Chapter 9
Quantum Neural Information Processing

Neural vs. quantum nets – discussion. This Chapter is devoted to discussion of neural-to-quantum (or holography-to-quantum, respectively) transforms of connectionist associative processing of Chapter 8. Equations (8.9), (8.10) and (8.11) come from basic quantum physics. Quantum interference is very fundamental and essential. With the Young experiment it was an early experimental predecessor of the Schrodinger quantum wave-mechanics and the Heisenberg quantum operator theory (Messiah, 1965; Bohm, 1954; AuxLit 16).

There is nothing "neural" (in biological sense) in the system of quantum equations (8.9) & (8.10). It is just *similar, according to their mathematical structure and coupling*, to the system of ANN equations (8.1) & (8.2). Because we are certain that the ANN system (8.1) & (8.2), and HNeT's formulas (8.5) & (8.6) as well, realize efficient information processing, I have taken the similar system of equations

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from the quantum-physics formalism in order to discover quantum ANN-like, or better HNeT-like, information dynamics. Using computer simulation experience with the Hopfield model and HNeT's successes, I have merely given a precise information-processing interpretation to a selected and deliberately connected set of quantum equations which are, each one alone, known to all physicists and well experimentally verified.

Since the proposed "algorithm" is realizable in any complex system obeying similar collective dynamics, information processing of the same type could in principle be realized in many such (classical) systems, if we neglect some specific features arising from the nature of *individual* elements of the system. The "algorithm" is thus relatively universal, with exception of some specific characteristics to be discussed now.

There is a difference between the neural "algorithm" (8.1)-(8.2)-(8.4) and the quantum "algorithm" (8.9)-(8.10)-(8.11): Neural variables in equations (8.1)-(8.2)-(8.4) are real-valued, but quantum variables are complex-valued, because they implicitly incorporate the phase. Thus, a quantum quantity or expression usually incorporates, at least implicitly, the imaginary unit i, the Planck constant $\hbar$, and/or the asterisk denoting complex conjugation. Complex numbers with phases as imaginary components accompany oscillatory dynamics, absent in the presented ANN, but present in holography and its simulation – HNeT. (An example of spectral, i.e. wave-dynamic, Hopfield-based ANN see: Spencer, 2001a,b.) Chapter 7 demonstrates explicitly in which case real-value processing is equivalent to oscillatory processing – the latter is usable for quantum-wave image recognition.

Quantum informatics. The quantum memory recall procedure is a special case of usual quantum measurements (Wheeler & Zurek, 1983). The difference is that usual physical processes in our case have an informational interpretation, i.e. our eigen-wave-functions have a specific prescribed *meaning*. Let us describe the reconstruction of the selected quantum eigen-wave-function from the informational or cognitive point of view.

In quantum language, the quantum system was perturbed by the experimenter in a specific way. Informationally, the new input was let to interact with quantum memory. Mathematically, the input vector was multiplied (convoluted) with the memory matrix (the Green-function propagator). Or, the input-wave-components (as shown in (8.11), similarly to (8.4)) were multiplied with the propagator's components (correlations of all possible learned quantum patterns) which encode the memory, and summed together. Because the propagator is a superposition of self-interferences of each eigen-wave-function, we can expand the above multiplication into a series. Each term of this series corresponds to an implicitly-present eigen-wave-function "interacting" with the input, i.e. the perturbation. If we choose the perturbation-pattern similar to one stored quantum pattern, the corresponding