Virtual Patients on the Net

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Multimedia and simulation models in medical teleeducation tools

Aim: The author's purpose was to create an interactive computer aided teaching tool to help the students understand the complex dynamic glycoregulatory mechanisms and the influence of theirs disorders on the pathology.

Methods: *1. Writing the script of the educational programme. 2. Construction of the multimedia parts of the educational programme* (we chose software tools from Macromedia - Director 8, Flash , which allows comfortable creation of interactive multimedia animations. *3. Development of the simulation models (simulation model design)* – the theoretical work itself, based on formalization of physiological relations. Here, developer's tools from Mathworks were used, mainly Matlab and Simulink. *4. Integration of multimedia and simulation models into the educational programme (simulator design).* We used Control Web – object oriented design system from Moravian Instruments.

Results: We have designed the multimedia simulation guide that combined hypertext explanation, picture animation and simulation models into the complex teleeducational tool.

Conclusion: Linking multimedia environment with simulation models facilitates demonstration of complex glycoregulatory processes (and their disorders) by an interactive simulation game. They represent, ideal combination for explanation of causal relations and multipart processes. Due to the interactive features they enable a better perception of the complicated dynamic relationships within complex physiological structures.

Simulator GOLEM: the following simple example of an acid-base disorder should demonstrate how easy it is to manipulate the simulator

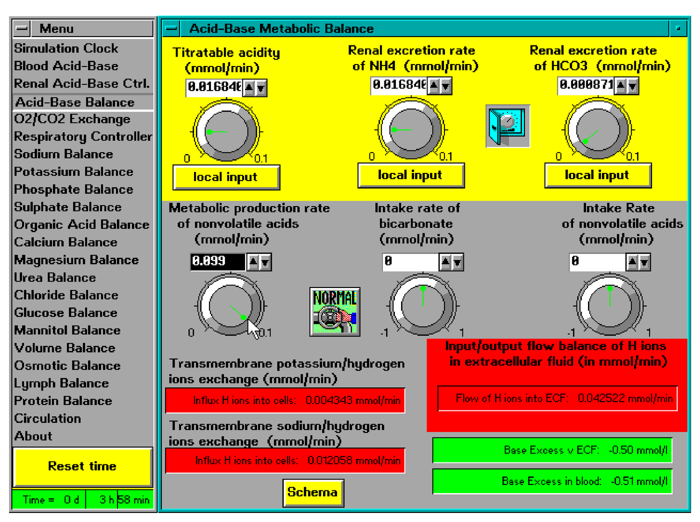

Fig. 1. Turning the knob we can increase the metabolic production rate of non-volatile acids. By increasing the strong acid production, we cause metabolic acidosis.

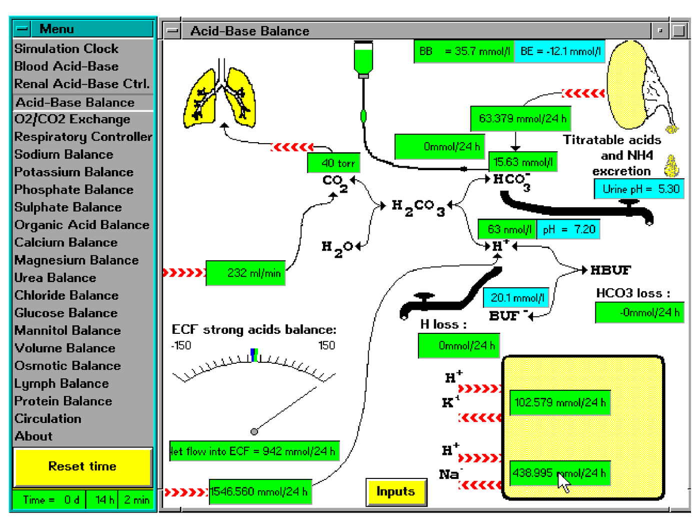

Fig. 2. Ratio of metabolic production and renal excretion of strong acids is highly increased. H^+/Na^+ and H^+/K^+ exchange on the cell membrane is activated. H^+ ions are buffered by intracellular and extracellular buffers.

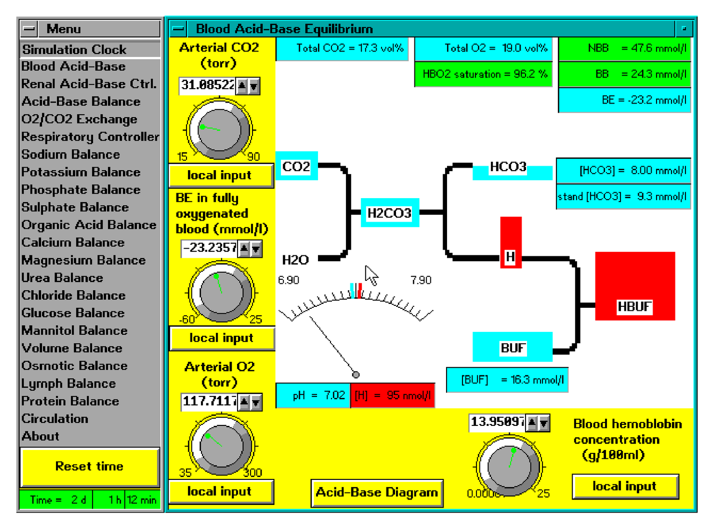

Fig. 3. Blood buffer system - the blood has been acidified, Base Excess and actual bicarbonate concentration are decreasing, and pCO_2 is also slowly decreasing.

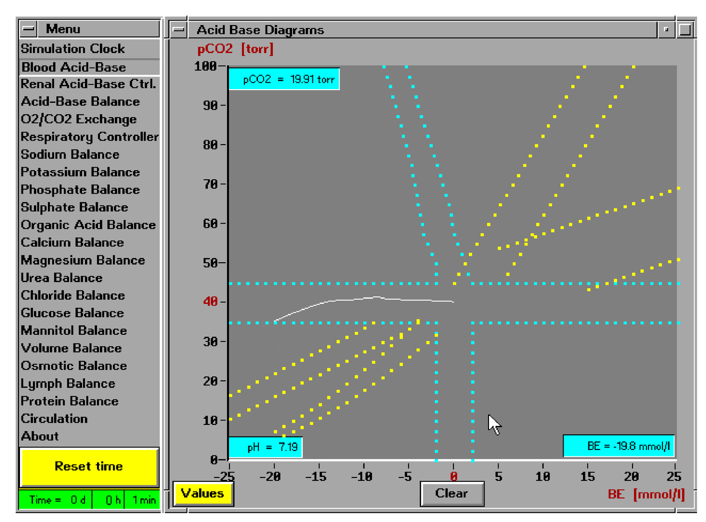

Fig. 4. Acid-base values on this compensatory diagram are in the acute metabolic acidosis range. This is the beginning of a progressive reaction by the ventilation centre to counteract metabolic acidosis.

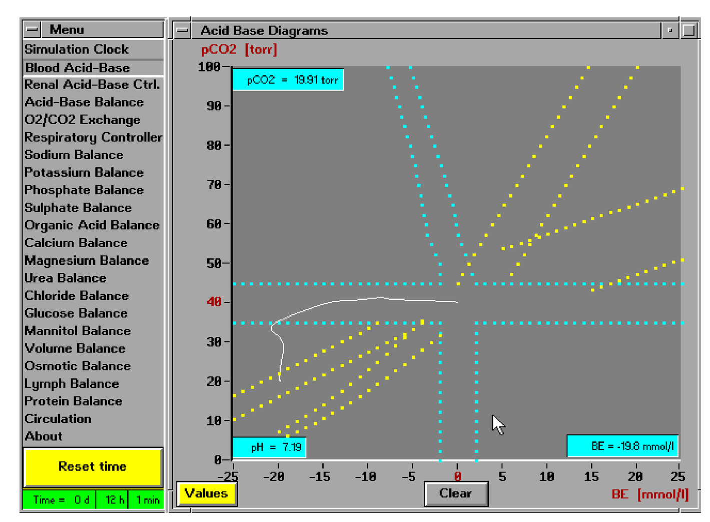

Fig. 5. Respiratory compensation is at a maximum in about 12 hours. Decreasing pCO2 is leading to a rise of arterial blood pH. Acid-base parameters are approaching a compensated metabolic acidosis range.

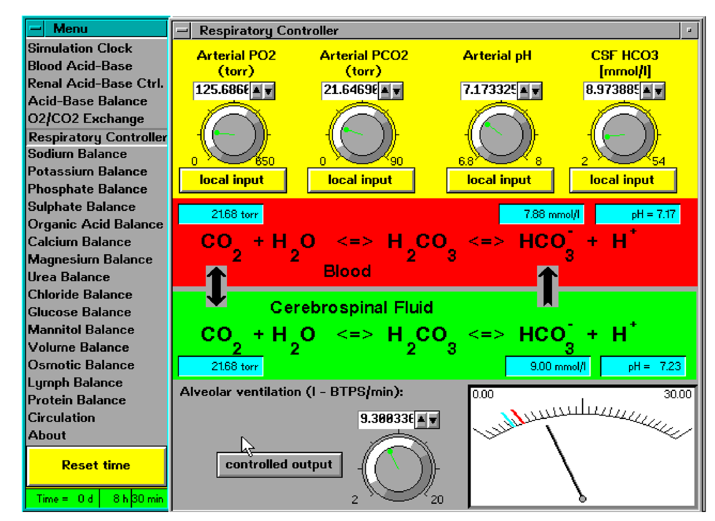

Fig. 6. The slow response of the respiratory system on metabolic acidosis is due to the relative impermeability of bicarbonate across the blood-brain barrier. While CO_2 penetrates easily and pCO_2 in blood and cerebrospinal fluid is at a similar level, this is not the case for bicarbonate. Thus bicarbonate reaches equilibrium, cerebrospinal pH decreases, and the respiratory centre is more stimulated, and alveolar ventilation increases resulting in a decrease of pCO_2. Values of acid-base parameters are slowly approaching to compensated metabolic acidosis range.

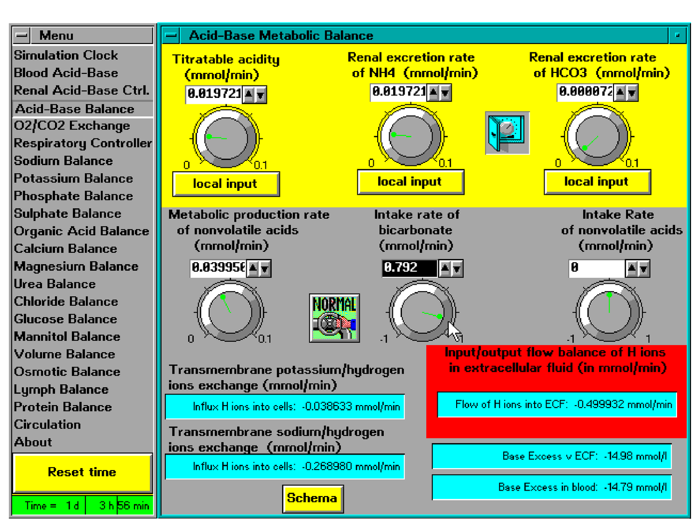

Fig. 7. The kidney's response progressively develops. Titratable acidity and NH_4 excretion increases, urine pH decreases. Renal response is in its maximum in 3-5 days. Only enough should be given to compensate pH. Turning the knob we are starting bicarbonate infusion therapy.

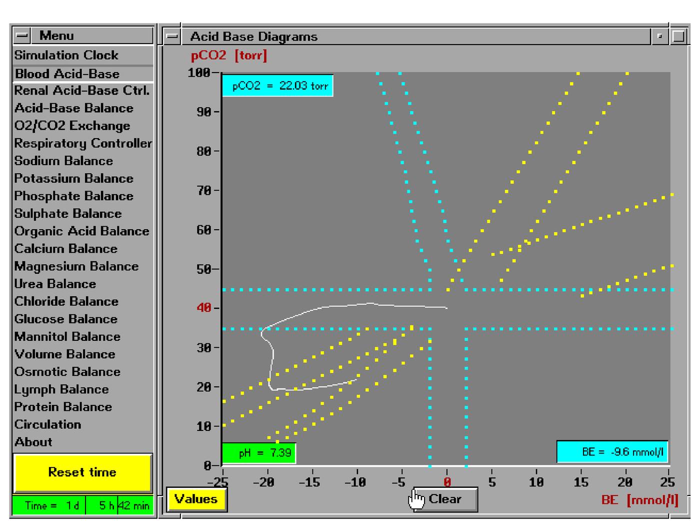

Fig. 8. BE and pH slowly increases after bicarbonate infusion. PCO_2 remains stable for a while (thanks to respiratory compensation), at its low level. We must take PCO_2 into account when choosing doses of alkaline infusion in order not to overdose.

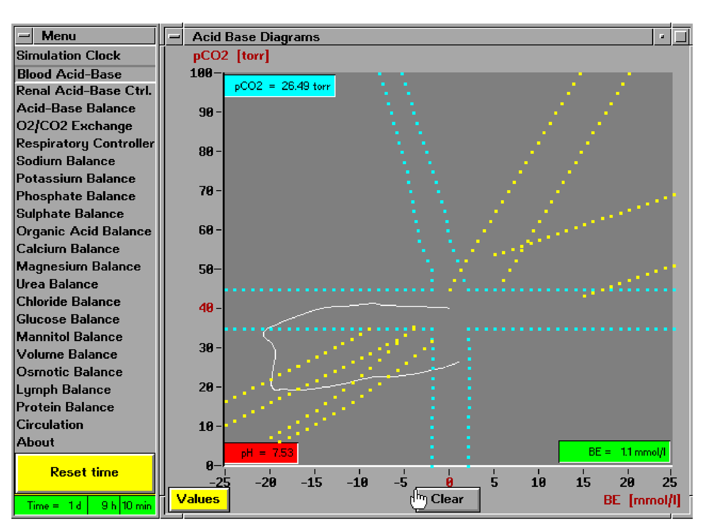

Fig. 9. If we overdose the infusion (as shown above), we correct BE, but hyperventilation leads the patient from acidemia to alkalemia, which can be dangerous.

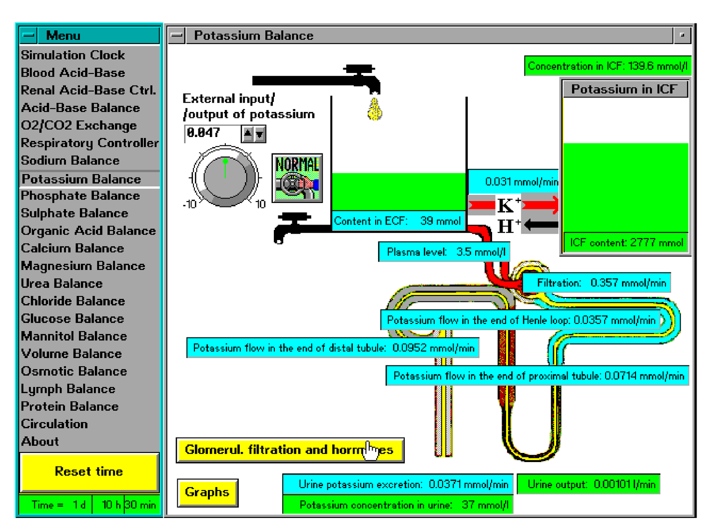

Fig. 10. Overdoses of alkaline infusion therapy would quickly lead the patient from acidemia to alkalemia, as the cell exchanges K^+ for H^+ (from the intracellular buffers). Because extracellular stores of potassium are limited, its plasma concentration will quickly and dangerously decreases. It is necessary to replace lost potassium.

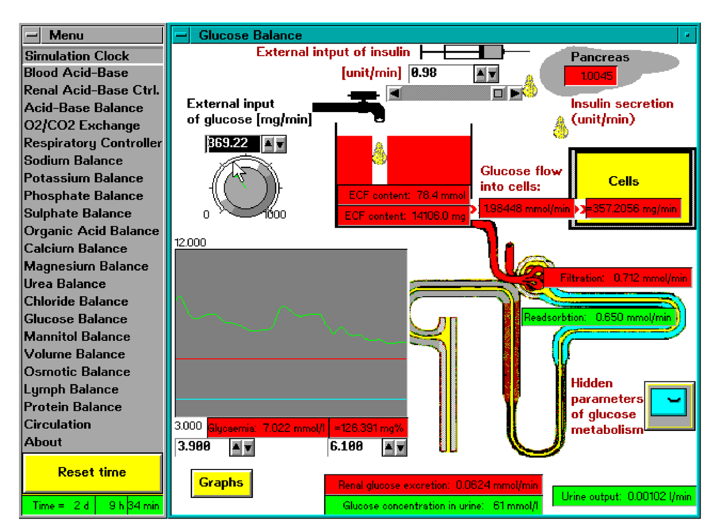

Fig. 11. To correct the K^+ depletion, we must use a potassium infusion in glucose and insulin - insulin takes glucose into cells...

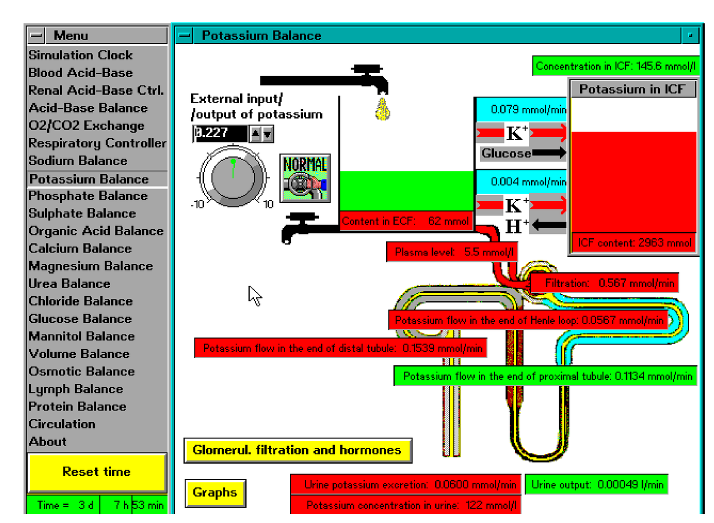

Fig. 16 ...but also increases the entry of potassium into cells resulting in a faster correction of K^+ depletion. The infusion must not contain too large concentrations of potassium (as this would increase K^+ to dangerous level).

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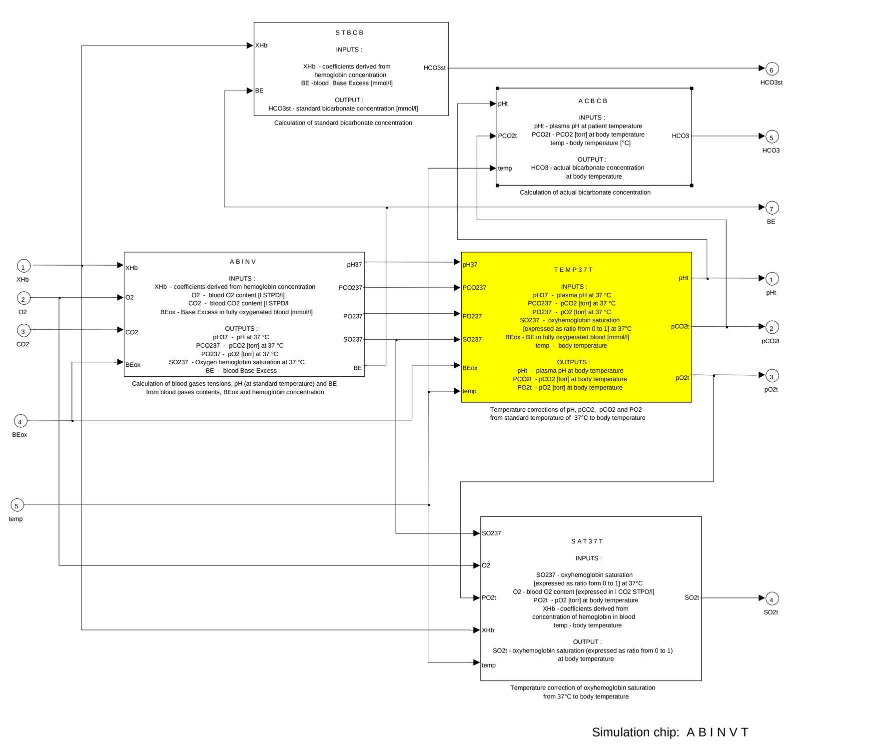
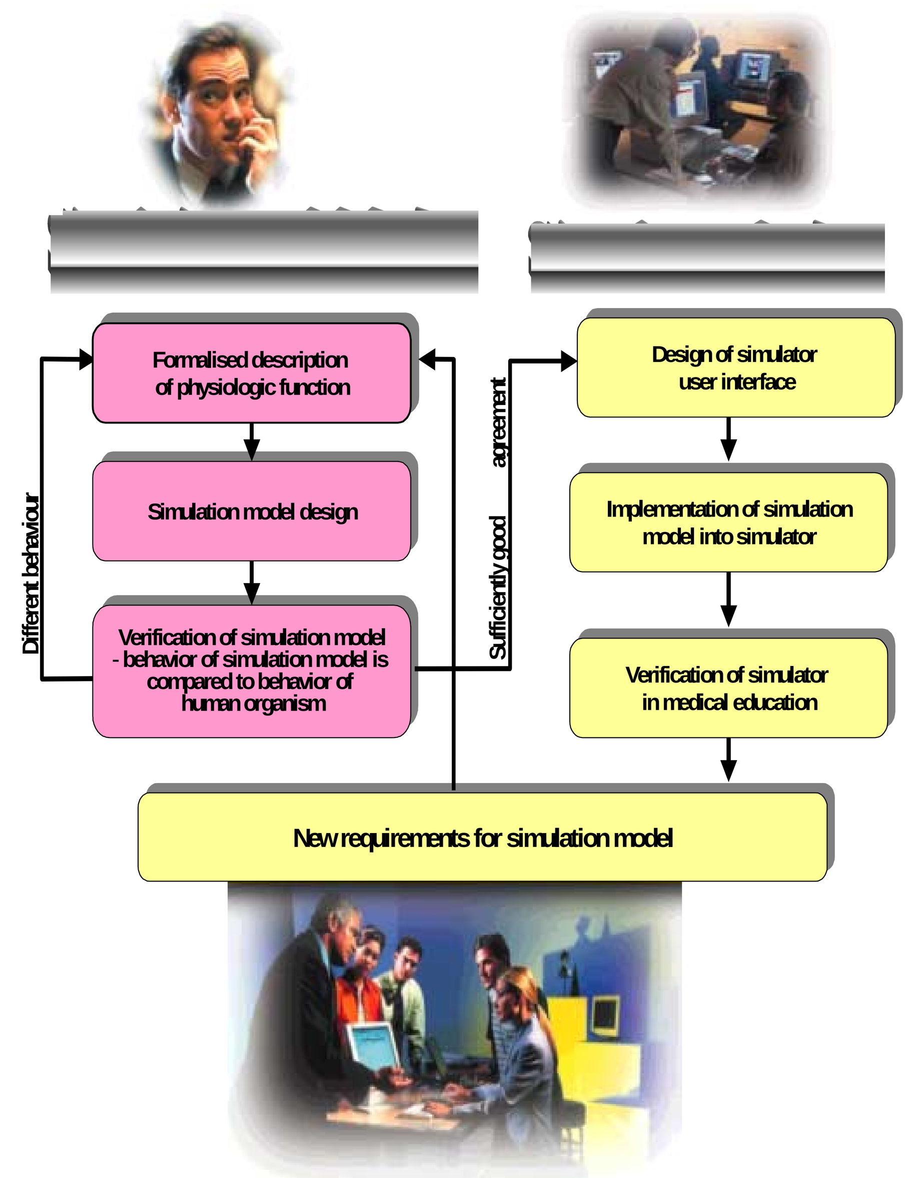
Simulation model design:



Simulation chips and simulation circuits as the results of Simulink are analogical to electronic circuits. Here, however, information is conveyed instead of electrical current. In electrical circuits, controlled power supplies and generators of signals can be connected to the electrical joints and the course of the electrical voltage can be displayed with measuring devices or oscilloscopes. Similarly, in the graphical environment of the Simulink programme, simulation model input values can be connected to separated "pins" of the simulation chips and the time-course of the corresponding variables can be registered on the virtual displays or oscilloscopes. Simulation circuits are constructed hierarchically, in the same way as in electronic circuits. In this figure, the inner structure of the simulation chip is shown. Its structure resembles again an electrical network with interconnected integrated circuits. Small circles represent the inputs and outputs from the entire scheme to the corresponding input and output "pins" of the software chip. Rectangles represent another interconnected software simulation chips ("integrated circuits") of the lower hierarchical level.

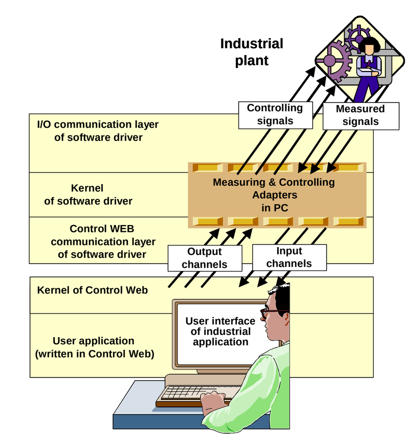


Two kinds of problems were to be solved by construction of the medical simulator: The development of the simulation model (the theoretical work itself, based on formalization of physiological relations) and the design of the simulator and the use of the simulator in education (practical application of the theoretical results), Each of the problems is specific and requires using different developer's tools.

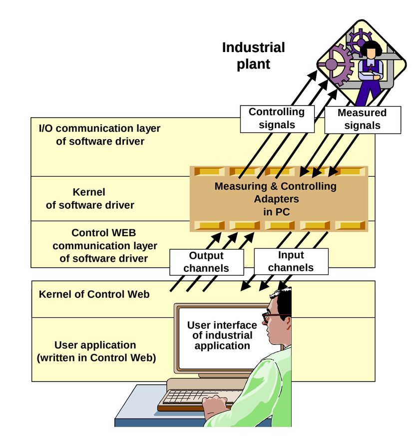
Simulator design:

Control Web (Moravian Instruments Inc.)

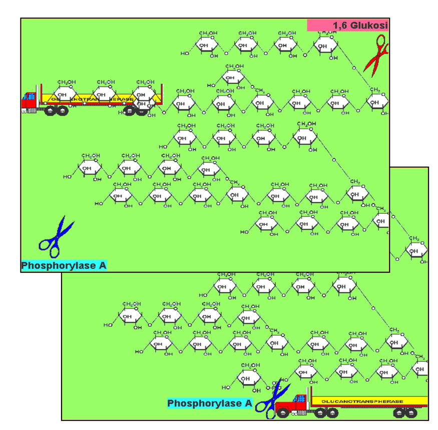
Macromedia Flash (Macromedia Inc.)



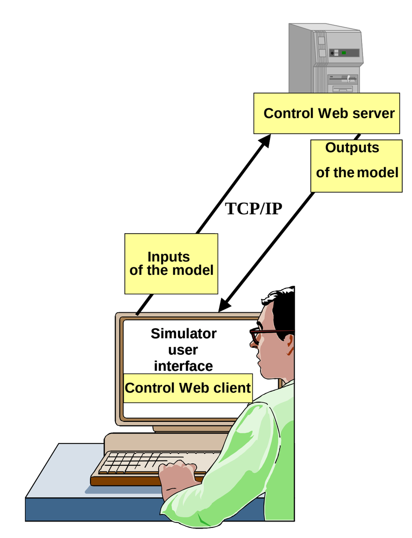
The communication of the *Control Web* information and control system with the driver of the measuring/controlling adapter during generation of industrial applications.



Integration of the simulation model into the driver of the "virtual adapter" during the generation of the medical multimedia simulators.



Multimedia animations are profusely used in the educational programmes. Interactive animation elements are designed using Macromedia Flash and implemented as Active X components.



Application of Control Web in distributed educational simulating application.

GOLEM - computer simulator of body fluid and acid-base disorders as an efficient teleeducation tool

Aim: Our aim was to create multimedia training simulator for learning diagnostics and therapy of the of the critical clinical disorders of body fluids homeostasis.
Methods: The theoretical basis of the simulator is the mathematical formulation of the relationship of the acid/base, electrolyte, osmotic and volume equilibrium, transport of blood gases, respiration, circulation and kidney functions. Mathematical description consists of 38 non-linear differential equations and containing 89 input and 179 output variables. Despite this complexity, the simulation model represents real body function with sufficient fidelity. When building the multimedia components of the simulator we have used developer's tools from Macromedia and for the development of the simulaion models we have used developer's tools from MathWorks (Matlab and Simulink). The integration of the tmultimedia components, hypertext and simulation models interface was realized using Control Web (developer's tool from Moravian Instruments).
Results: Our simulator "Golem" was implemented as an teleeducation tool on University Intranet. "Golem" is used as a clinical physiological trainer to help improve diagnostic and therapeutic decisions.
Conclusion: "Golem" is efficient teleeducation tool that enables students to try out solving of individual critical situations out of reality on simulator. "Golem" considerably helps the students to understand complex regulatory relations of body fluid homeostasis.

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