Prediction and modeling of the forest using neural networks and supercomputers

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Abstract

The evaluation of forest fire danger is the actual issue. We see the improving possibility of forest fire danger evaluation. It means the correct definition of places with high probability of ignition occurrence. To solve this problem we developed the new computational scheme, which considers the variety of different factors. The offered method is based on the neural network technology and consists of three main blocks. 1. Block of forest combustible material humidity and soil humidity. It calculates the danger on the base of soil moisture content, averaged humidity of dead wood and forest inflammability according to Nesterov's criterion. 2. Block of human factor and thunderstorm activity. It considers the closeness of localities, highways, the presence of major hazard and thunderstorm activity. 3. Data base of wildfire hazard categories on the defined area. Forest sites are divided into five categories of wildfire hazard according to the composition of vegetation, topography of the area and its condition.

Our research group also established the following developments in the field of forest fires: Mathematical modeling of forest fire distribution (Original equations, the splitting into physical processes, regularization according to the method of Buleev, Scalar sweep, the combination of the computational grid with a geographical map); Electronic forester (device for gathering information about the state of forests, needed to assess the likelihood of fire and fire modeling); The application of supercomputers with graphic accelerators for prediction and

WIT Transactions on Ecology and The Environment, Vol 158, © 2012 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/FIVA120051

modeling of forest fires (high-speed computing. increasing efficiency with increasing dimension, the use of a software system Cuda).
Keywords: mathematical modeling, forest fires danger, neural network, supercomputer.

1 Introduction

The progress of modern computer engineering permits us to formulate and solve two actual problems. Firstly, to improve the evaluation of forest fire danger, that is the definition at any given moment the most probable locations of fires. Secondly, to predict the direction and speed of fire spread, depending on weather conditions, the composition and state of forests. Adopted at the present time in Russia calculation method of forest fire danger based on the division of forests comes into five categories by the level of fire danger and the use of Nesterov's criteria for evaluating the weather factor. Noting the ease, convenience and success of this technique, we see the improvement possibility of the assessment of forest fire danger, based on the increased capabilities of modern computers. We believe that the forest fire danger assessment should include soil humidity, forest fuel moisture content, the human factor and the risk of storm. As to humidity of a forest combustible material, first of all humidity of dry dead branches of small diameter. The offered method is based on the neural network technology. Being adaptive, it allows us to accumulate useful information and, as for work, improve its performance.

The research is carried out with the support of Education and Science Ministry of Russia. Government Contract № 13 G25.31.0077.

2 Development of a mathematical model of forest fire danger assessment using data on forest fuel humidity content, human factors and thunderstorm activity on the basis of neural network algorithm

The offered neural network system consists of three main blocks:
1. Block of forest combustible material humidity and soil humidity.
2. Block of human factor and thunderstorm activity.
3. Data base of wildfire hazard categories on the defined area.

2.1 Block of forest combustible material humidity and soil humidity

Suppose that there are many "branches" of dead forest fuel with different diameters. They are the "powder", which ignites a forest fire.

Let d_i - diameters and i=1,2,…,N - size classes of these "branches". Very thick branches are not of interest, because they are not the cause of fire start. For each size class you can describe the process of drying-wetting with such an eqn as Likov [1]:

$$\frac{\partial w}{\partial t} = A_{11}\Delta w + A_{12}\cdot\Delta T\,, \qquad \frac{\partial \mathrm{T}}{\partial \mathrm{t}} = \mathrm{A}_{21}\cdot\Delta \mathrm{T} \tag{1}$$

Here, w – mass of water divided by the weight of dry wood, T - absolute temperature, t – time, A_{ij} – coefficients depending on temperature and humidity, Δ – Laplace operator, which for bodies with axial symmetry ("branch") has the form:

$$\Delta A = \frac{1}{r}\cdot\frac{\partial}{\partial r}\left(r\frac{\partial A}{\partial r}\right). \tag{2}$$

Here, r – current radius, $0 \le \mathrm{r} \le \mathrm{R}$.
R – outer radius: $\mathrm{R} = \mathrm{d}/2$.

Eqns (1) align the boundary conditions. It is the symmetry condition in the center of a branch:

$$\frac{\partial \mathrm{w}}{\partial \mathrm{r}}\Big|_{\mathrm{r}=0} = 0\,, \qquad \frac{\partial \mathrm{T}}{\partial \mathrm{r}}\Big|_{\mathrm{r}=0} = 0 \tag{3}$$

On the surface of the branches are placed conditions of the third kind, taking into account heat and mass transfer with the environment. This exchange depends on the humidity, the temperature, wind speed, solar radiation, atmospheric pressure, humidity and temperature on the surface of most branches. The important role is played by the wind speed. The differential eqns (1) are replaced by the corresponding difference schemes. For the first equation, this scheme will have the form:

$$\frac{w_j^{k+1} - w_j^k}{\tau} = \frac{A_{11}(w_j^k, T_j^k)}{r_j h}\left(\frac{r_{j+1}+r_j}{2}\cdot\frac{w_{j+1}^k - w_j^k}{h} - \frac{r_j + r_{j-1}}{2}\cdot\frac{w_j^k - w_{j-1}^1}{h}\right) +$$
$$+\frac{A_{12}(w_j^k, T_j^k)}{r_j}\cdot\left(\frac{r_{j+1}+r_j}{2}\cdot\frac{T_{j+1}^k - T_j^k}{h} - \frac{r_j + r_{j-1}}{2}\cdot\frac{T_j^k - T_{j-1}^k}{h}\right),\ j = 2,\ldots,N-1 \tag{4}$$

Here, the superscript denotes the number of points in time, and the bottom - the node number on the radius.
τ – time steps, h – radius steps.

$$\mathrm{t}^{k+1} = \mathrm{t}^k + \tau\,, \qquad \mathrm{r}_{j\pm1} = \mathrm{r}_j \pm \mathrm{h}$$

In addition to moisture content of dead branches we should also take into account the soil moisture. Soil moisture should not count. It is quite inert. Next, use the soil moisture content obtained by direct measurement.

We have included Nesterov's criterion to the proposed design scheme:

$$GN^{k+1} = GN^k\xi^k + T^k(T^k - T_p^k) \tag{5}$$

Here, ξ^k – factor which takes precipitation into account, k – number of days, O^k – daily rainfall in millimeters, T^k, T^k_p – air temperature and dew point temperature for 01–03 pm.

$$\xi^k = \begin{cases} 0 & \text{at} \quad O^k \rangle 3mm \\ 1 & \quad O^k \langle 3mm \end{cases} \tag{6}$$

The general scheme of assessment of forest fire danger has the form – figure 1.

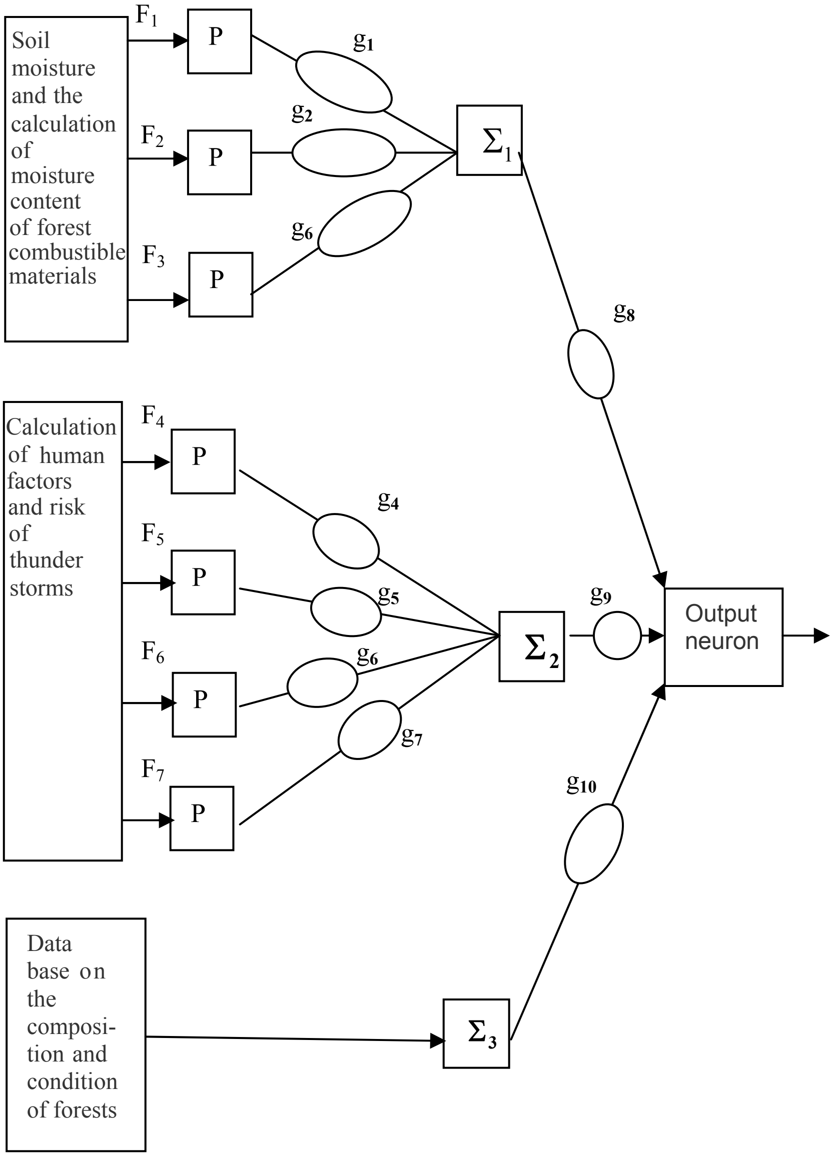

Figure 1: General scheme of assessment of forest fire danger.

There, block of forest combustible material humidity and soil humidity consists of F_1, F_2, F_3 factors.

$$F_1 = w_n, \tag{7}$$

$$F_2 = \sum_{s=1}^{3} \beta_s w(d_s) \tag{8}$$

Here, F_1 – soil humidity, F_2 – averaged moisture content of dead wood, d_s – branch diameter, β_s – weights in averaging of branches humidity on their fire risk.

$$F_3 = GN^K \tag{9}$$

F_3– inflammability according the Nesterov's criterion.

Each of the presented variables F_1, F_2, F_3 arrives on an entrance of the corresponding neuron, where it is transformed according to one of the following sigma functions:

For F_1, F_2:

$$P_i = 1 - \frac{1}{1 + \exp(-\alpha_i (F_i - F_i^0))} \tag{10}$$

For F_3:

$$P_3 = \frac{1}{1 + \exp(-\alpha_3 (F_3 - F_3^0))} \tag{11}$$

Here, parameter α_i determines the sharpness of the transition, F_i^0 – threshold or shift in the transition and the choice of the function P_i.

Such design of the block allows to lead all various sizes F_1, F_2, F_3 to sizes P_1, P_2, P_3 from interval [0,+1]:

$$\sum\nolimits_1 = g_1 P_1 + g_2 P_2 + g_3 P_3 \tag{12}$$

Growth of P_1, P_2, P_3 means fire danger growth. Here, g_1, g_2, g_3 - weights, which are found in the neural network training.

2.2 Block of human factor and thunderstorm activity

It is known that around the world more than 90% of forest fires occur through the fault of humans. The block of the human factor is arranged similarly to the block accounting of forest fuel moisture. Factors considered here are that.

Factor F_4 considers proximity of settlements:

$$F_4 = f_c f_н \sum_{i=1}^{n} \frac{N_i}{\varepsilon^2 + r_i^2}, \tag{13}$$

where, n – number of the nearest to the given point (taken into consideration) settlements, N_i – number of inhabitants in i-th settlement, r_i – distance from the given point to the i-th settlement, ε – constant for protection against zero in a denominator, f_c – seasonal multiplier (depends on day and month of a fire-dangerous season), $f_н$ – week multiplier (on Saturday and Sunday the number of ignitions in woods is more on 40%). $f_н$ =1 on weekdays, fн =1,4 on weekends and public holidays.

F_5 – considers affinity to highways:

$$F_5 = f_c f_н \sum_{s=1}^{nд} \frac{I_s}{\varepsilon_s + r_s}, \tag{14}$$

where, I_s – intensity of use of the road number S (the number of cars per hour), r_s – the shortest distance from a given point to the road.

F_6 – takes into account the presence of objects that represent an increased risk:

$$F_6 = \sum_{\mu=1}^{n_\mu} \frac{O_\mu}{\varepsilon^2 + r_\mu^2}, \tag{15}$$

where O_μ – variable that determines the level of danger of the object (metallurgical, chemical and other industries), fires in neighboring areas, peat fires.

F_7 – parameter, considering storm activity.

$$F_7 = M, \tag{16}$$

where, M – number of lightning strokes.

Similarly previous:

$$\sum\nolimits_2 = g_4 P_4 + g_5 P_5 + g_6 P_6 + g_7 P_7 \tag{17}$$

Growth of Σ_2 means fire danger growth.

2.3 Block considering fire danger of various categories of forest

Areas of forest depending on structure of vegetation, topography of territory and its condition share on five categories of fire danger. For inclusion of this information in the general scheme the territory becomes covered by a rectangular Cartesian grid with constant step H. Grid knots will have accordingly coordinates

$$x_{i\pm1} = x_i \pm H, \quad y_{j\pm1} = y_j \pm H, \quad i=1,\ldots,N_x;\ j=1,\ldots,N_y \tag{18}$$

Thus, the territory breaks into small square cells with the area h^2, each of which can be carried to a certain category of danger. These data are stored in the computer memory in the form of the corresponding database. As the considerable part of cells can get on places not taken with the forest it is advisable to number in the order only the cells getting on forest lots. Then under cell number we can call from memory coordinates of a cell and its characteristic concerning natural fire danger. This data is written down in the specified base.

$$\Sigma_3 = \chi_i \tag{19}$$

where i – number of cell.

By defining i, we can receive cell coordinates x_i, y_i and its fire danger χ_i from database.

2.4 Neuronet training

Neural network weights $g_1,...,g_{10}$ may be found by means of back propagation method Haykin [2], coefficients $\alpha_1,...,\alpha_7$ may be found by means of genetic algorithm. Using parallelism of the computer, population of networks with various values α is created, which generate the following populations at success of the previous generation. This adaptive technology allows to accumulate useful information and to improve quality of prediction in process of actual data receiving. Included here constants calculated by the method of least squares on the map of the area, which marked the place of forest fires over the last ten years.

3 Mathematical modeling of the forest fire spreading

Below we consider the three-dimensional time-dependent model of forest fire. The equations describing processes are presented in the split form. It allows us to avoid bulky records and corresponds to procedure of their integration. Movements of air and combustion products are described by the eqns MChS [3]:

$$\frac{\partial \rho}{\partial t} + \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(\rho u_j) = 0, \tag{20}$$

$$\frac{\partial}{\partial t}(\rho u_i) + \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\tau_{ij} + \rho g_i, \tag{21}$$

$$\tau_{ij} = \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}\mu\sum_{k=1}^{3}\frac{\partial u_k}{\partial x_k}\cdot\delta_{ij}, \tag{22}$$

$$\frac{\partial}{\partial t}(\rho h) + \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(\rho u_j h) = \frac{\partial p}{\partial t} + \sum_{j=1}^{3}\frac{\partial}{\partial x_j}\left(\frac{\partial}{c_p}\frac{\partial h}{\partial x_j}\right) - \frac{\partial q_j^R}{\partial x_j}, \tag{23}$$

$$h = h_0 + \int_{T_0}^{T} c_p dT + \sum_{k=1}^{N} Y_k H_k, \qquad c_p = \sum_{k=1}^{N} Y_k C_{pk}, \tag{24}$$

$$\frac{\partial}{\partial t}(\rho Y_k) + \sum_{j=1}^{3}\frac{\partial}{\partial x_j}(\rho u_j Y_k) = \sum_{j=1}^{3}\frac{\partial}{\partial x_j}\left(\rho D\frac{\partial Y_k}{\partial x_i}\right) + S_k, \tag{25}$$

$$p = \rho R_0 T \sum_{k=1}^{N}\frac{Y_k}{M_k}. \tag{26}$$

Here, t – time, u_i, $(i=1, 2, 3)$ – three components of speed, ρ, P, h – Density, pressure and enthalpy of a gas mix, Y_k – weight shares of its components with molecular weight M_k and warmth of formation H_k, $(k=1, 2, ..., N)$, q_j^R, $(j=1, 2, 3)$ – radiant stream in a direction j, g_j – acceleration of free falling, T – temperature.

All of the above differential equation can be reduced to a single form:

$$\frac{\partial Q}{\partial t}+\sum_{j=1}^{3}u_j\frac{\partial Q}{\partial x_j}=\sum_{j=1}^{3}\frac{\partial}{\partial x_j}\left(\frac{\nu}{\sigma_Q}\frac{\partial Q}{\partial x_j}\right)+F_Q. \quad (27)$$

Here, Q – any of the following variables: $Q=(u_1, u_2, u_3, T, P, K, E, \rho_1, \ldots, \rho_N)$, $\rho_1, \ldots, \rho_N$ – densities of the gas mixture components.

The exception represents only the continuity equation (5). We suggest replacing it with the equation:

$$\frac{\partial \rho}{\partial t}+\sum_{j=1}^{3}\frac{\partial}{\partial x_j}(\rho u_j)=\sum_{j=1}^{3}\ \sum\frac{\partial}{\partial x_j}\left(\frac{\nu}{\sigma_\rho}\frac{\partial \rho}{\partial x_j}\right). \quad (28)$$

Here, σ_ρ – some specially picked up constant considering carrying over of weight in a stream at the expense of turbulent pulsations, not just the convective, as is usually done.

Transition from (20) to (28) not only justified from the physical point of view, but (most importantly) leads to great computational simplification. These simplifications are made, not only in the consequent uniformity in the determination of all unknown quantities according eqn (28), but in a more rapid convergence. The above system of equations is supplemented by the equations of chemical kinetics. If X_α – symbol of a component number α, and $a_{\alpha r}$ and $b_{\alpha r}$ – stoichiometric coefficients of r-reaction

$$\sum_\alpha a_{\alpha r}X_\alpha \leftrightarrow \sum_\alpha b_{\alpha r}X_\alpha , \quad (29)$$

then change in density ρ_α in a given liquid microvolume of the component number α due to the reactions described by:

$$F_\alpha=\left(\frac{d\rho_\alpha}{dt}\right)_c=M_\alpha\sum(b_{\alpha r}-a_{\alpha r})\frac{d\omega_r}{dt}, \quad (30)$$

$$\frac{d\omega_r}{dt}=\hat{K}_{fr}\prod_\alpha\left(\frac{\rho_\alpha}{M_\alpha}\right)^{a_{\alpha r}}-\hat{K}_{br}\prod_\alpha\left(\frac{\rho_\alpha}{M_\alpha}\right)^{b_r}, \quad (31)$$

where $\hat{K}_{fr}$, $\hat{K}_{br}$ – rate coefficients for forward and reverse reaction, strongly dependent on temperature:

$$\hat{K}_r=K_r^0T_{\exp}^{nr}\left(-\hat{E}_r/T\right), \quad (32)$$

K_r^0, $\hat{E}_r$, n_r – constants, typical for r–reaction.

Generation or absorption of heat on the set of reactions and the corresponding change in temperature is determined by source term for the temperature equation:

$$F_T=\frac{1}{c\cdot\rho}\sum_r q_r\frac{d\omega_r}{dt}, \quad (33)$$

$$\frac{\partial T}{\partial t}+\sum_{j=1}^{3}u_j\frac{\partial T}{\partial x_j}=\sum_{j=1}^{3}\frac{\partial}{\partial x_j}\left(\frac{\lambda}{\sigma_\rho}\frac{\partial}{\partial x_j}T\right)+F_T. \quad (34)$$

Our computational practice allows us to recommend the following integration method of the described system of equations. To calculate the turbulent viscosity and diffusion we restricted ourselves to the following algebraic model:

$$\nu_T = l^2 \cdot \left|grad(u)\right|, \qquad u = \sqrt{u_1^2 + u_2^2 + u_3^2}, \tag{35}$$

$$\left|grad\ u\right| = \sqrt{\left(\frac{\partial u}{\partial x_1}\right)^2 + \left(\frac{\partial u}{\partial x_2}\right)^2 + \left(\frac{\partial u}{\partial x_3}\right)^2}, \tag{36}$$

$$l = 0{,}4 \cdot x_3 \text{ at } x_3 < H, \qquad l = 0{,}4 \cdot H \text{ at } x_3 > H, \tag{37}$$

where u – velocity magnitude, H – height of forest, x_3 – vertical coordinate, l – the mixing length of L. Prandtl.

At calculation of movement of air and burning products it is necessary to consider aerodynamic resistance of wood and Coriolis acceleration. It is carried out by means of the equation:

$$\frac{d\vec{u}}{dt} = -c_d S\left|\vec{u}\right| \cdot \vec{u} + 2\vec{\varpi} \times \vec{u}. \tag{38}$$

Here, $\vec{u} \equiv (u_1, u_2, u_2)$ - vector and component of speed, c_d - aerodynamic coefficient, S – specific surface of vegetation, $\vec{\varpi}$ – angular speed of the Earth rotation.

Let's notice that for preservation of the account stability it is convenient to replace last equation (38) with the following semi-explicit difference scheme:

$$\frac{u_1^{K+1} - u_1^K}{\tau} = -c_d S\sqrt{\left(u_1^K\right)^2 + \left(u_2^K\right)^2 + \left(u_3^K\right)^2} \cdot u_1^{K+1} + 2\left(\omega_2 u_3^{K+1} - \omega_3 u_2^{K+1}\right), \tag{39}$$

$$\frac{u_2^{K+1} - u_2^K}{\tau} = -c_d S\sqrt{\left(u_1^K\right)^2 + \left(u_2^K\right)^2 + \left(u_3^K\right)^2} \cdot u_2^{K+1} + 2\left(\omega_3 u_1^{K+1} - \omega_1 u_3^{K+1}\right),$$

$$\frac{u_3^{K+1} - u_3^K}{\tau} = -c_d S\sqrt{\left(u_1^K\right)^2 + \left(u_2^K\right)^2 + \left(u_3^K\right)^2} \cdot u_3^{K+1} + 2\left(\omega_1 u_3^{K+1} - \omega_3 u_1^{K+1}\right).$$

Here, τ – time step, $\omega_1, \omega_2, \omega_3$ - projections of a vector of angular speed of the Earth to coordinate axes x_1, x_2, x_3.

The top index is number of the moment of time. Thus, concerning the required $u_1^{K+1}, u_2^{K+1}, u_3^{K+1}$ we receive linear algebraic system which can be easily solved.

Let us designate through T_S, T – temperatures of forest combustible materials and a gas mix of air and combustion products. Suppose that 1 m^3 of forest fuel, which has a mass m, contains m_1 organic substances, subjected to pyrolysis, m_2 – mass of the water, that evaporates, m_3 – coke, m_4 – ash:

$$m = m_1 + m_2 + m_3 + m_4. \tag{40}$$

Then the equations of continuity and energy get the following additions:

$$\frac{\partial \rho}{\partial t} = R_{1S} + R_{2S} + \frac{\mu_C}{\mu_{O_2}} R_{3S}, \tag{41}$$

$$m_1 = m_1^T + m_1^G, \qquad m_2 = m_2^T + m_2^G, \tag{42}$$

$$-\frac{dm_1^T}{dt} = \frac{dm_1^G}{dt} = K_1 m_1^T \exp\left(-\frac{E_1}{RT}\right) = R_{1S}, \tag{43}$$

$$-\frac{dm_2^T}{dt} = \frac{dm_2^G}{dt} = K_2 m_2^T \exp\left(-\frac{E_2}{RT}\right) = R_{2S}, \tag{44}$$

$$-\frac{dm_3^T}{dt} = \frac{m_3^T}{\left(D^{-1} + \left[A \cdot T^n \exp\left(-\frac{E_3}{RT}\right)\right]^{-1}\right)} = R_{3S} \tag{45}$$

Here, top icons T and G mark the solid and gaseous masses (in the process of burning solid converted to gaseous), R_{1S} - pyrolysis rate, R_{2S} - water evaporation rate, R_{3S} - burning rate of coke, μ_C, μ_{O_2} - molecular weights of carbon and oxygen.

The system of energy equations is added by the equations of heat transfer between solid and gaseous phases:

$$\frac{\partial T_S}{\partial t} \cdot \sum_{i=1}^{3} m_i^T c_i^T = \alpha_S S(T - T_S) + \hat{K}\sigma(T^4 - T_S^4) - q_1 R_{1S} - q_2 R_{2S} + q_3 R_{3S}, \tag{46}$$

$$\frac{\partial T}{\partial t} \cdot \sum_{i=1}^{3} m_i^G c_i^G = \alpha_S S(T_S - T) + \hat{K}\sigma(T_S^4 - T^4) - q_4 R_{1S} \tag{47}$$

Here, q_1, q_2, q_3, q_4 – respectively, the heat of pyrolysis, water evaporation, combustion of coke and gas, α_S – coefficient of convective heat transfer, $\hat{K}$ – coefficient of emission absorption, σ – Stefan-Boltzmann constant, S – specific surface of vegetation, c_i^T, c_i^G - averaged by temperature, heat capacities of solid and gaseous constituents of burning components.

For the sustainable integration of these equations with not too small time step it is necessary to use the semi-explicit schemes. The form:

$$-\frac{dm}{dt} = B \cdot m \cdot \exp\left(-\frac{E}{RT}\right) \tag{48}$$

is replaced by the difference scheme:

$$\frac{m^{K+1} - m^K}{\tau} = -B \cdot m^{K+1} \cdot \exp\left(-\frac{E}{RT^K}\right). \tag{49}$$

Hence:

$$m^{K+1} = m^K \frac{1}{1 + \tau \cdot B \cdot \exp\left(-\frac{E}{RT^K}\right)}. \tag{50}$$

This simple technique can significantly speed up the computation.

When integrating the equations of motion and diffusion, regularization is used according to Buleev, which consists of replacing:

$$\frac{\partial U}{\partial t} \to \frac{\partial}{\partial t}\left(U - \psi \sum_{j=1}^{3} \frac{\partial^2 U}{\partial x_j^2}\right). \tag{51}$$

Here, ψ - small positive quantity – the regularization parameter.

If there is an equation $\frac{\partial U}{\partial t} = F(U)$, then after such replacing, for example in one-dimension case, we can see:

$$\frac{U_i^{K+1} - U_i^K}{\tau} - \psi \frac{U_{i+1}^{K+1} - 2U_i^{K+1} + U_{i-1}^{K+1}}{h^2} + \psi \frac{U_{i+1}^K - 2U_i^K + U_{i-1}^K}{h^2} = F(U_i^K) \tag{52}$$

This equation reduces to:

$$\alpha_i U_{i-1}^{K+1} + \beta_i U_i^{K+1} + \gamma_i U_{i+1}^{K+1} = \Phi(U_{i-1}^K, U_i^K, U_{i+1}^K), \tag{53}$$

to which we can apply the scalar sweep:

$$L_{i+1} = -\gamma_i / (\beta_i + \alpha_i L_i), \tag{54}$$

$M_{i+1} = \left(\Phi(U_{i-1}^K, U_i^K, U_{i+1}^K) - \alpha_i M_i\right) / (\beta_i + \alpha_i L_i)$ – direct sweep,

$U_{i-1}^{K=1} = L_i U_i^{K+1} + M_i$ – back sweep.

That provides rapid and sustainable calculation.

4 Electronic forester

In order to successfully fight forest fires, except for such obvious means as aviation, space patrol, unmanned aerial vehicles and careful tending in our view it would be appropriate use of "electronic foresters" (figure 2) with supercomputer simulation and forecasting of forest fires.

The title "electronic forester" means a device that measures and reports in the center of monitoring and management of data on forest fire danger in the area where the device is installed. The transmitted data includes the following parameters: wind speed and direction, humidity of forest combustible materials, soil humidity, air temperature, number of lightning strikes in the immediate vicinity of the device for a fixed period of time.

"Electronic forester" must meet the following requirements:

It must be a small device (about the size of a mobile phone), so that it can be safely hidden from the eyes of tourists and hunters; 2) It should have a renewable energy source – battery charging from solar panel or a small "pinwheel"; 3) Data transfer should be done in a short time (seconds) in the set points or on command from the control center. During the rest of the time instrument should be in the standby state; 4) Electronic forester should be simple and cheap; 5) The optimal site, which is under the control of the "Electronic forester" – a square of side 10 to 10 kilometers; 6) The device responds only to a signal containing a special code known only to the center management and system maintenance.

Above you can see its schematic diagram – figure 2. There marked: 1 – pinwheel, 2 – wind direction sensor, 3 – forest fuel humidity sensor, 4 – soil humidity sensor, 5 – temperature sensor, 6 – lightning strikes recorder, 7 – barometer, 8 – analog-digital converter, 9 – device for serial poll of sensors, 10 – wind speed sensor, 11 – generator for a battery charging, 12 – accumulator, 13 – solar battery, 14 – control device, 15 – radio transmitter.

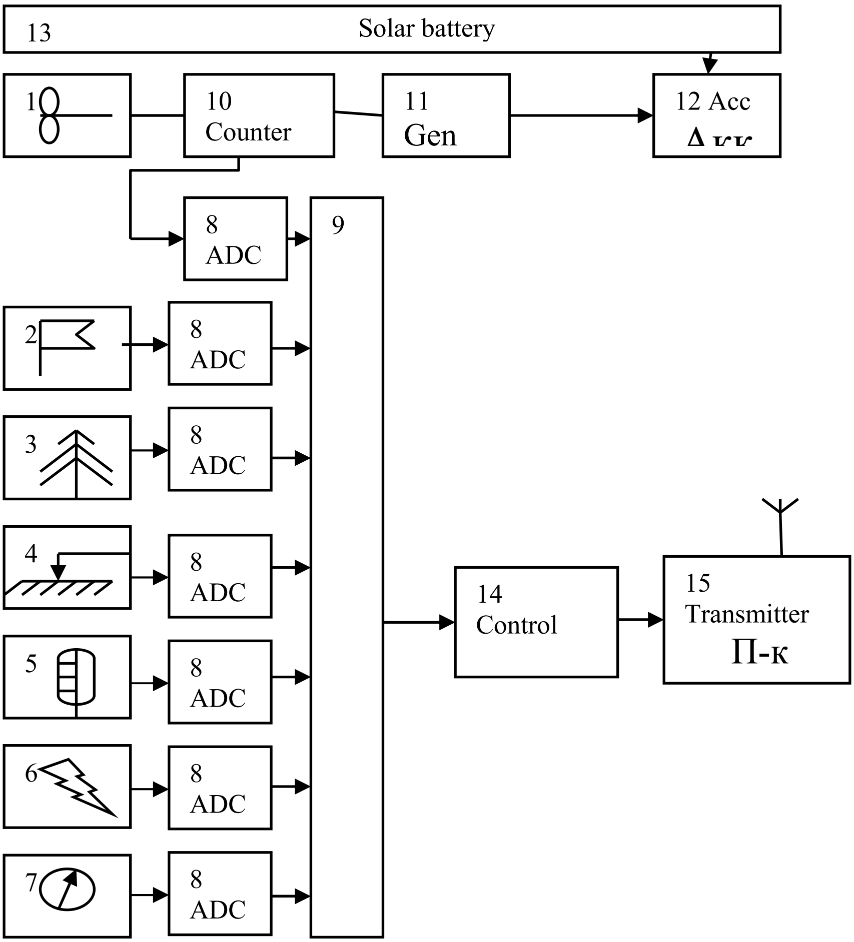

Figure 2: Electronic forester.

For this purpose we developed and tested the first version of the device.

Experiments with the devices have shown that at its certain operational development it is possible to recommend to introduction in practice for preventive maintenance and suppression of forest fires.

5 Conclusion

The developed methods allow us to organize the center for prevention and control of forest fires. It contains a multiprocessing supercomputer with the graphic accelerators and equipped with:
1. Neural network system for forecasting of forest fire danger, taking into account the moisture content of forest fuel, human factors and thunderstorm activity.
2. Software modeling of an already existing forest fire depending on the direction and force of wind, the state of forest fuel. Predictive calculations of speed and direction of forest fire propagation will allow the fire service to dispose of its associated forces and means to successfully extinguish a forest fire arising.
3. Devices called electronic foresters transfer to the control center data on weather conditions, soil moisture and forest fuel.

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