

Tangible Projection Mapping onto Deformable Moving Thin Plants via Markerless Tracking

Tomoki Sueyoshi
Kyushu University
Fukuoka, Japan
2DS18075M@s.kyushu-u.ac.jp

Yuki Morimoto
Kyushu University
Fukuoka, Japan
morimoto@design.kyushu-u.ac.jp

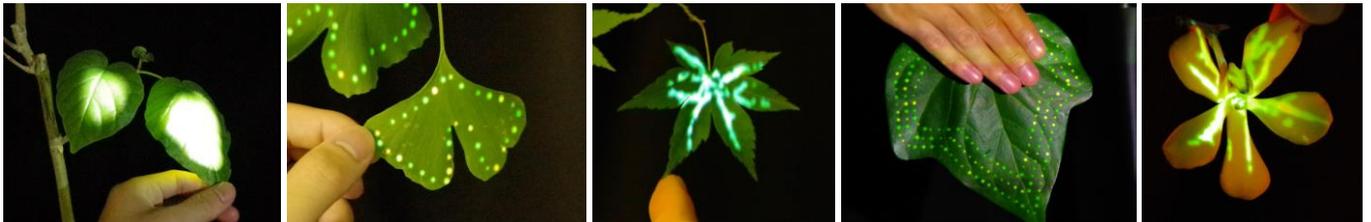


Figure 1. Our projection mapping results: the animation effects track the moving leaves and flowers.

AUTHOR KEYWORDS

Interactive Projection Mapping, Image Processing, Visual Effects

CCS Concept

•Applied computing → Media arts

INTRODUCTION

We propose a system that automatically generates a projection mapping (PM) onto natural objects such as leaves and flowers, for which it is currently difficult to apply tracking markers. Our PM allows user interactions such as contact and covering. We describe our results with some animated effects on various moving leaves and flowers (Figure 1).

Recently, the targets of PM have included objects ranging from buildings to fish. However, it is difficult to project onto dynamic and deformable natural objects such as leaves.

Some fantastic artwork related to the PM of plants was created using the motif of bioluminescence [1]. However, the mapping required a considerable length of time to register the projection images manually for the plants in a forest.

Various automatic high-speed registration methods have been proposed [2,3]. However, it is difficult to automatically register images for dynamic and deformable targets at high speed without inputting a 3D model or attaching markers in advance. As leaves have various shapes, a method that

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.

UIST '19 Adjunct, October 20–23, 2019, New Orleans, LA, USA

© 2019 Copyright is held by the owner/author(s).

ACM ISBN 978-1-4503-6817-9/19/10.

<https://doi.org/10.1145/3332167.3356887>

automatically registers images for dynamic and deformable targets without such preparations has been developed [4]. However, this method can only be applied to limited target shapes such as ginkgo and maple leaves because of its assumption that the distance between the longest contour points is the long side of a leaf. Our system achieves more flexible and robust performance by applying tracking at two scales using the Laplacian.

SYSTEM OVERVIEW

Layout of devices: Our proposed system, comprises an infrared (IR) camera, an IR light, and a projector. The projector–camera system consisted of a camera and projector packed as closely together as possible.

Camera and projector registration: In the pre-processing stage, we record the sizes of the images projected by the camera, and fit the images to the whole projection area [4].

Tracking: In the first frame ($t=0$), the projection areas are specified by the user from among the regions via contour extraction from the image I^t obtained by the camera. The contour vertex of each area is \mathbf{p}_{ij}^t for $i=1,2,\dots,l$, where l is the number of projection areas by texture mapping, and $j=0,1,2,\dots,m$, where m is the number of vertices in an area. The animated effects are then generated from the acquired contours. After $t=0$, the system finds position \mathbf{p}_{ij}^t , which is the result of tracking \mathbf{p}_{ij}^{t-1} (Figure 2). The effects are deformed to the tracked projection area by texture mapping using \mathbf{p}_{ij}^t . The process applied to every frame after $t=0$ is summarized below.

A. Edge image E^t is generated from I^t by image processing (Figure 2a).

B. Template T^L is generated by drawing lines between \mathbf{p}_{ij}^{t-1} . Its size is the minimum bounding box of the contour points needed to apply template matching TM^L to E^t . Then, \mathbf{q}_{ij}^t is

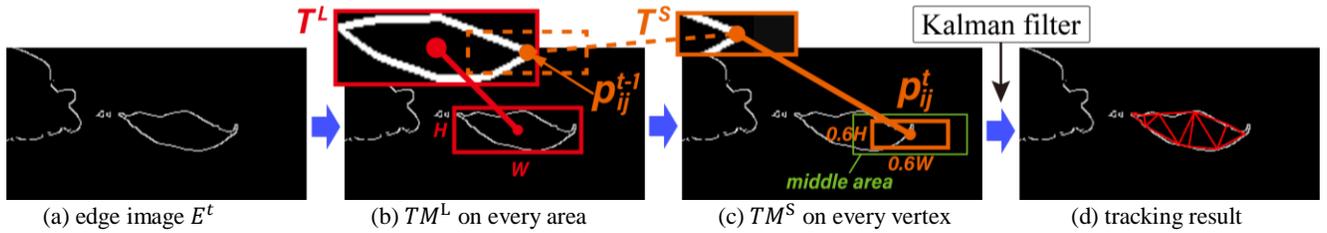


Figure 2: overview of our process every frame

calculated by translating \mathbf{p}_{ij}^{t-1} to the position given by TM^L (Figure 2b).

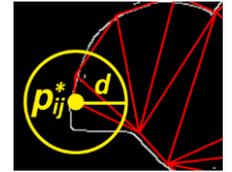
C. Template T^S is generated by extracting the small area around \mathbf{p}_{ij}^{t-1} in T^L and applying template matching TM^S to the middle area around \mathbf{q}_{ij}^t in E^t (Figure 2bc).

D. The pixel positions \mathbf{r}_k that have high matching rates are calculated by TM^S . Then, \mathbf{p}_{ij}^t with the closest geometry is chosen from \mathbf{r}_k using $\Delta\mathbf{r}_k$ and $\Delta\mathbf{p}_{ij}^t$.

E. Corner correction is applied.

F. For display purposes, a Kalman filter is applied to \mathbf{p}_{ij}^t (Figure 2d). Parts of the animation are then extracted to consider area that are shielded through touching interactions, and so on.

In step E, the system corrects the positions of edge corners, because such corners are sometimes calculated wrongly. Points \mathbf{p}_{ij}^* are judged to be corners if \mathbf{p}_{ij}^t is less than 120° . Points \mathbf{s}_o are then extracted from E^t using contour extraction, where $o=1,2,\dots,c$, and c is the number of points. If \mathbf{s}_o is within a distance of d from \mathbf{p}_{ij}^* , it is compared with \mathbf{p}_{ij}^* using the Laplacian (see the right image). Further, if $|\Delta\mathbf{p}_{ij}^t - \Delta\mathbf{s}_o|$ is less than some threshold, \mathbf{p}_{ij}^t is updated by \mathbf{s}_o .



In step F, a Kalman filter is applied for denoising using the predicted value. Additionally, the system considers the simple occlusions between the projector and target object is only when the area is at initial position. The effect animation is extracted so as not to be projected onto the occluding object, such as a hand.

TRACKING METHOD FOR DEFORMABLE OBJECT

Our method applies TM^L to every projection area (step B), and then applies TM^S to every vertex (step C).

Further, in step D, the matching rates (Figure 3c) obtained by TM^S are multiplied by the area of E^t (Figure 3d) to restrict the vertices on the edge area (Figure 3e). Positions with matching rates above some threshold are classified as candidate points \mathbf{r}_k , $k=1,2,\dots,n$, where n is the number of candidates.

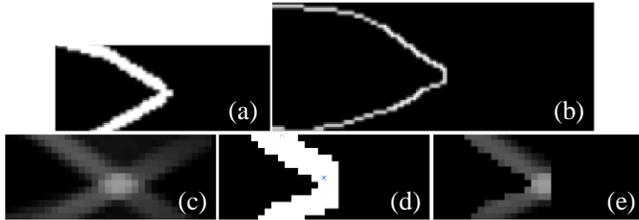


Figure 3. Template T^S (a), a search range (b), matching rates (c), part of E^t (d), the result of multiplication (e)

For each vertex, the tracking result is chosen from \mathbf{r}_k so that its local geometry is as close to \mathbf{p}_{ij}^{t-1} and/or \mathbf{p}_{ij}^0 as possible. Here, the Laplacian is considered for robust tracking against local deformation. The Laplacians are defined as $\Delta\mathbf{p}_{ij}^t = (\mathbf{p}_{ij-1}^t - \mathbf{p}_{ij}^t) - (\mathbf{p}_{ij}^t - \mathbf{p}_{ij+1}^t)$, $\Delta\mathbf{r}_k = (\mathbf{p}_{ij-1}^t - \mathbf{r}_k) - (\mathbf{r}_k - \mathbf{p}_{ij+1}^t)$. Their weighted average is calculated as $\Delta\mathbf{p}_{ij}^{com} = w\Delta\mathbf{p}_{ij}^t + (1-w)\Delta\mathbf{p}_{ij}^{t-1}$, ($0 \leq w \leq 1$); \mathbf{p}_{ij}^t is then calculated as $\min|\Delta\mathbf{p}_{ij}^{com} - \Delta\mathbf{r}_k|$.

RESULTS AND CONCLUSION

We have proposed the automatic generation of tangible PM on deformable objects with various shapes without any markers (Figure 4). One limitation of our current system is its sensitivity to the lighting environment. In future work, we would like improve our method to consider targets besides leaves and flowers. This work was supported by JSPS KAKENHI Grant Number 18K11956.

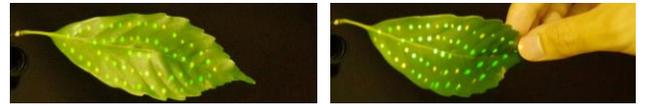


Figure 4: The result of local deformation

REFERENCES

1. Friedrich van Schoor, Tarek Mawad. 2014. Projections in the Forest
2. Amit H. Bermano, Markus Billeter, Daisuke Iwai, Anselm Grundhöfer, Makeup Lamps: Live Augmentation of Human Faces via Projection, 2017. Eurographics
3. Gaku Narita, et al.: Dynamic Projection Mapping onto Deforming Non-rigid Surface using Deformable Dot Cluster Marker, IEEE Transactions on Visualization and Computer Graphics, Vol.23, No.3, pp.1235-1248, 2017.
4. Tomoki Sueyoshi and Yuki Morimoto. 2018. Automatic generation of interactive projection mapping for leaves. In SIGGRAPH Asia 2018 Posters (SA '18).