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Title:	Vision based Human Tracking from a Mobile Robotic Platform
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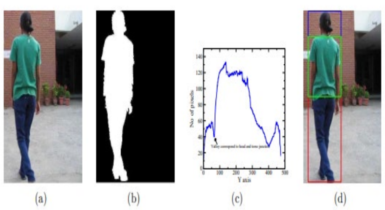
Abstract:

Abstract This thesis deals with the human tracking from a mobile platform while addressing issues such as abrupt object motion, change in appearance pattern including pose, non-rigid object structure, occlu- sion, and camera motion. A novel color based human detection algorithm is proposed. The algorithm uses the color histograms of human clothing alongwith the concept of head and hand creation that is based on depth of interest, to construct the complete human silhouette in a dynamic environment. To make the algorithm robust, a series of detectors (e.g., height, size, shape) is utilized to distinguish the target human from other objects. To meet the real-time processing requirements, a shape analysis algorithm is developed, which is computationally effective and identifies the object as a human by finding the two legs apart pattern in the vertical projection histogram of the object. An unscented Kalman filter is used to predict the human location in the image frame to maintain the continuity of the robot motion. To avoid the inherent shortcoming of the color-based techniques, point-based methods which use gradient features such as SIFT or SURF are explored for the human tracking. The point-based methods have two major limitations: (1) The number of matching points obtained vary significantly from one frame to another and may diminish over time, and (2) the high computational complexity associated with computing SURF correspondence between a pair of images. To overcome these limitations, a SURF-based human tracking algorithm is developed which uses a dynamic object model. The proposed dynamic object model consists of a set of SURF descriptor points and it evolves over the time to accommodate the changes that might arise due to change in poses over subsequent frames. This object model derives its points from a template pool that helps in reinforcing the features which occur more frequently compared to others. In this process, it aims to resolve the stability-plasticity dilemma in object tracking and to overcome the limitation of unavailability of a sufficient number of matching key-points. Further, to reduce the computational complexity, an algorithm is developed which uses the concept of dynamic object model and searches for the human in local regions. Most of the existing point based methods do not deal with pose change due to out-of-plane rotations, which is a very difficult problem to solve. To address the issue of pose change due to out-of-plane rotations, a SURF-based algorithm is developed in which the object model is updated over time by selecting new templates and projecting points from previous templates using an affine transformation. The pose change due to out-of-plane rotations is confirmed by using the aspect ratio of the bounding region of points projected using affine transformation. An innovative application of the commonly used region growing algorithm is demonstrated on point-based methods, where it helps in removing background descriptors from the object model used by the SURF-based tracker. A k-d tree based

classifier is used to differentiate between a case of occlusion from that of a case of pose change. Further, a SURF-based mean-shift tracker is combined with optical flow tracker to provide a robust algorithm for tracking a human from a mobile robot platform. The hybrid tracker serves several purposes. It is used for selecting new templates online, and hence, solves the template update problem. It provides robust tracking over a long run compared to the individual trackers - SURF-based mean- shift algorithm and Optical flow tracker. It provides a way to deal with out-of-plane rotations, which is not yet solved in point-based methods. A Kalman filter based motion predictor is used to deal with the cases of occlusions. Finally, a robust, computationally effective human tracking algorithm is proposed which utilizes the color information along-with SURF-based tracker. The limitations of point-based methods are overcome using color information and imposing a structure on the color blobs. Whenever the SURF based tracker fails, the presence of a human is detected using a Markov random field based graph matching algorithm. Imposition of structure on the colored blobs helps in eliminating background objects having similar color distributions. The stability-versus-plasticity dilemma inherent in tracking over a long run is resolved by selecting new templates online, and maintaining a fixed-size tree of templates which is updated with new information. All the human tracking algorithms developed in this thesis are computable in real-time. In order to implement these visual human tracking algorithms on a mobile robot, a visual servo controller is designed which takes data from the tracking algorithm and gives motion commands (translational and rotational velocities) to the mobile robot. The control problem is formulated using the equations of the kinematic model of the robot and the pin-hole model of the camera. Then, the controller is designed using the approach of dynamic inversion. The human tracking algorithms developed in this thesis are combined with the proposed controller and real-time experiments are conducted in indoor as well as in outdoor environments.



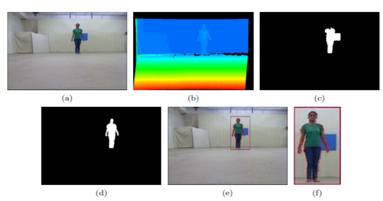


Figure 2.15: Human detection where some part of the background matches with the human color. (a) RGB image. (b) Depth image. (c) Back-projected image. (d) Reconstructed human silhouette. (e) Detected human image. (f) Magnified image of human detection.

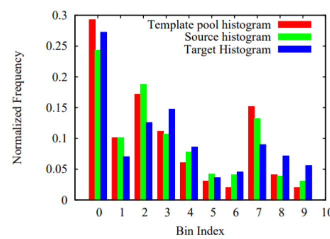
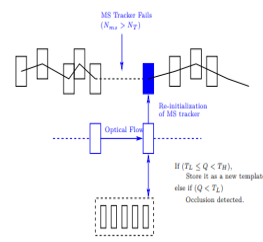


Figure 3.3: An example image of SURF histograms



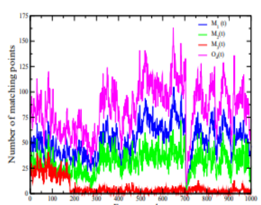
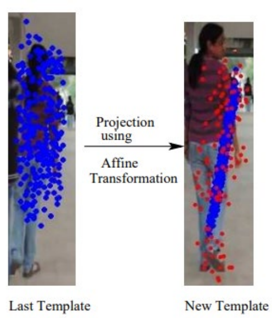
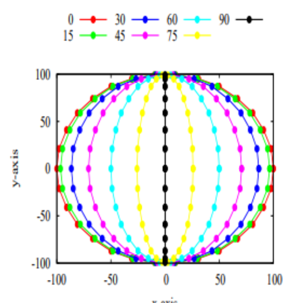
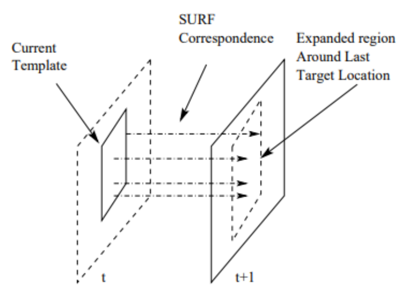


Figure 3.8: Object model $O_m = M_1(t) \cup M_2(t) \cup M_3(t)$.







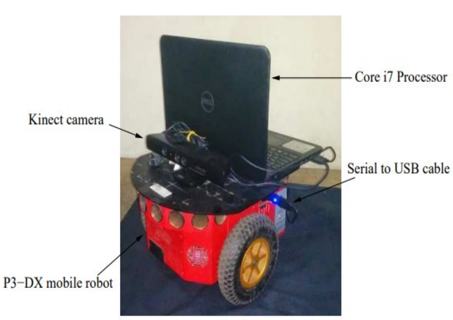


Figure 6.2: Experimental setup.