# Exercise

13 January 2014

In this exercise, you will solve the stereo matching problem using Loopy Belief Propagation. We formulate the stereo problem in terms of an MRF with the following energy function :

$$\mathcal{E}(\ell) = \sum_{p \in \mathcal{I}} D_p(\ell_p) + \sum_{(p,q) \in \mathcal{N}} V_{pq}(\ell_p, \ell_q)$$

The unary term is

$$D_p(d) = |I_L(x, y) - I_R(x - d, y)|$$

And the pairwise is

$$V_{pq}(\ell_p, \ell_q) = w_{pq} * Potts(\ell_p, \ell_q),$$

where

$$Potts(\ell_p, \ell_q) = \begin{cases} 1 & \text{if } \ell_p \neq \ell_q \\ 0 & \text{otherwise} \end{cases}$$

For this exercise, we use the same Tsukuba image pair, from the previous assignment, available here with 16 disparity levels, i.e, $d = 0, 1, ...15$. The smoothness weight $w_{pq}$ is set to be 15. You can evaluate the accuracy of your disparity map using the ground-truth available here.

**Loopy BP** : Consider an MRF as in Figure 1. Loopy BP is an iterative method, with messages from all nodes being passed in parallel. Each message is a vector of dimension given by the number of possible labels. Let $m^t_{p \to q}$ be the message that node $p$ sends to a neighbouring node $q$ at iteration $t$. All entries in $m^0_{p \to q}$ are initialized to zero, and at each iteration new messages are computed in the following way :

$$m^t_{p \to q}(\ell_q) = \min_{\ell_p} \left\{ V_{pq}(\ell_p, \ell_q) + D_p(\ell_p) + \sum_{s \in \mathcal{N}(p) \setminus q} m^{t-1}_{s \to p}(\ell_p) \right\} \tag{1}$$

After $T$ iterations, a belief vector is computed for each node

$$b_q(l_q) = D_q(\ell_q) + \sum_{p \in \mathcal{N}(q)} m^T_{p \to q}(\ell_q)$$

Finally, the label that minimizes the belief at each node is selected.

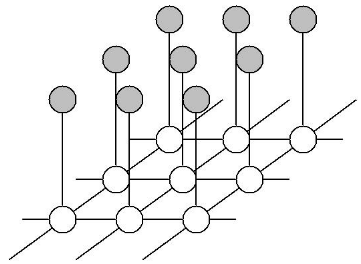

Figure 1: MRF for the stereo matching problem

**Loopy BP with fast computation of messages** : As your second task modify your Loopy BP algorithm introducing a fast computation of messages. We can re-write equation 1 as

$$m^t_{p\to q}(\ell_q) = \min\left(h(l_q), \min_{\ell_p} h(l_p) + w_{pq}\right) \tag{2}$$

where $h(l_q) = D_p(\ell_d) + \sum_{s\in\mathcal{N}(p)\backslash q} m^{t-1}_{s\to p}(\ell_p)$. Separating the minimization over $\ell_p$ in this manner reduces the time necessary to compute a message. First we compute $\min_{\ell_p} h(l_p)$, and then use that to compute the message value for each $\ell_q$ in constant time.

**Submission** Mail your source code and report to `nikos.komodakis@enpc.fr` The report should include the obtained disparity map, accuracy for the stereo matching problem and a comparison of speed of the two methods. The deadline for this exercise is $27^{th}$ January.