Cellular neural network based PTV

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In the recent years, artificial neural networks and genetic algorithms have been attractive in the field of visualization. Among them neural networks seem particularly attractive where the use of the learning principle facilitates the development of fully automated knowledge based system of measurement. Hopfield neural network based approaches had been carried out by some of the authors for particle matching of two-dimensional particle tracking velocimetry (2D-PTV), but their practical application is inconvenient due to inherent demerit of high computation time with the increase in number of particles. So far as three-dimensional measurement technique, where two different stages of particle matching namely: spatio-differential and time-differential pairing are carried out, is concerned, the time-differential algorithms developed for 2-D PTV can be used with slight modification for the second stage while for the first stage the basic methodology is to check the proximity of a particle image and its related epipolar line in either of the two or more camera frames. The conventional method, accompanied by certain concepts, are able to yield the better pairing results but the computation time and CPU load are largely increased with number of particles

In the present study, network model based on cellular neutral network, a massive parallel computing paradigm defined in discrete N-dimensional space, has been implemented time-differential as well as spatio-differential particle pairing. Unlike the Hopfield neural network, connections are limited to units in local neighborhood of individual units in cellular neural network. In other words, any cell is connected only to its neighbor units, *i.e.* adjacent units interact directly with each other. Units not in the immediate neighborhood have indirect effect because of the propagation effects of the dynamics in the network. Thus, the point of this study lies on the connection scheme of the neurons, according to which the network is reduced from fully connected to partially connected scheme.

The mapping of the particles for particle pairing algorithm is as shown in the Figure 1.
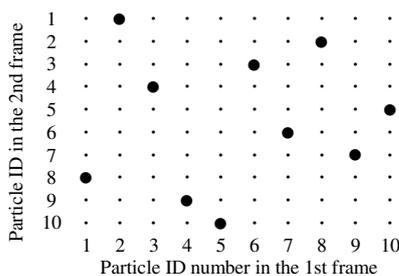
Fig.1   Neuron units' arrangement for PTV

The physical state of neuron units is expressed as "active" or "inactive" as shown in Figure. The active neurons (designated by large dots) stand for correct pairing of particle ID numbers and the inactive ones (designated by small dots) for incorrect pairing. As a general rule of this type of particle pairing problem, the particles in the first and second frames have to meet with a unique one-to-one correspondence. So, every row or column of Figure 1 ought to have at least but no more than one active neuron.

The basic principle now is that the Lyapunov energy function of the network system should be minimized as formulated below,

$$E = -\frac{1}{2} \sum_{\substack{(i,k)}} \sum_{\substack{(j,l) \\ C_{jl} \in N^r_{ik}}} T_{ik,jl}.V_{ik}.V_{jl} - \sum_{(i,k)} I_{ik}V_{ik}$$

where V_{ik} is the neuron state at the crossing of row i and column k (so is V_{jl} in like manner), $T_{ik,jl}$ is the connection weight of the two neuron units ik and jl, and I_{ik} the energy threshold of unit ik. N and M defined in (1) represents the number of particles in the first and second frames.

The particle matching algorithm is tested by using the 3-D PIV Standard Images available from the Visualization Society of Japan. A sample of time-differential matching has been shown in Table 1. This time-differential matching has been carried out for the 3-D coordinates obtained after the successful matching of the spatio-differential images by the algorithm which is also developed in the present study. The notable improvement in computation time, which is now no more than two minutes instead of around more half an hour of conventional methods, is the another achievement in addition to the accuracy results shown in the table.

Table 1 Sample results of particle matching

Frame #	Number of particles	Pairing results	
		Conventional method	CNN
000/001 (Image series #351)	1509/ 1509	25.84%	88.53 %
000/001 (Image series #352)	277/ 277	83.03%	97.83 %

Thus, in conclusion, the concept of Cellular neural network has been successfully implemented for particle pairing algorithm of particle tracking velocimetry with significantly low computation time and adequate accuracy. The significant improvement in computation time has cited a comfortable way for the use of such networks, which was previously seemed tedious due to long computation time.