Simulation of the gas-turbine aviation engine under flight conditions using the ABSynth multiagent platform

Authors: Valeev S.S., Kovtunenko A.V., Zagitova A.I.

USATU, Department of Computer Science

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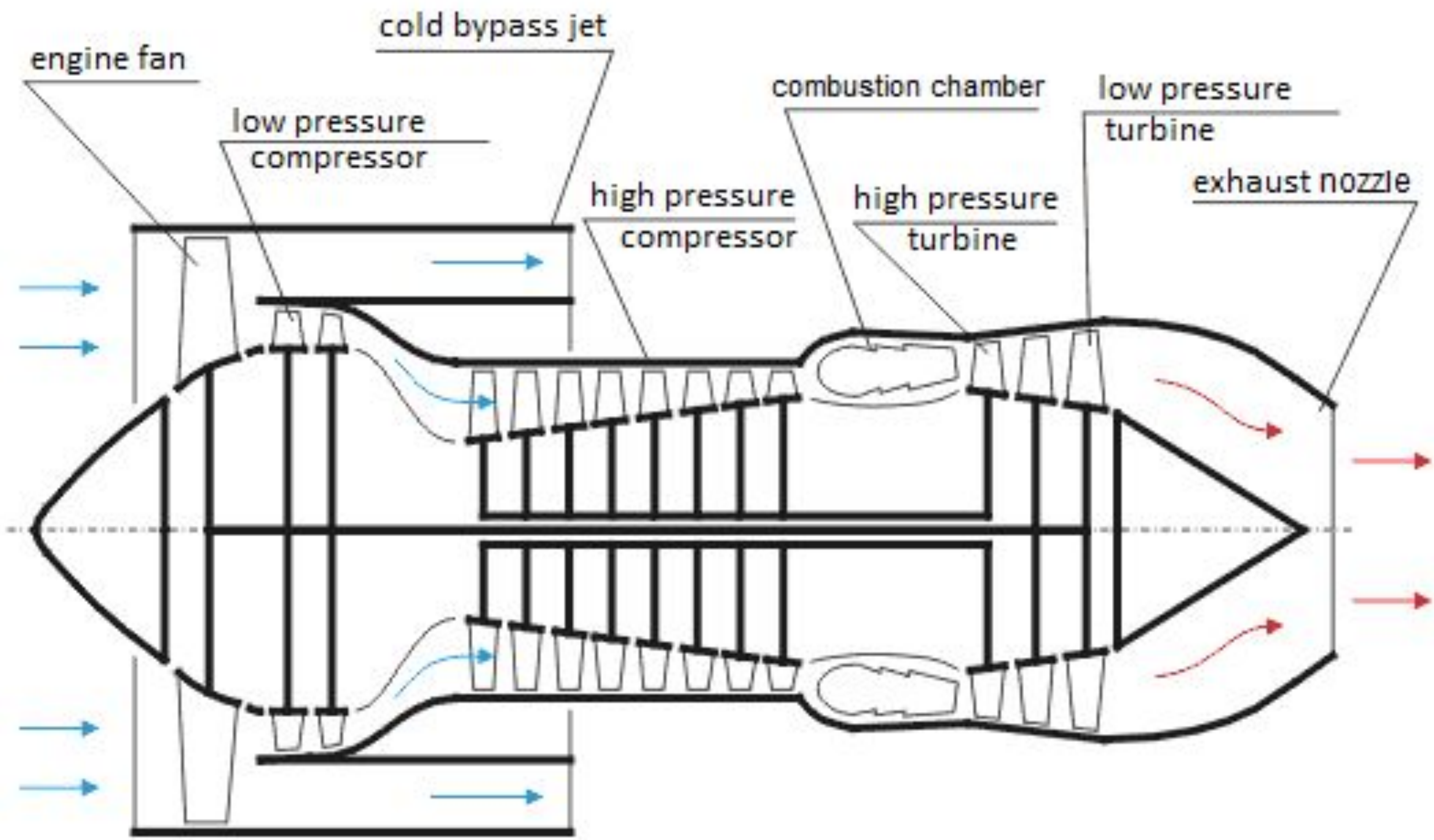
Problem definition

- **Purpose:** to develop an effective simulation model of the gas-turbine aviation engine under flight conditions.

- **Requirements:** high computation performance, multi-user access to the model and results of its execution, real-time execution, high reliability and fault-tolerance.

Object of simulation



Turbojet bypass aircraft engine

Mathematical model of the aircraft engine

Input variables: T_{in}, P_{in} – temperature and pressure of the inlet air,
G_T – combustion chamber fuel feed

Rotary acceleration of the low pressure turbine (LPT) and high pressure turbine (HPT):

$$\dot{n}_{HPR} = \frac{75 \cdot \left(N_{HPT}(T_{in}, P_{in}, G_T) \cdot \eta_{HPR}(T_{in}, P_{in}, G_T) - N_{HPS}(T_{in}, P_{in}, G_T)\right) \cdot \left(\frac{30}{\pi}\right)^2}{n_{HPR}(T_{in}, P_{in}, G_T) \cdot I_{HPR}}$$

HP and LP rotors speed:

$$n_{HPR\,i} = n_{HPR\,i-1} + \dot{n}_{HPR} \cdot \Delta t$$

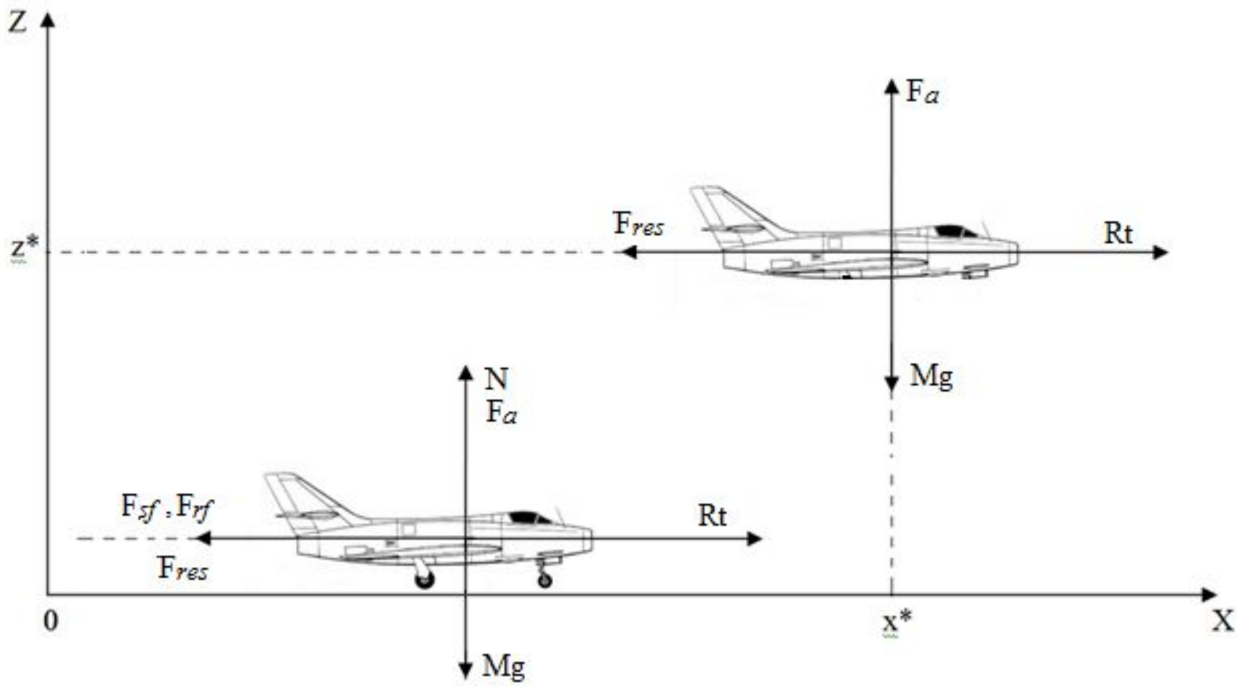
Driving force:

$$R_t = \left(G_{EN}(T_{in}, P_{in}, G_T) \cdot w_G(T_{in}, P_{in}, G_T) - G_{AF}(T_{in}, P_{in}, G_T) \cdot w_{FS}\right) \cdot \frac{1}{g}$$

N_{HPT} – high pressure turbine power;
N_{LPT} – low pressure turbine power;
N_{HPS} – high pressure spool power;
N_{LPS} – low pressure spool power;
η_{HPT} - high pressure turbine efficiency;
η_{LPT} - low pressure turbine efficiency;

I_{HPR} – high pressure rotor inertia;
I_{LPR} – low pressure rotor inertia;
G_{EN} – gas flow through the exhaust nozzle critical section;
G_{af} – air flow through low pressure spool;
w_G – exhaust jet gas velocity;
w_{FS} – flight speed.

Mathematical model of flight conditions



Mg – gravity;
F*a* – ascensional force;
F*res* – air frontal resistance force;
F*rf*– rolling friction force;
F*sf*– static friction force;
N – support reaction force;
Rt – driving force.

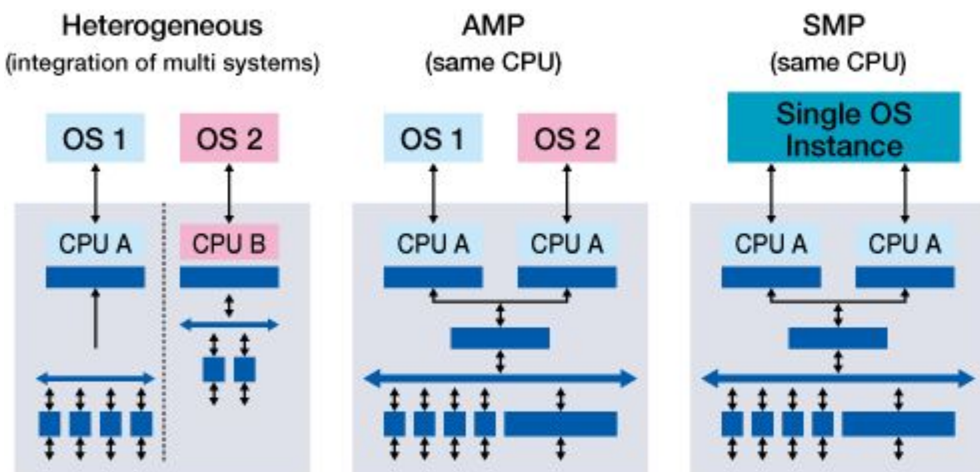
Quiescence: Rt ≤ F*sf*

Ground motion (z = 0, Mg ≥ F*a*):

Flight (Mg ≤ F*a*):

Parallel and Distributed Technologies

Architectures of multiprocessing systems:



SMP – Symmetric multiprocessor system;
AMP – Asymmetric multiprocessor system;

Parallel programming technologies:

❖ MPI (Message Passing Interface):

+ portability,
+ high performance efficiency;

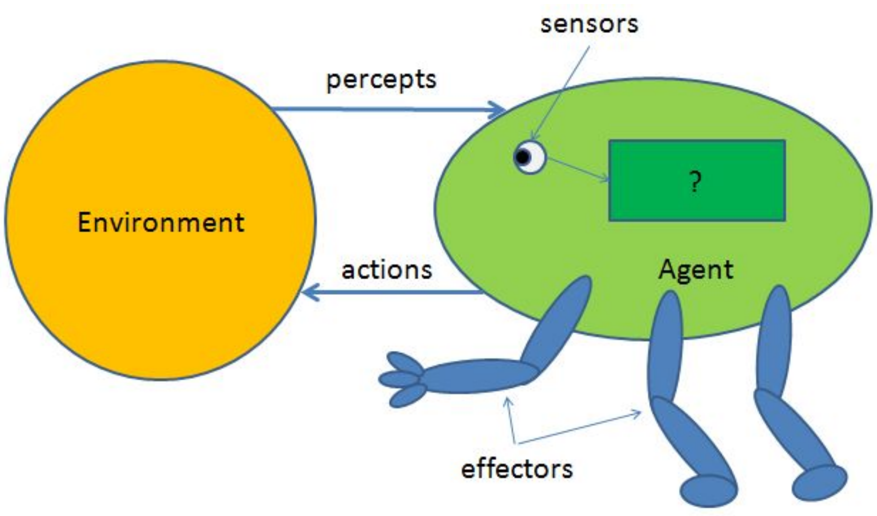
- works well only for the fine-grained parallelism,
- requires special skills for programming.

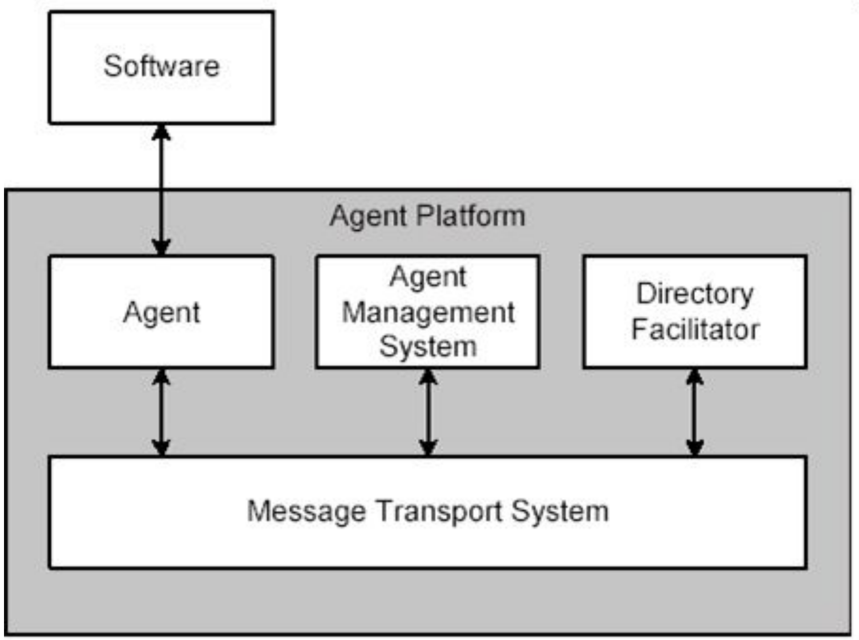
❖ OpenMP (Open Muliti-Processing)

+ ease of programming,
+ high flexibility,
+ high code reusability;

- parallelizes only cyclic blocks,
- works only on SMP systems.

Agent-oriented technology

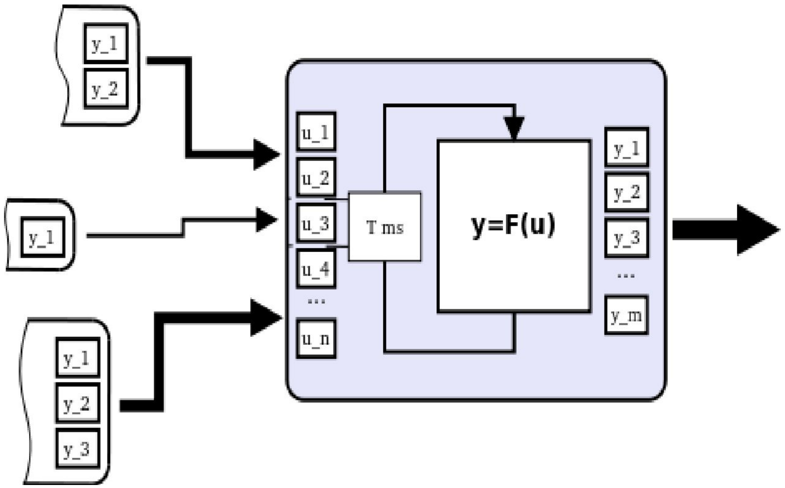




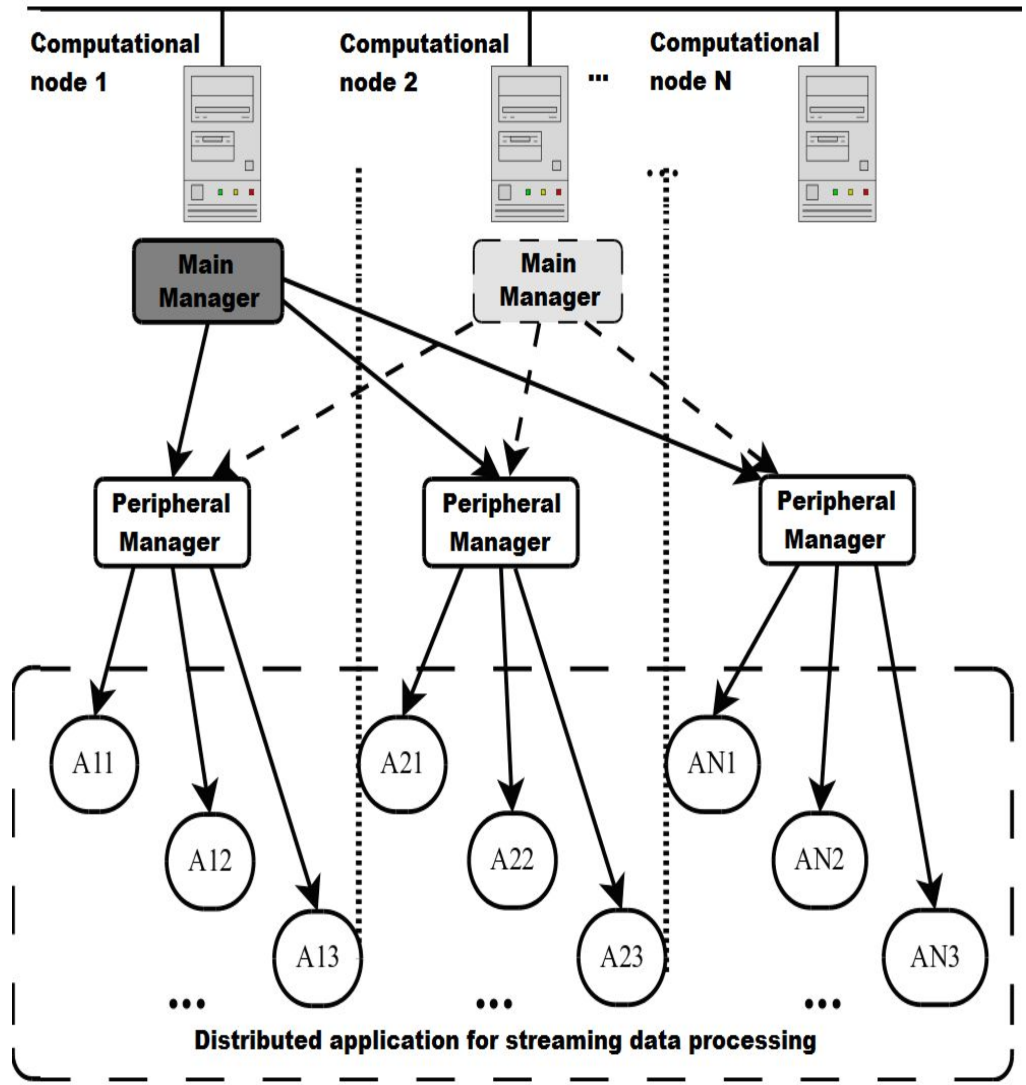
Agent is a hardware or (more usually) software-based computer system that has the following properties:

- ❖ autonomy: agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state;
- ❖ social ability: agents interact with other agents (and possibly humans) via some kind of agent-communication language;
- ❖ reactivity: agents perceive their environment, and respond in a timely fashion to changes that occur in it;
- ❖ pro-activeness: agents do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking the initiative.

ABSynth platform



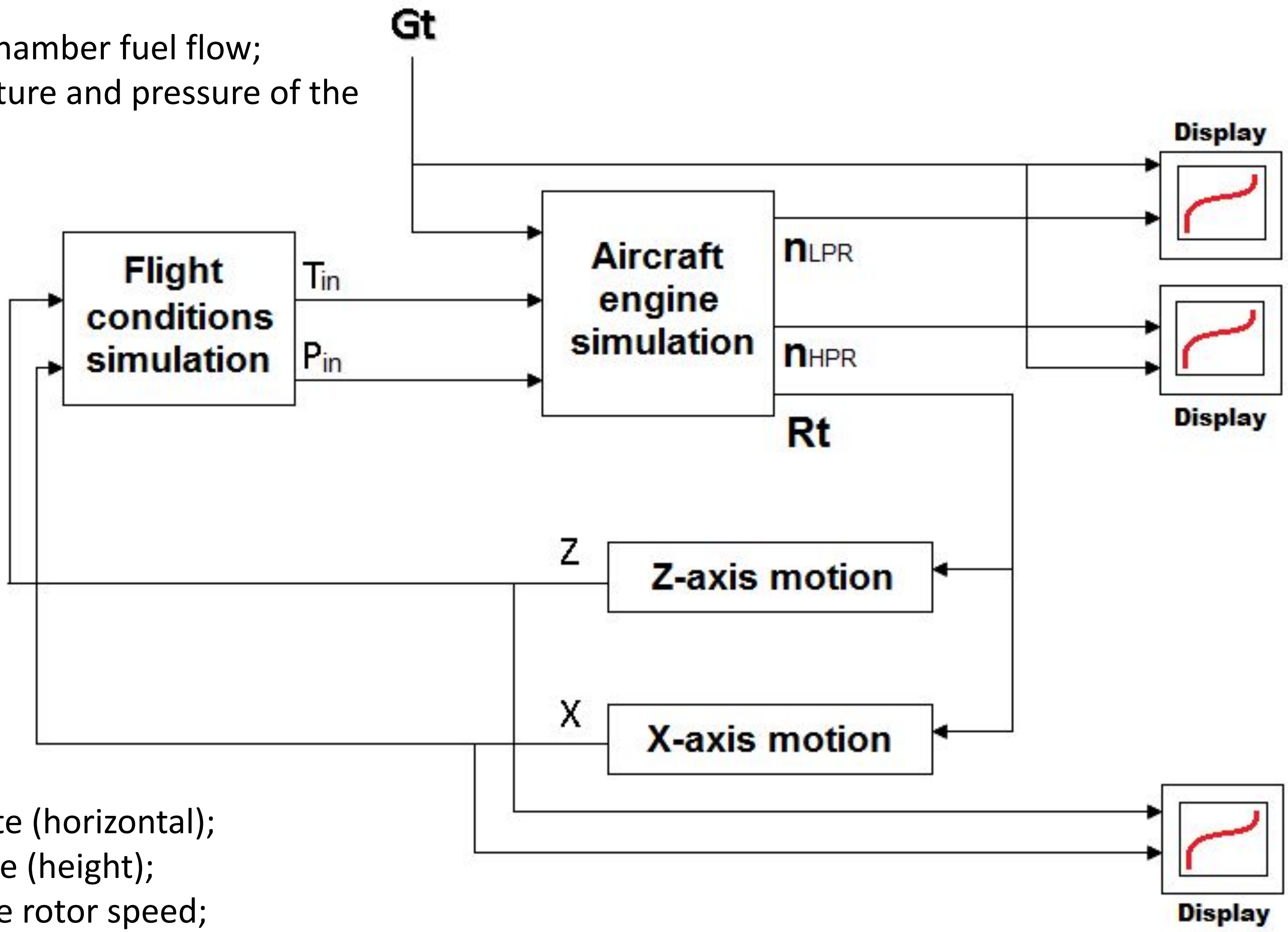
Dedicated agent



y_1, … y_n – agent state;
u_1, …, u_n - input signals;
y = F(u) – main procedure;
T_ms – main procedure period.

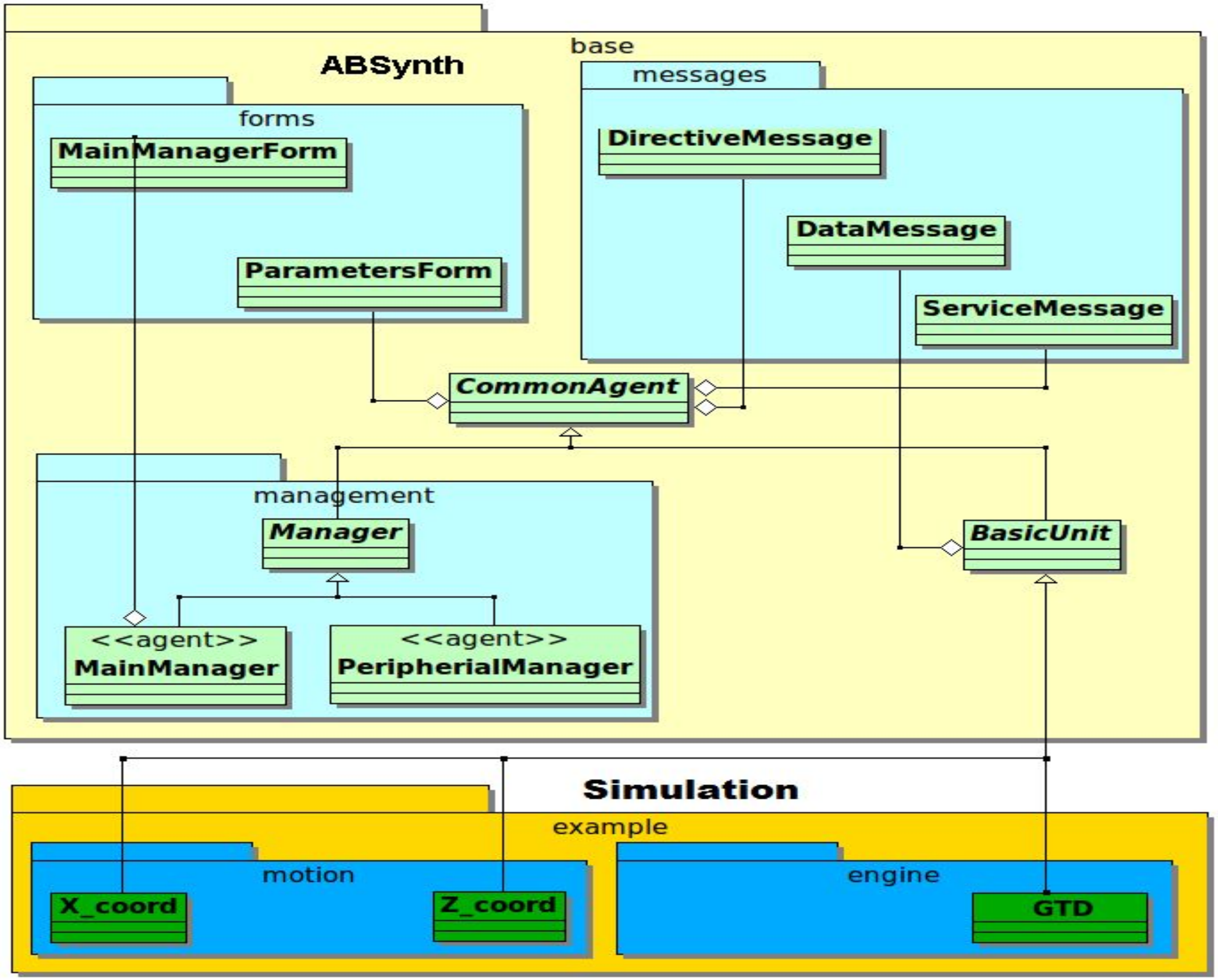
Simulation scheme

Gt – combustion chamber fuel flow;
T_{in}, P_{in} – temperature and pressure of the inlet air;
R – driving force;



X – the ***x*** coordinate (horizontal);
Z – the ***z*** coordinate (height);
n_{HPR} –high pressure rotor speed;
n_{LPR} – low pressure rotor speed.

Agent representation of the model in ABSynth



Model description on TSDL (Task Specification Description Language)

```
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    <parameter>100</parameter>
    <parameter>3000</parameter>
    <parameter>50</parameter>
    <parameter>500</parameter>
  </agent>
----------------------------------------------------------------------
  <agent name="gtd" class="GTD_AL55I" refreshperiod="500" container="1" dimension="5">
    <input refreshperiod="100">
        <slot name="gt"/>
        <slot name="Z_coord"/>
        <slot name="X_coord"/>
   </input>
  </agent>
----------------------------------------------------------------------
  <agent name="X_coord" class="X_coord" refreshperiod="500" container="1" dimension="2">
    <input refreshperiod="100">
        <slot name="gtd"/>
   </input>
  </agent>
----------------------------------------------------------------------
  <agent name="Z_coord" class="Z_coord" refreshperiod="500" container="1" dimension="2">
    <input refreshperiod="100">
        <slot name="X_coord"/>
         <slot name="gtd"/>
   </input>
  </agent>
----------------------------------------------------------------------
</model>
```
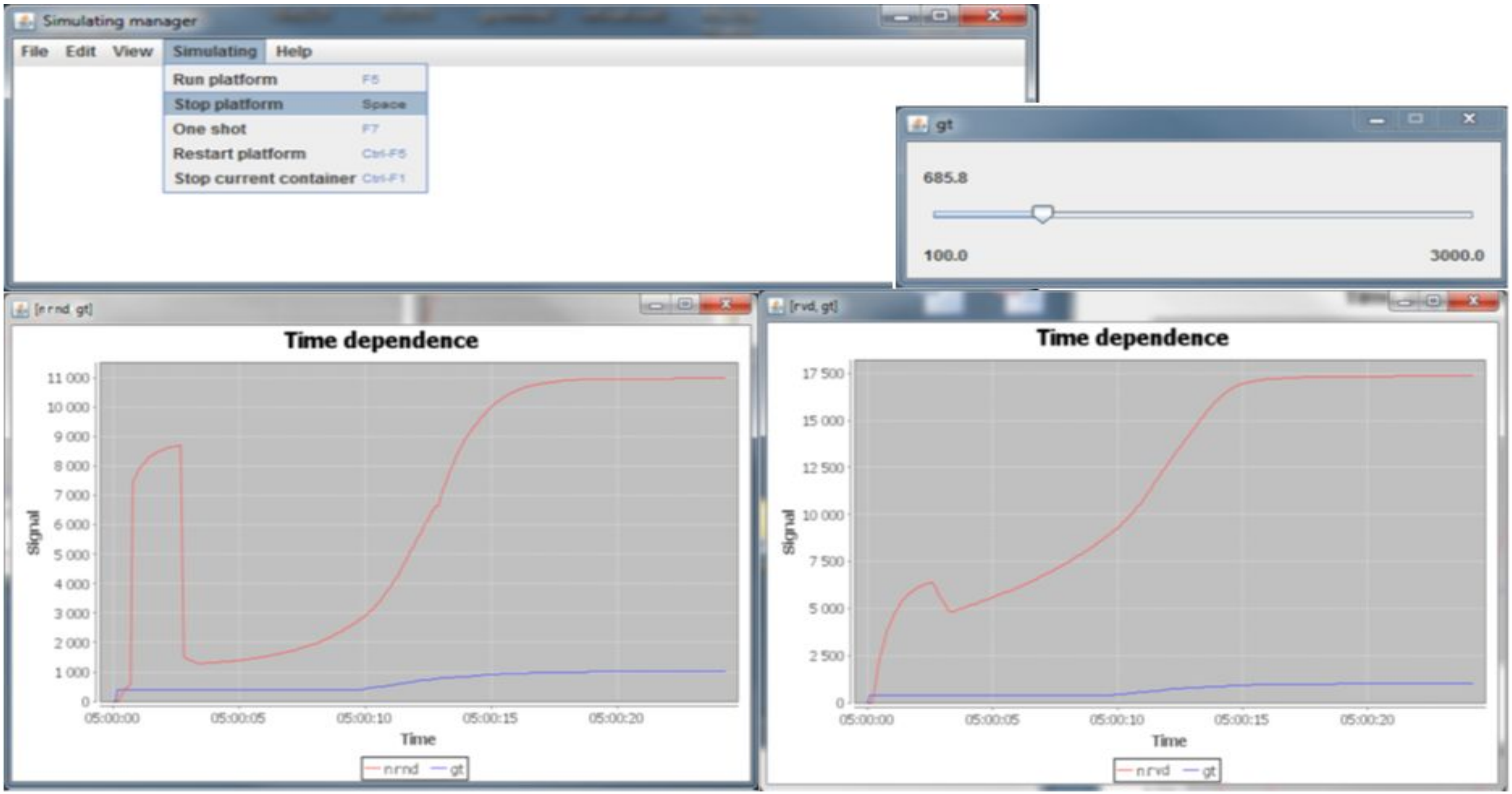

Results of model execution – time dependencies of rotors speeds/fuel flow

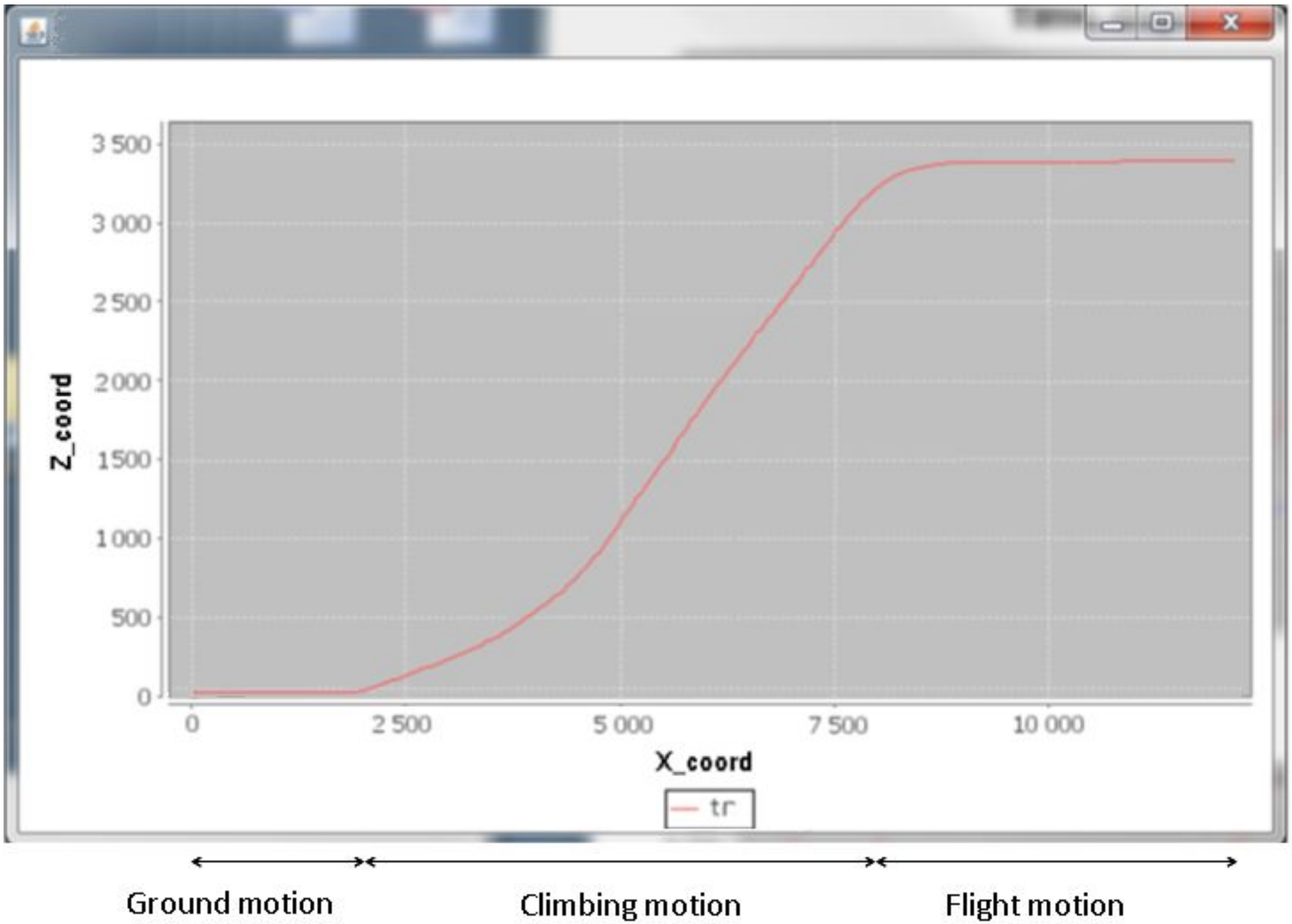


combustion chamber fuel flow - $G_T(t)$

low pressure rotor speed - $n_{LPR}(t)$

high pressure rotor speed - $n_{HPR}(t)$

Results of model execution – the aircraft trajectory



Conclusions

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