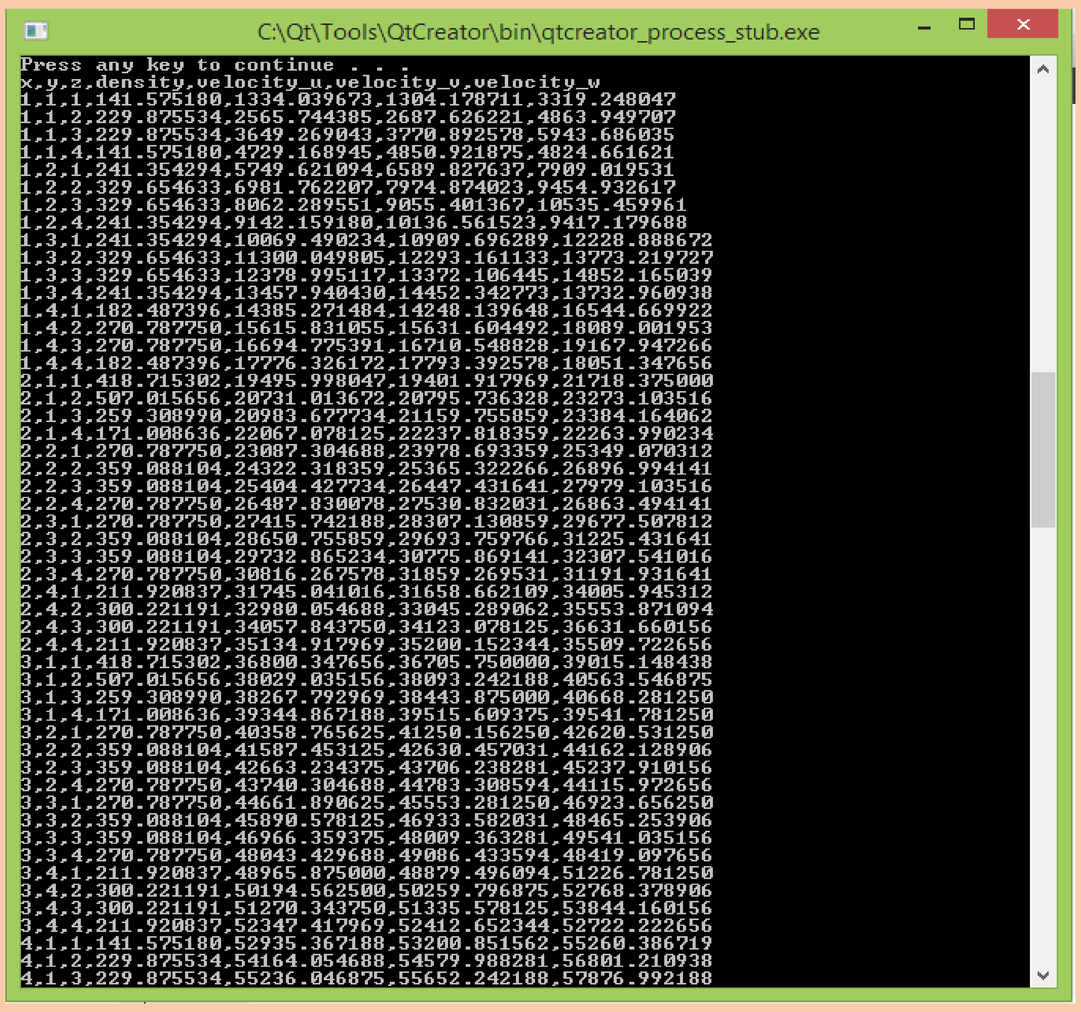
Paraview support .csv files. Examples from our results are presented below.
Density:



Velocity:



Program Output: (density, velocity, energy)



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