An Improved Belief Propagation Method for Dynamic Collage

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Outline

- Introduction
- Related work
- Problem description
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- Experiments and discussion

Introduction

- Photo collage
  - Photo collage creates a compact and plausible summary of several photos in a canvas.
  - Three requirements
    - Visual Information Maximization
    - Blank Space Minimization
    - Single Photo Visibility
  - Allows unimportant part of each photo to be occluded.
  - Only the salient and informative part of each photo can be visible on the canvas, so the finite canvas space is sufficiently utilized.

Introduction

- An example of photo collage

Introduction

- Drawback of photo collage
  - The scalability of photo collage is limited.
  - It is not acceptable to show hundreds of photos in a limited canvas.
  - Providing a desirable way for users to view a large amount of photos is challenging.
- Dynamic collage
  - Allows dynamic change of photo collage.
  - New photos are added into canvas, old photos are removed out of canvas.
  - The layout of photos is adjusted in a local and incremental manner to maintain visual continuity.

Introduction

- Advantages of dynamic collage
  - The scalability is significantly extended while maintaining the advantage of photo collage.
  - Users can browse large photo collections by dynamic collage.

Introduction- photo browsing using dynamic collage

- Butterfly Demo

Related work

- Collage
  - [CVPR’06] Picture collage
    - Salience Maximization
    - Blank Space Minimization
    - Salience Ratio Balance
  - [ACM Trans. Graph’06] Auto-collage
    - produce a dense and seamless collage

- Belief Propagation
  - [Int. J. Comput. Vis.06]

    Efficient belief propagation for early vision
    - Belief propagation is useful for many computer vision problems

Problem description

- Formulation of dynamic collage
  - Given N photos $\{I_i\}_{i=1}^{N}$ and their importance map $\{A_i\}_{i=1}^{N}$, dynamic collage aims to find their optimal states $X = \{x_i\}_{i=1}^{N}$ to maximize the visible information in canvas through object function minimization using belief propagation.
  - For each photo I_i, it has state $x_i = (t_i, \theta_i, l_i)$. t_i is its center coordinates, θ_i is its orientation angle and $l_i \in \{1, 2, \ldots N\}$ is its layer which determines its display order.
  - We compute a importance map for each photo, so each pixel of the photo has a importance value indicating the amount of information it has.

Algorithm

- Three Stage Optimization
  - In order to reduce the label size in BP, we divide the optimization process into three stages, which optimizes the central coordinates, orientation angle and layer respectively.
  - When optimizing one component of the state, we treat the other two components as constant.

Algorithm

- Center Coordinates Optimization
  - Object function to minimize information loss and blank area

$$E(X) = M(X) + \sum_{i} O(x_i; X_{N(i)}) + \sum_{i=1}^{N} B_i(x_i) \qquad (1)$$

$M(X)$ is the blank area in canvas

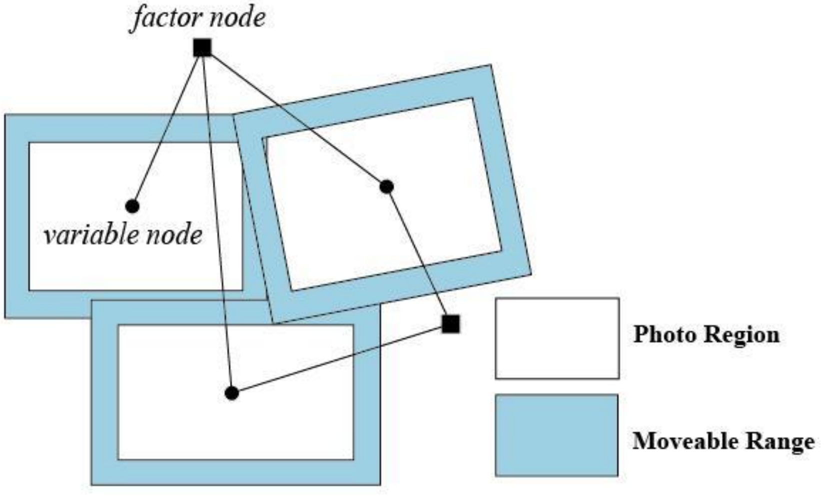
$O(x_i; X_{N(i)})$ is the information loss of photo I_i due to occlusion by other photos. $X_{N(i)}$ is the set of photos which can occlude I_i

$B_i(x_i)$ is the information loss of photo I_i due to out of canvas

  - We restrict the movable range of each photo to a neighborhood of its initial position so as to maintain visual continuity.
  - (1) is a high order object function, so we construct factor graph model to apply belief propagation.

Algorithm

- Factor Graph Model



  - The state of each photo is represented as factor node and the potential function is represented as factor node.

  - The movable ranges of all photos form the solution space of the central coordinates optimization problem.

Algorithm

- Approximate Message Computing
  - Computing the messages for high order potential function requires searching the solution space of all variable nodes simultaneously, so the complexity is exponential.
  - Develop an approximate method of message computing.
  - The center coordinates only varies in a neighborhood.
  - We search the solution space of all nodes in order. When we search the solution space of one node, we treat the states of other nodes as constant.
  - Therefore the complexity is reduced to quadratic.

Algorithm

- Comparison between factor graph and pariwise Markov Random Field

Algorithm

- Orientation Angle Optimization
  - Assign each photo an orientation angle to further increase the visible information.
  - We pre-defined five discrete angles.

    $$\{n\theta\}_{n=-2}^{2} \quad \theta = 5^{\circ}$$

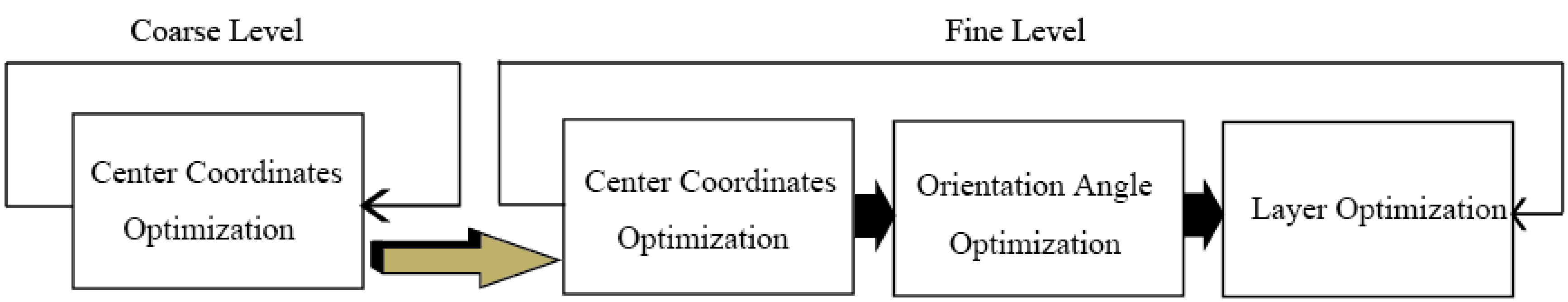
  - Run BP to optimize the object function to minimize information loss due to occlusion as before.

Algorithm

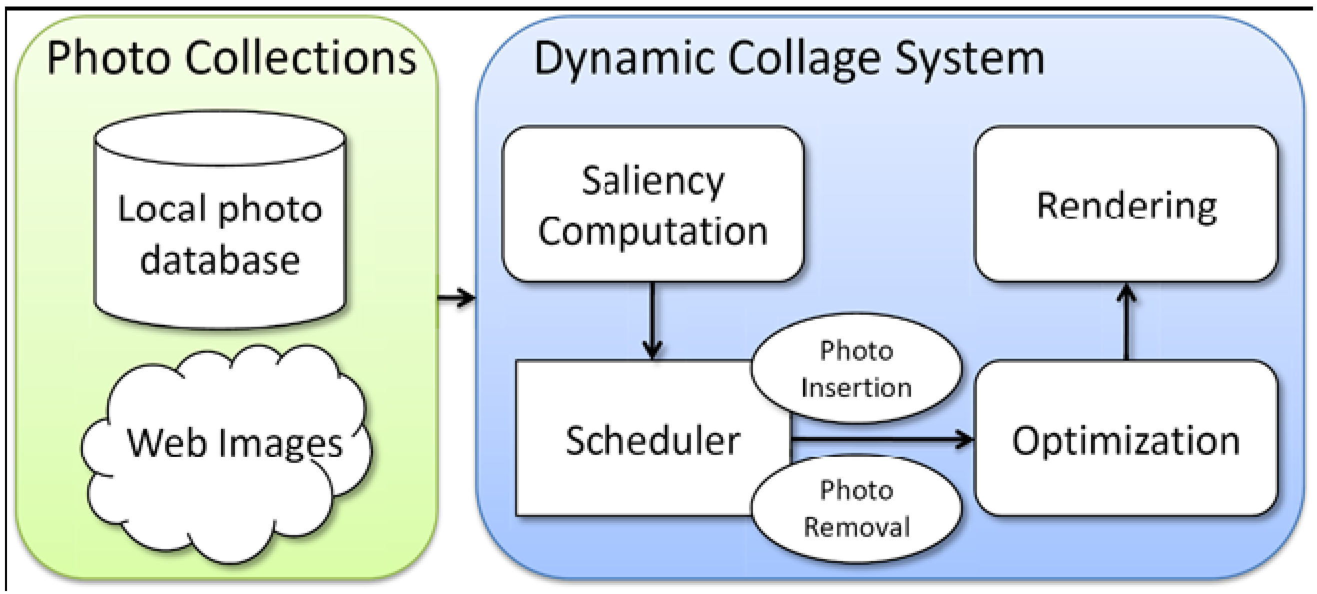
- Layer Optimization
  - Construct a directed graph according to pairwise display order for all photos in canvas.
  - Use topological sort algorithm on this directed graph to determine the display order of all photos, and assign layers to them accordingly.

Algorithm

- Combine the three optimization stages
  - We run the three optimization stages in order as an integral optimization cycle.
  - Two-scale acceleration
    - In coarse level, we define a large movable region for all photos, and only do center coordinates optimization.
    - In fine level, we define a small movable region for all photos, and do the whole optimization cycle.



System Overview



- Four modules
  - Saliency computation module, scheduler module, optimization module and rending module.

Experiment

- In a 1024 × 768 canvas, the two-scale method costs 0.8s averagely to form a photo collage for 12 photos with a size of 300× 300.

- Efficient enough to render real-time photo browsing.

Experiment

- [Flower Demo]

Discussion

- Dynamic collage allows dynamic change of photo collage so users can browse large photo collection via it.

- Dynamic collage enables real time photo browsing by the efficient two-scale acceleration method while maintaining the visual continuity when the canvas is updated.

Limitation and future work

- Perform multiple optimization cycles, so the displacement of some photos may be large and visual continuity is hard to maintain for these photos.
- Further confine the movable region for specific photos with semantic information.
- Combine the lifetime of photo into the object function to render a spatio-temporal dynamic collage.