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In this issue

Technology Developed in GICE

A Hybrid Approach for Finite-Size Fabry-Pérot Antenna Design with Fast and Accurate Estimation on Directivity and Aperture Efficiency

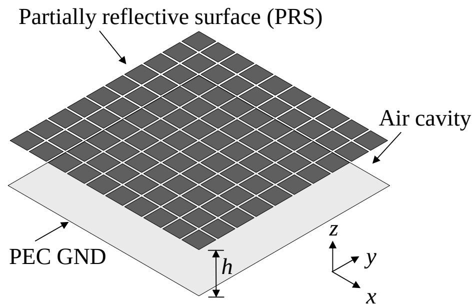
from Electromagnetics Group

Introduction

A Fabry-Pérot antenna (FPA) consists of a partially reflective surface (PRS), a resonant cavity, and a backed ground plane. Unlike antenna arrays using complex feeding networks, the FPA requires only a single feed port, which may reduce the feed loss and hence increase the antenna efficiency. Recently, several FPA designs have been proposed, including the classic one using a single metallic layer as a PRS [1]–[3].

The leaky wave radiation phenomenon for a FPA was also investigated in [4], where an FPA was modeled as an equivalent transverse network (TEN) and its radiation characteristics were obtained by the reciprocity theorem. In this paper, we present a simple and accurate approach to model a finite-size FPA and obtain optimal design curves of estimated directivity or aperture efficiency. The presented approach employs the TEN, the Fourier transform method, and the approximated formula of antenna directivity.

Analysis for Maximum Directivity and Aperture Efficiency a typical FPA with a one-layered PRS and a grounded air-cavity is depicted in Fig. 1(a), and its corresponding transverse equivalent network (TEN) model is shown in Fig. 1(b). In the TEN model, a lossless EBG-based PRS layer can be modeled as a shunt susceptance Bs. Applying this subseptance into the resonant equation in [5]. One can obtain the leaky wave dispersion relation in Fig. 2.



(a)

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GICE Honors

2014 Network Communications Research Project Excellent Project Award

Prof. Huei Wang

Prof. Ruey-Beei Wu

Prof. Liang-Hung Lu

Prof. Tian-Wei Huang

Prof. Yi-Cheng Lin

Prof. Kun-You Lin

Prof. Hsin-Chia Lu

Message from the Director

Tzong-Lin Wu

Professor & GICE Director

Dear Colleagues and Friends,
May is a rainy season in Taiwan, the fresh air in the misty NTU campus can further stimulate our research and innovation. Two outstanding professors of GICE share their recent research outcome in the second issue of 2014 GICE Newsletter. Prof. Yi-Chen Lin' Group developed an efficient and accurate model to predict the directivity and aperture efficiency for Fabry-Perot Antenna. Prof. Homer Chen' group proposed an autofocus algorithm that allows the video camera to continuously focus on moving objects. In addition, a Talent Cultivation Program for Smart Living Industry, leaded by Prof. Zsehong Tsai of GICE, has developed 141 courses materials in more than 28 Universities in Taiwan. The annual conference of this program is held in this quarter.
This issue is quite rich and informative both in technology development and activity reports. Please have a cup of coffee or tea, and enjoy the reading of GICE Newsletter!

Technology

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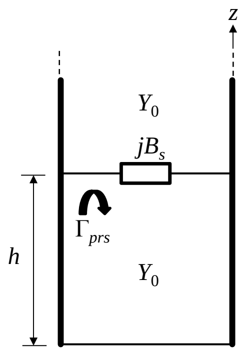
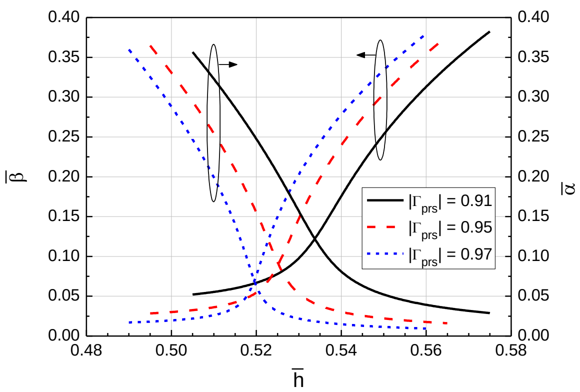
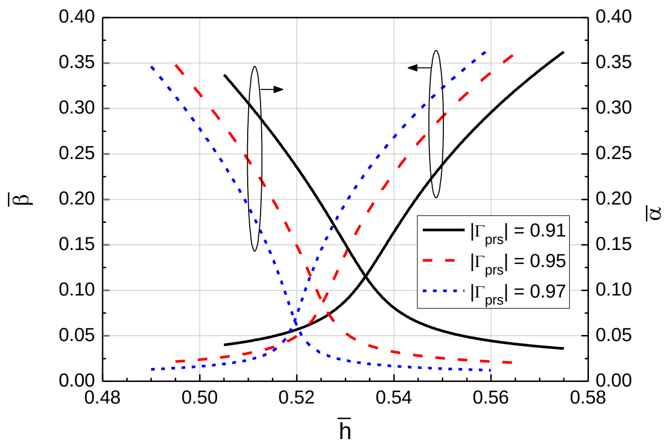


(b)

Fig. 1. Fabry-Pérot antenna (FPA) consisting of a free-standing partially reflective surface (PRS) with distributed aperture fields and a grounded air cavity beneath the PRS: (a) Configuration and coordinates. (b) The corresponding transverse equivalent network (TEN) model.



(a)



(b)

Fig. 2. Dispersion diagrams based on TEN model for different reflection magnitudes: (a) TE mode and (b) TM mode.

Once the wave number is obtained, we can use Fourier transform method in [6] to evaluate the far field pattern and estimate the directivity. Fig. 3 shows the directivity with different PRS reflectivity and the corresponding antenna size provides a rough guildline for the PRS design.

Fig 3 and Fig 4 show directivity and aperture efficiency with different cavity heights and PRS sizes. And the estimated model provides an accurate result compared to the full wave simulated ones. This method provides a fast estimating guideline for designing a PRS antenna.

1) Select the operating frequency.
2) Specify a range for the desired directivity and aperture efficiency range.
3) Find a PRS with respect to the PRS reflection magnitude and the PRS length to satisfy the specified directivity and the proper aperture efficiency. Without time consuming full wave simulation, this method could speed up the design procedure significantly.

IMPLEMENTATION AND EXPERIMENTAL RESULTS

For illustration, we built an FPA with a PRS reflection magnitude of 0.91 targeting a desired directivity of 20 dBi. From Fig. 4, the model predicts the optimal PRS length is 100 mm. The air-cavity height h is 15.4 mm between the PRS and the ground plane. A printed PCB dipole was implemented for the antenna feed. Figs. 5(a) and 5(b) show the configuration of the built FPA and the dimensions of the dipole feed, respectively.

The performance of the FPA prototype in terms of the reflection coefficients and the realized gain spectrums are shown in Figs. 6(a) and (b), respectively. It can be observed that the measured

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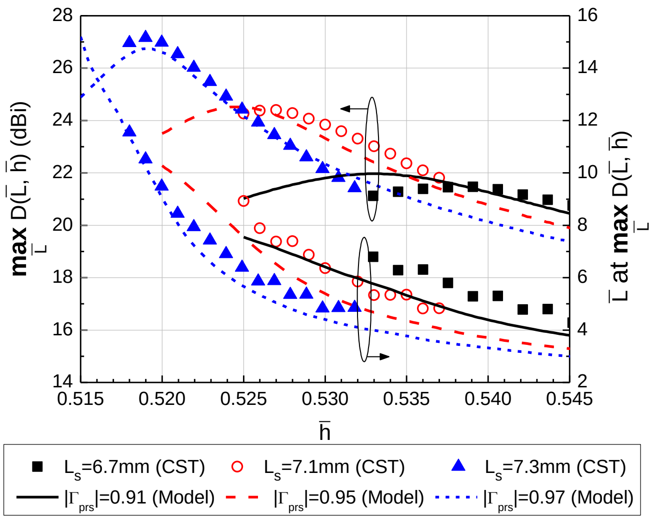

Fig. 3. The maximum directivity and the corresponding aperture length $\bar{L}$ as a function of the normalized height $\bar{h}$ with comparison of the CST simulation and the model

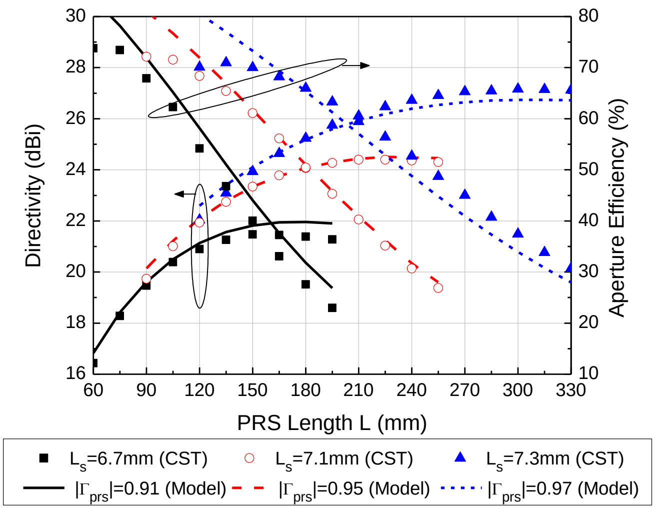

Fig. 4. The maximum directivity and the corresponding aperture efficiency versus PRS length L with comparison of the CST simulation and the model prediction.

10-dB return loss bandwidth is very wide. The realized gain patterns at the frequency of 10.5 GHz are shown in Figs. 7(a) and 7(b), exhibiting broadside directive patterns in the xz- and yz-planes, respectively. The measured peak gain is exhibited as 19.7 dBi at the operating frequency of 10.5 GHz. The cross-polarization discrimination (XPD) is about 22.9 dB. The final aperture efficiencies of measurement are about 74%, based on the calculated directivity. In general, the overall measured performances of the developed FPA prototype are well consistent with the simulation results and model predictions.

Conclusions

This work presents a new hybrid approach for the FPA design. The model provides fast estimated directivity and aperture efficiency in terms of basic design parameters: the PRS reflection magnitude, the air-cavity height, and the PRS aperture area. Through the optimal design curves, one can easily find the required PRS reflection magnitude and antenna dimensions for a given maximum directivity and aperture efficiency.

The presented model has been validated by numerical simulation and experimental measurement. For illustration of the design curves, we implemented an FPA prototype of a target design, where measured results exhibited a measured realized gain of 19.7 dBi. In addition, the aperture efficiency of measurement was 74%.

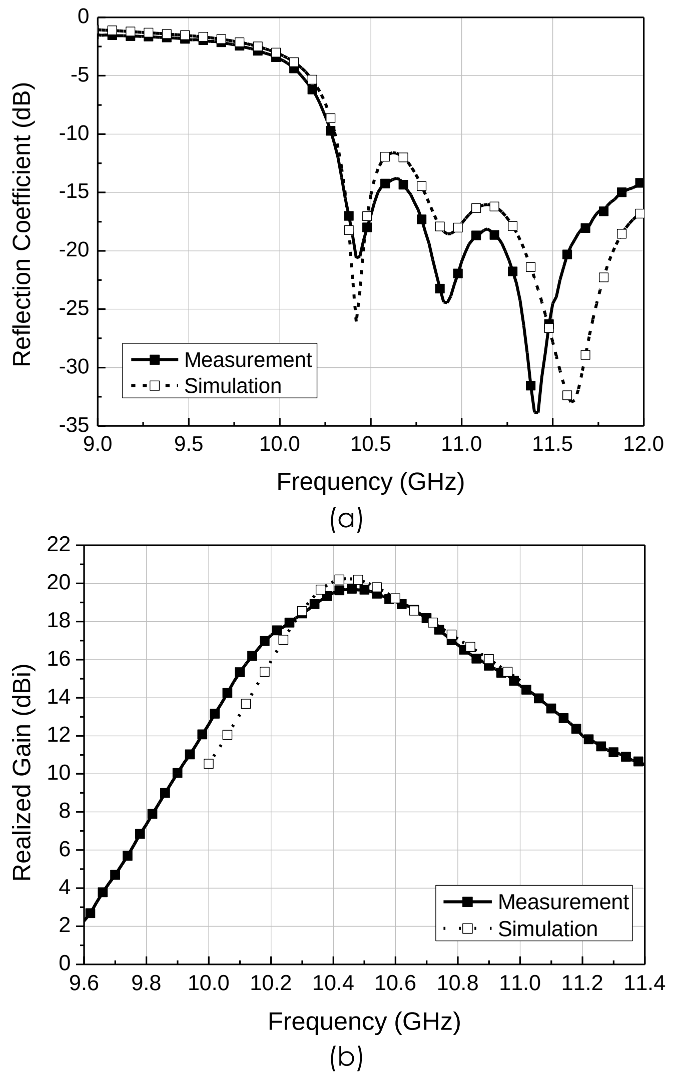

Fig. 6. (a) Measured and simulated reflection coefficients of the FPA prototype with a dipole excitation. (b) Measured and simulated realized gain of the FPA prototype versus the frequency.

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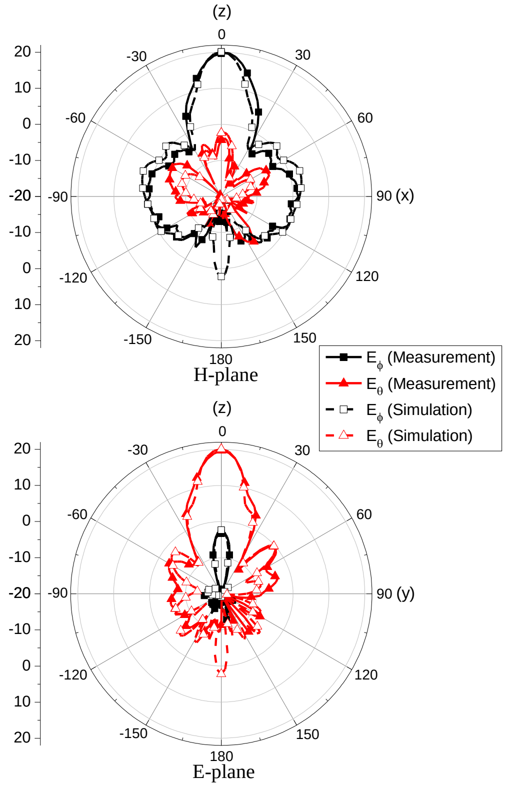

Fig. 7. Measured and simulated realized gain patterns of the FPA prototype on H- and E-plane at 10.5 GHz.

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Autofocus of digital cameras

from Communication and Signal Processing Group

Digital cameras are popular electronic devices that help us freeze the exciting or historic moment of our daily life in the form of image and video. Despite that cameras come in different forms, such as smartphone, webcam, surveillance camera, digital cinema camera, etc., autofocus may be considered the most important function that enables a camera to capture sharp images without human intervention. Normally, the autofocus function of a video camera is more complexity than that of a still camera, mainly because it needs to deal with dynamic scenes where the objects are moving.

Preliminary of Autofocus

The autofocus algorithm of a digital camera typically contains two basic elements: focus measurement and search strategy. The former measures the sharpness of an image and outputs a focus value, whereas the latter uses the resulting focus value to determine if the captured image is sufficiently sharp or if the camera has to adjust its lens position to get a better image. The search strategy guides a camera to find the best (in-focus) lens position at which the captured image has the maximum focus value. The curve obtained by plotting the focus value against the lens position is called focus profile. Generally, the focus profile is a bell-shaped curve, and a high focus value means a high degree of focus. The focus profile can be constructed by measuring the focus value at all lens positions. In practice, however, it is desirable that the search strategy can work without the complete focus profile because collecting the focus data at all lens positions is a time-consuming process that cannot be completed in real time.

The focus value of an image can be measured in either the image domain or the frequency domain. Pertuz et al. [1] have given a complete review and discussion of recent focus measurement techniques, including the Tenengrad technique, the sum-modified Laplacian technique, the frequency selective weighted median filtering technique, the statistical techniques, discrete cosine transform based techniques, and wavelet based techniques.

Many search strategies for autofocus have been developed. These search strategies can be divided into the following categories: global search strategy, Fibonacci search strategy, rule-based search strategy, and hill-climbing search strategy, as illustrated in Fig. 1. The global search strategy, although easy to implement, is the most time consuming one. The Fibonacci search strategy uses fewer steps to find the best lens position but requires long acquisition time and hence high power consumption due to back-and-forth lens movements. To alleviate the problem, hill-climbing and rule-based search strategies were developed. However, these strategies require many tuning parameters and are difficult to guarantee speed and accuracy at the same time.

Focus Profile Representation

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Key to autofocus is accuracy and speed. Since the noise sensitivity of focus measurement near the in-focus lens position is higher than that in the out-of-focus region [2], focus profiles that have a steep peak at the in-focus lens position are able to combat the noise better (and hence lead to more accurate autofocus) than those that have a dull peak. But a focus profile with a steep peak normally has a flatter out-of-focus region on either side of the profile. Because of the lack of robust clue about where the next lens position should be when the lens is in such positions, where the autofocus process needs the most boosts, a slow search is resulted. To address the problem, we propose a Cauchy model and a new approach to focus profile representation that transforms the focus profile to the reciprocal domain in which the reciprocal focus profile is modeled by a quadratic function [3], [4]. This transformation makes AF mathematically tractable not only in the in-focus region but also in the out-of-focus regions and helps boost the search speed in the out-of-focus regions.

The results of fitting are shown in Fig. 2(d)-(f), with the close-ups of Areas 1 and 2 shown in Figs. 2(g)-(i) and 2(j)-(l), respectively. It can be seen that, regardless of the scene, the proposed Cauchy model works well for both the peak and the rising zones. In contrast, the generalized Gaussian model only works well for the peak zone. Furthermore, from the reciprocal focus profiles shown in Fig. 2(m)-(o), we can see that a good portion of the reciprocal focus profile can indeed be approximated by a quadratic function.

Smooth Control of Continuous Autofocus

Based on the proposed focus profile representation, we have developed an autofocus algorithm that allows a video camera to continuously focus on a moving object in the autofocus process. To avoid the so-called bouncing phenomenon due to back-and-forth lens movements around the in-focus lens position, an accurate estimate of the in-focus lens position is required. We improve the accuracy of in-focus lens position estimate for dynamic scenes by a Kalman filter and provide good user experience by a smooth control of the lens movements in the autofocus process [4]. Fig. 3 shows the flowchart of our continuous AF method. The focus data selection component determines the focus data for estimating the in-focus lens position. The in-focus lens position estimation component provides an initial estimate of the in-focus lens position using the proposed focus profile model described in the previous section. The smooth control of the lens movement generates a less noisy estimate of the in-focus position using Kalman filter to provide a better user experience.

The performance of our continuous autofocus algorithm is evaluated in real time by loading the code to a video camera provided by a manufacturer. As the code runs, the output video of the autofocus process is recorded. We test our method on a number of dynamic scenes. Example video frames of a test scene generated by our method are shown in Fig. 4. In this particular video sequence, we can see that the moving object (a water bottle) stays sharp throughout the entire video sequence. The traces of the lens position of our method with and without the Kalman filter are shown in Fig. 5. We can see that the one with the Kalman filter gives rise to a smoother trajectory.

Smooth and sharp video without bouncing is the most fundamental requirement of digital autofocus for video camera. We have described an effective method to achieve it in this article. The method applies a Kalman filter to smooth the lens movement. The performance of our method is extensively tested using a real video camera. The results show that our method works well in real time for dynamic scenes.

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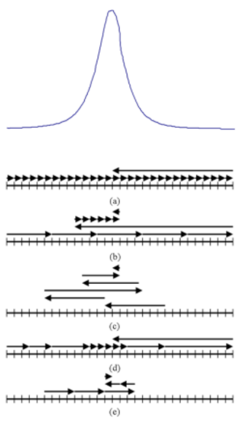

Fig. 1. Existing search strategies for autofocus: (a) global search, (b) two-step search, (c) Fibonacci search, (d) rule-based search, and (e) hill-climbing search. The arrows represent lens movements.

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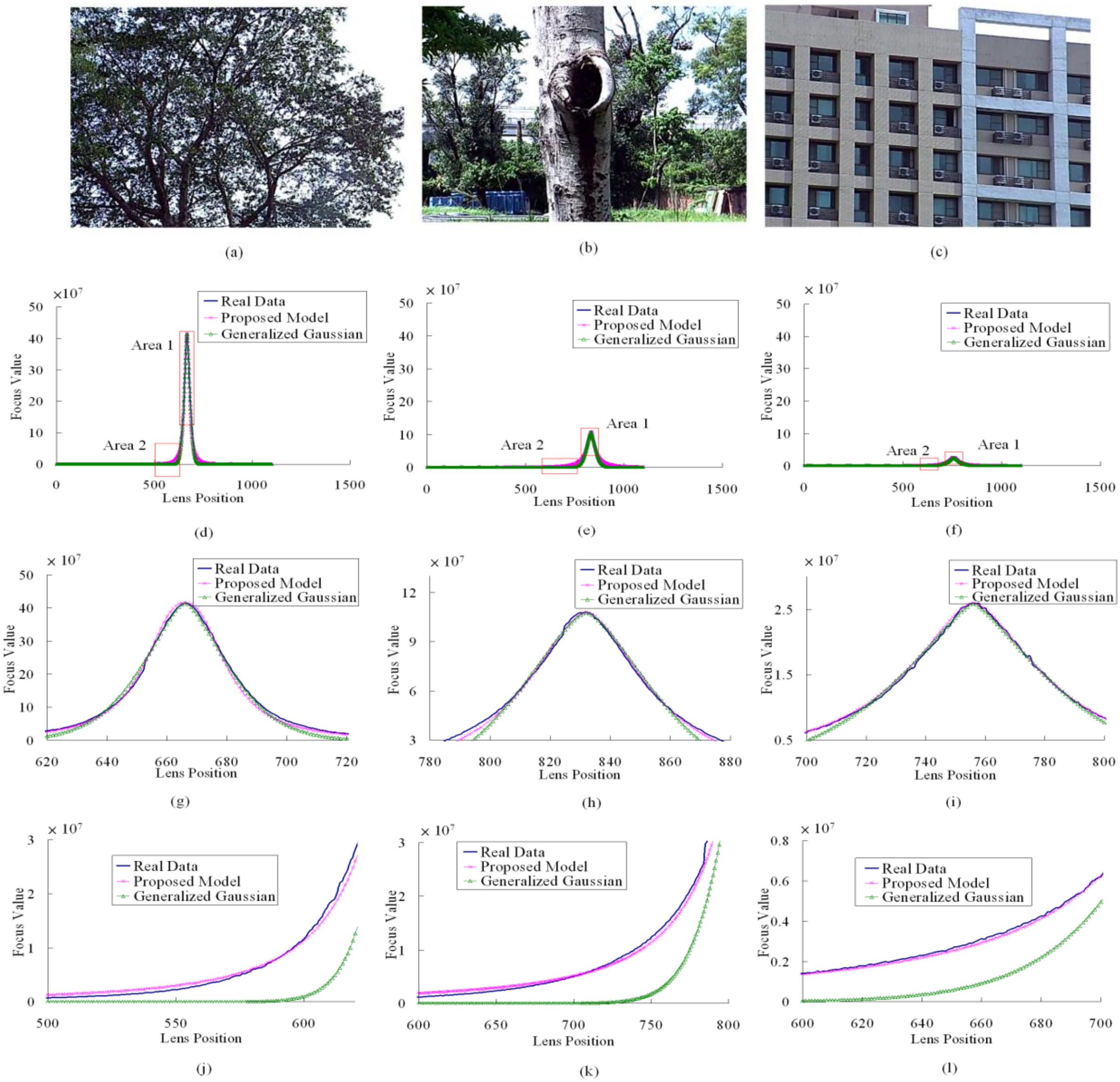

Fig. 2 Verification of the proposed and the generalized Gaussian models using (a) Tree, (b) Trunk, and (c) Building as the test scenes. (d)-(f) The results of fitting for (a)-(c). (g)-(h) The close-up of Area 1 labeled in (d)-(f). (j)-(l) The close-up of Area 2 labeled in (d)-(f).

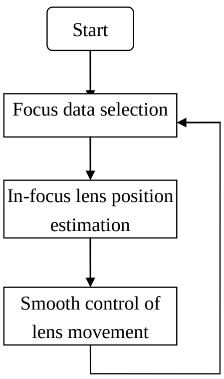

Fig. 3. Flowchart of our continuous AF method.

Fig. 4. Example frames of the recorded video of a test scene.

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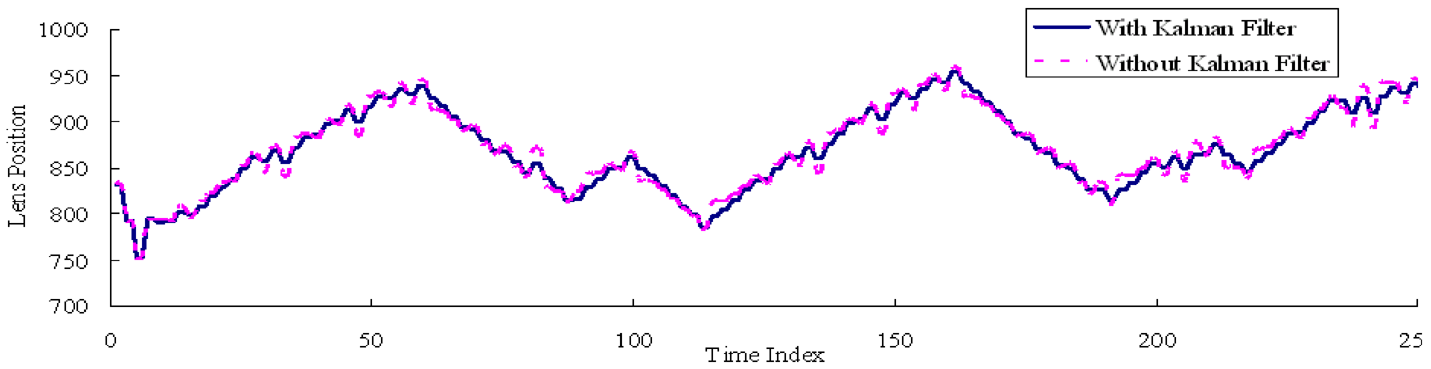

Fig. 5. The traces of the lens position generated by our method for the test scene shown in Fig. 3.

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Activities The Talent Cultivation Program for Smart Living Industry

The Talent Cultivation Program for Smart Living Industry was started 3 years ago by an NTU program office team, with official sponsorship from the Ministry of Education (MOE). This program aims to cultivate university students and teachers through interdisciplinary training, service-by-learning, and the Living lab methodology, to equip them with the ability to fit the future needs of emerging industries in smart health care, culture-oriented high-tech products, and sustainable smart living space. As a bridge between MOE and the entire program, the Program Office located in NTU Telecommunication Research Center is responsible for program orientation, planning, organizing, performance evaluation, and coordinating the whole program including all projects and taskforces. Currently, the program office of this Smart Living Talent Cultivation

Program is leaded by Prof. Zsehong Tsai of NTU GICE, and the Smartliving Talent Cultivation program has developed 141 courses and related tutoring/hand-on materials in more than 28 universities and colleges, all with innovations in course designs and cross-discipline training methodology.

On March 22, 2014, the annual conference of this program, called the 2014 Smart Living Seed-Teacher Training Camp and Achievements Conference, is again held in the international conference hall in the Tsai Lecture Hall, National Taiwan University. The Communication Research Center of National Taiwan University is one of the key co-organizers of this event and the participants include teachers, graduate students (TAs), NGO/community workers, as well as industrial partners, such as III, Chunghwa Telecomm, and the Smart Living Space Association. In this event, special awards are granted for those industrial/ NGO partners with special contributions and those teachers with contributions to distinguished courses. Important records of this annual event, the distinguished course material, and other program activities are available in the program web site http://www.smartliving.org.tw/.

Corner of Student News

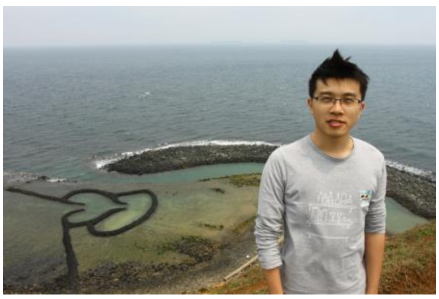
by Shi Hao

I have been studying in Taiwan for nearly two years since September 2012. Taiwan has left me a lot of feeling. It will be a memorable place during my life time.

I lived in Shanghai before I came to Taiwan. As a fast-paced place, everyone there seems to be rushing from one place to another and hardly talk to strangers. Everyday life is tense and full of pressure. In contrast, the life in Taiwan is much more comfortable. Both the leisurely tempo of life and harmonious relations between people improves the life quality greatly. During my life in Taiwan, I contact with different kinds of people. What impresses me most is their kindness and warmness. For example, when I go outside for a trip, they will initiatively talk to me, give me guidance and suggestion. Each person's face is filled with a sincere smile.

In addition, NTU has really excellent teachers. They have very outstanding performance in the professional field. More importantly, they can offer a lucid explanation of the profound theories. Teachers and students can interact with each other equally both in and out of class. The atmosphere is very relaxed and everyone can speak their mind freely.

Nobody knows how many surprises are waiting for him in his life, just like I never thought that one day I can study in Taiwan for two years. Compared with curiosity at the beginning, I really enjoy my life on this land at present. I believe this will happen to everyone besides me since this is such a friendly and open place and you will never feel strangeness and loneliness.



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