# Manga-Style Conversion of Natural Images via Adaptive Screentones

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## 1 Motivation

In studying traditional halftoning, we observed that its dot patterns are similar to the screentones which often appear in manga. Manga artists employ diverse patterns—dots, lines, grids, noise, and custom motifs—to evoke material qualities and mood. For example, dot patterns can suggest softness or volume, while linear textures convey rigidity or motion (see Fig. 1). However, standard halftoning ignores these semantic textures, producing results that feel flat and mechanical. Motivated by this gap, we implement a method to replace color regions in photographs with contextually appropriate manga screentones, preserving both surface texture and perceptual contrast.

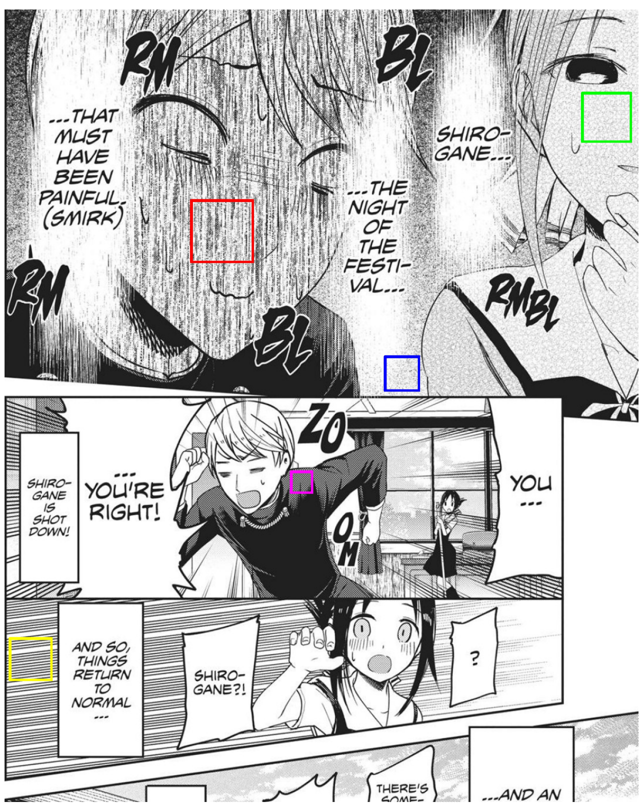


Figure 1: Examples of screentone usage in manga. Artists use dot and line patterns to render chromaticity difference or material textures, and some different patterns establish mood and atmosphere. [1]

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## 2 Problem definition

Let $I \to \mathbb{R}^3$ be an input color image. Our screentone library comprises $n$ distinct pattern types, each supporting a set of discrete density levels, as illustrated in Fig. 2. We represent each library entry as a pair $(t, d)$, where $t \in \{1, \ldots, n\}$ indexes the pattern type and $d \in \mathcal{D}_t$ is one of its available densities. We segment $I$ into regions $\{S_j\}_{j=1}^m$ and seek to assign to each segment $S_j$ a library entry $(t_j, d_j)$ such that:

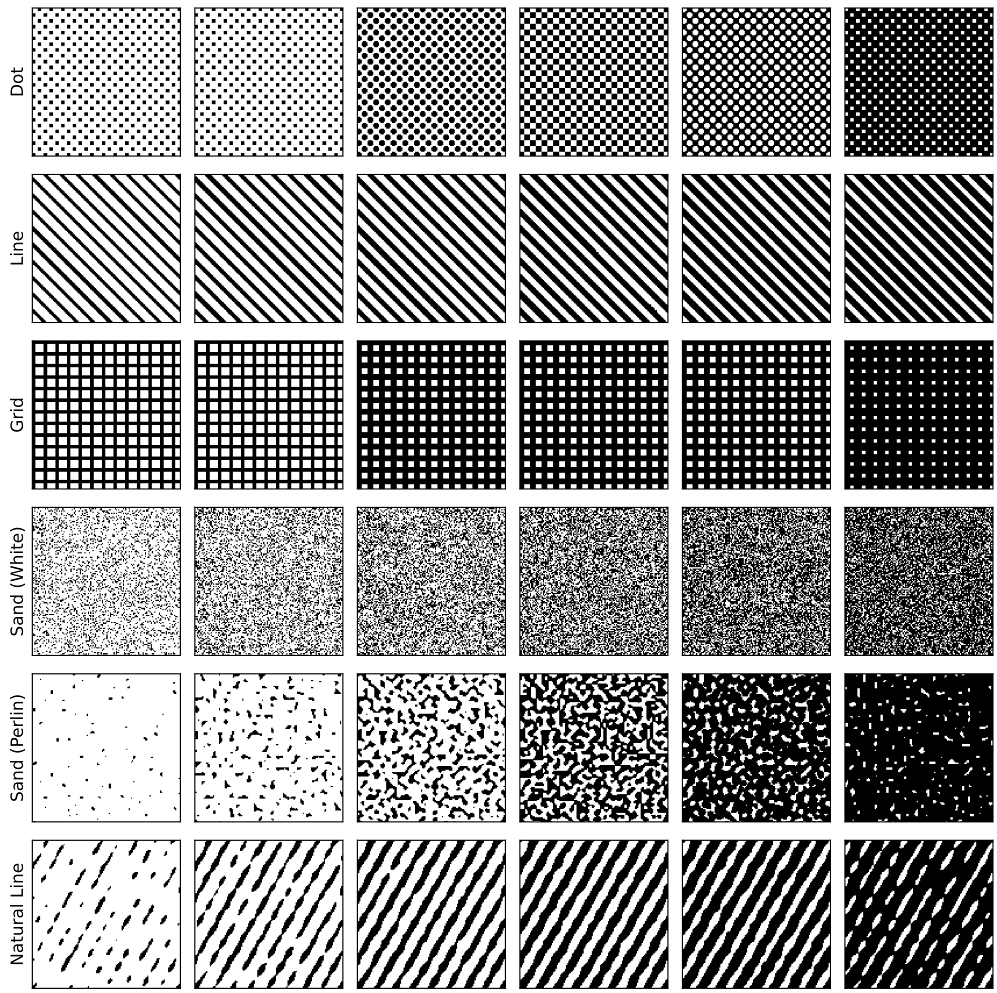



Figure 2: Screentone library organized by pattern type and density levels.

1. **Chromaticity preservation:** Segments with distinct chromaticities are mapped to distinguishable pattern types, ensuring that color differences yield pattern differences.
2. **Tone accuracy:** The luminance of each segment matches the gray level implied by the selected density $d_j$, preserving the original tonal structure.

## 3 Algorithm

Some components of our method are adapted from the framework proposed by [5]. We begin by constructing a screentone library that includes a variety of screen types and densities. The input image undergoes preprocessing to better align with the visual characteristics of manga. To automate the conversion from color images to manga style, the image is first segmented into regions. Screen textures are then assigned to each region based on the original image's tones and colors. This involves a color-to-pattern matching process, where segments are mapped to appropriate screen types to preserve chromatic separability. Screen densities are then selected according to the tones. Finally, the screentone map is combined with the Sobel edge map to produce the final manga-style image.

### 3.1 Screentone Library Construction

Most screentone libraries available online are either proprietary or lack flexibility in controlling tone density. To address this, we design a set of procedural mathematical algorithms capable of generating common screentone types with adjustable densities. The following tone patterns are included in our library:

**Dot tone:**

$$\mathbf{1}\left[\frac{\sin(\omega x)\cdot\sin(\omega y)+1}{2}>\tau\right]$$

**Line tone:**

$$\mathbf{1}\left[\frac{\sin(\omega r)+1}{2}>\tau\right]$$

**Grid tone:**

$$\mathbf{1}\left\{\left[\frac{\sin(\omega r)+1}{2}>\tau\right]\wedge\left[\frac{\sin(\omega r^{\perp})+1}{2}>\tau\right]\right\}$$

**Sand tone (white noise):**

$$\mathbf{1}\left[\epsilon>\tau\right],\quad \epsilon\sim U(0,1)$$

**Sand tone (Perlin noise):**

$$\mathbf{1}\left[\mathrm{Norm}_{[0,1]}\left(\mathrm{Perlin}\left(\frac{x}{s},\frac{y}{s}\right)\right)>\tau\right]$$

**Natural line tone:**

$$\mathbf{1}\left[\mathrm{Norm}_{[0,1]}\left(\mathrm{Perlin}\left(\frac{x}{s},\frac{y}{s}\right)+\sin(\omega r)\right)>\tau\right]$$

These mathematical formulations are used to procedurally generate screentone textures with visual qualities as those shown in Fig. 2, and are sufficient for rendering most manga-style scenes. The parameters $\omega$ and $s$ control the granularity and scale of the tone textures. The threshold parameter $\tau\in[0,1]$ adjusts the tone density.

The variables $x$ and $y$ represent pixel coordinates. For anisotropic patterns, directional variation is introduced by projecting $(x,y)$ onto a specific vector direction $\mathbf{r}$, with $r=\mathbf{r}\cdot(x,y)$ and $r^{\perp}$ being its orthogonal complement.

Among these patterns, the Sand tone based on Perlin noise is unique in exhibiting local continuity, owing to the nature of Perlin noise as a smooth gradient-based pseudo-random function. However, we observed that this pattern lacks the visual aesthetic often sought in manga illustrations. Interestingly, by combining Perlin noise with sinusoidal stripes, we obtain a "natural line tone" with both structure and organic variation, producing visually appealing results reminiscent of hand-drawn textures.

### 3.2 Image Preprocessing

Our empirical observations suggest that directly applying our automatic manga conversion process does not always yield optimal visual results. To address this, we introduce an optional preprocessing stage designed to enhance the compatibility of the input image with manga-style aesthetics.

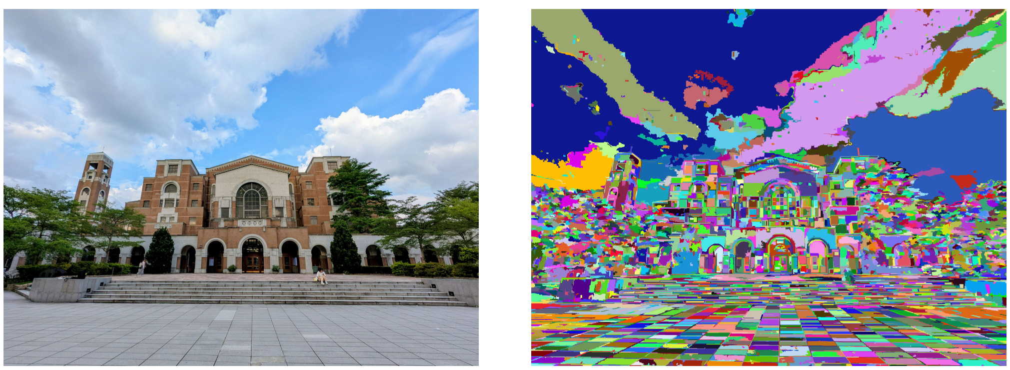
One such preprocessing technique is brightness adjustment. Since manga illustrations often feature large areas of white space and exhibit a higher overall brightness than natural photographs, directly converting images captured under natural lighting conditions can result in outputs that appear darker than expected. To mitigate this, we increase the brightness of the input image by scaling the intensity values of all pixels. This overexposure effect helps produce results that are more visually consistent with the manga style. An example of this improvement is illustrated in Fig. 3. Another optional preprocessing step is histogram equalization. In some cases, redistributing the tonal values of the image can enhance contrast and improve the overall visual quality of the converted output.

(a) Original image. (b) Conversion with original image. (c) Brightened image. (d) Conversion with brightened image.

Figure 3: Comparison of applying manga conversion process to the original image and the brightened version of the image.

### 3.3 Image Segmentation

To facilitate the assignment of screentones, the input image is first segmented into distinct regions, enabling accurate pattern matching during the conversion process. We employ the Felzenszwalb segmentation algorithm [3], which is based on a graph-based approach utilizing minimum spanning trees, due to both its effectiveness and efficiency. An example of the segmentation output is shown in Fig. 4.



(a) Input image. (b) Segmentation map of the input image.

Figure 4: Example of image segmentation.

### 3.4 Color-to-Pattern Mapping

To assign screentone patterns to segmented regions, our goal is to preserve the perceptual relationships between the original colors. That is, regions with similar colors should be mapped to the same screentone pattern type, while perceptually distinct colors should be represented by different patterns. We model perceived color using the two chrominance channels (A and B) from the CIELAB color space as a two-dimension vector. To quantify the visual texture of each screentone pattern, we extract Gabor wavelet features [4]. A Gabor function in the spatial domain is defined as:

$$g(x, y) = \left(\frac{1}{2\pi\sigma_x\sigma_y}\right) \exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right) + 2\pi jWx\right].$$

A family of filters $g_{m,n}(x, y)$ is generated by dilating and rotating $g(x, y)$, given parameters $m$ for scale and $n$ for orientation. The transform of an image $I(x, y)$ using these filters is given by:

$$W_{m,n}(u,v) = \int_{\Omega} I(x,y)\, g^*_{m,n}(u-x, v-y)\, dx\, dy$$

which yields a response map for each $m$ and $n$. To obtain a feature representation of each screentone pattern, we compute the mean and standard deviation of the magnitude response:

$$\mu_{m,n} = \iint |W_{m,n}(x,y)|\, dx\, dy, \quad \sigma_{m,n} = \sqrt{\iint \left(|W_{m,n}(x,y)| - \mu_{m,n}\right)^2 dx\, dy}.$$

We use 4 scales and 6 orientations, resulting in a 48-dimensional feature vector per pattern.

In order to map the colors to screentone pattern types while preserving the distance relationships, we project the 48-dimensional features to 2D via multi-dimensional scaling [2]. Let each pattern type $i$ have a high-dimensional feature vector $p_i$, and construct the pairwise distance matrix $D = [d_{i,j}]$ with $d_{i,j} = \|p_i - p_j\|_2$. We compute the double-centered Gram matrix:

$$QQ^T = -\frac{1}{2}[I - \frac{1}{n}[\mathbf{1}]]D^2[I - \frac{1}{n}[\mathbf{1}]].$$

Perform SVD to obtain:

$$QQ^T = V\Lambda V^T, \quad Q = V\Lambda^{1/2}.$$

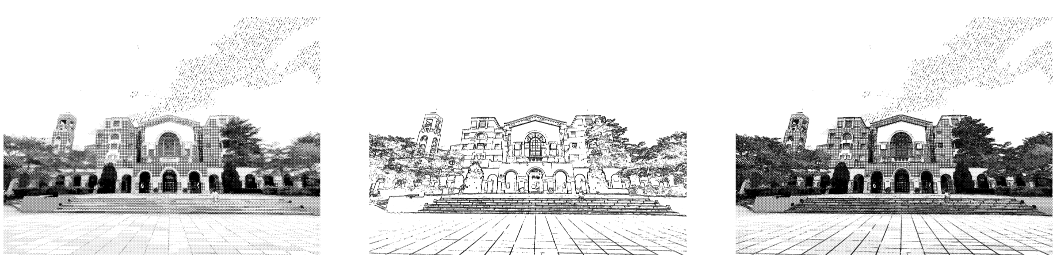
To reduce dimensionality, we truncate $Q$ to the first two rows to form $\hat{Q} \in \mathbb{R}^{2\times n}$, where each column $q_i$ represents the projected 2D vector of pattern $i$. Finally, after normalizing the feature vectors, we compute the average AB color vector for each segmented image region and assign the region the screentone pattern whose feature vector $q_i$ is nearest in Euclidean distance.

### 3.5 Tone Matching

After assigning a screentone pattern type to each segment based on chromatic similarity, we determine the appropriate screen density by matching the segment's luminance to the perceived brightness of available screentone densities. Specifically, we use the $L$ channel from the CIELAB color space to represent luminance. For each segment, we compute its average $L$ value and assign the screentone density whose average gray level most closely matches this luminance. This ensures that tonal variations in the original image are preserved in the final manga-style rendering.

### 3.6 Combination with Edge Detection

In traditional manga production, artists typically begin with detailed line art and then apply screentones to convey shading and texture. To emulate this visual structure, we generate line art using Sobel edge detection, which highlights prominent contours and boundaries in the image. The final manga-style output is produced by overlaying the Sobel edge map onto the previously generated screentone map. This combination results in an image that closely resembles hand-drawn manga artwork. An example of this process is shown in Fig. 5.



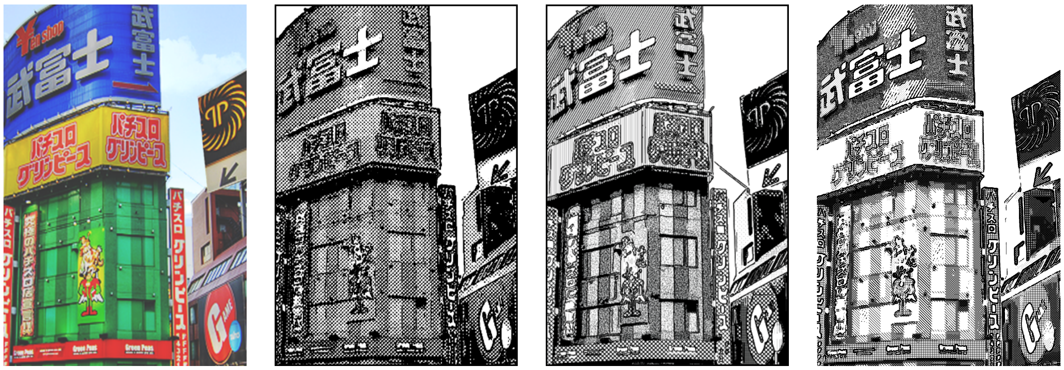
(a) Screentone map. (b) Sobel edge map. (c) Output image.

Figure 5: Final image generation by combining the screentone map with the Sobel edge map.

# 4 Experimental Results and Discussions

## 4.1 Comparison with Previous Work

To evaluate the effectiveness of our method, we apply it to the same input images used in the work of [5] and perform a visual comparison.

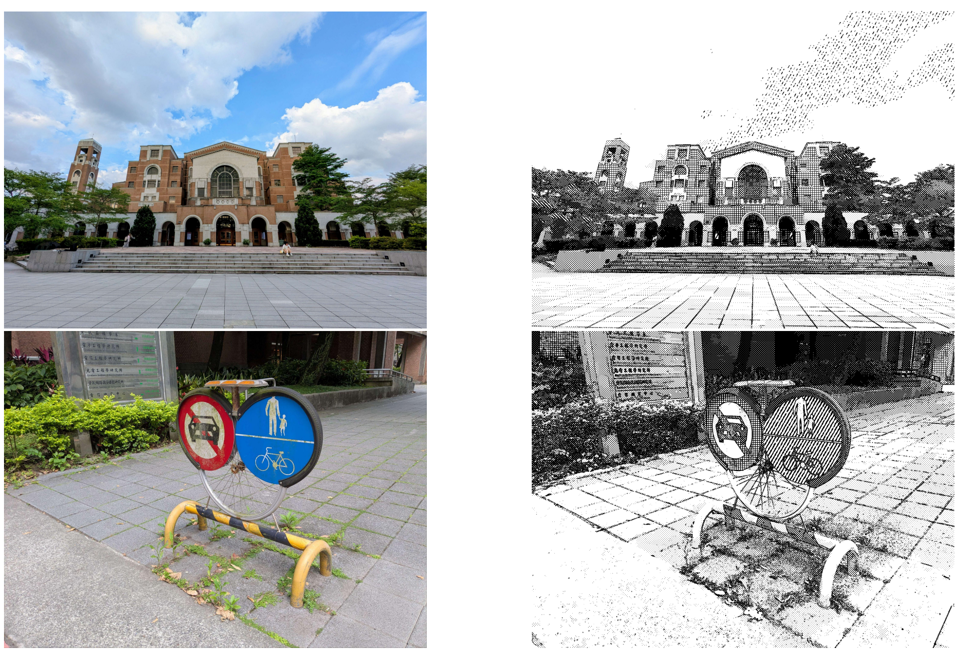



(a) Original image. (b) Halftoned image. (c) Result from [5]. (d) Result from our method.

Figure 6: Visual comparison of our manga conversion approach with previous work.

As shown in Fig. 6, our method achieves comparable manga-style quality to that of [5], while clearly outperforming traditional halftoning in terms of visual aesthetics. By leveraging a variety of screentone patterns, our method successfully preserves the chromatic contrast between regions—for instance, distinguishing signage colors more effectively through pattern allocation.

## 4.2 Successful Cases



(a) Original image (b) Generated image

Figure 7: Examples of successful results generated by our method.

As illustrated in Fig. 7, our method effectively differentiates between architectural elements and ground surfaces. For example, the orange facade of the building is rendered using a grid tone, while the gray pavement is represented with a dot tone. Moreover, the pedestrian signal—featuring a blue hue that strongly contrasts with the surrounding scene—is assigned a distinct natural line tone, further enhancing perceptual separation.


(a) Original image (b) Generated image

Figure 8: The most visually appealing result among our successful cases.

Fig. 8 presents the most visually satisfying result among our experiments. This particular scene features a diverse color palette and sharp structural lines. All types of screentone patterns are utilized, contributing to a rich, multi-layered visual composition.

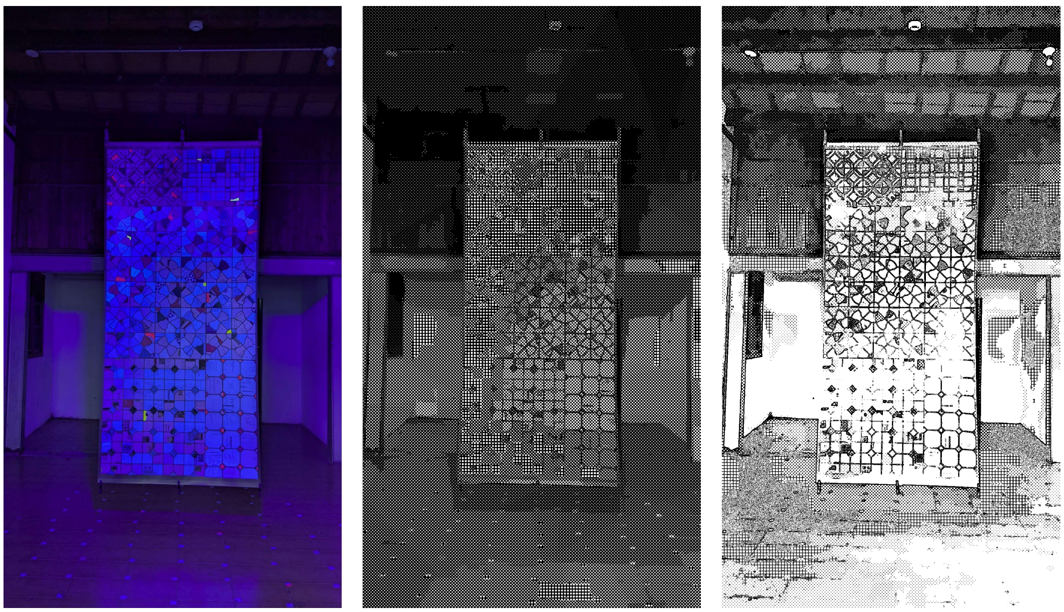
### 4.3 Failure Cases


(a) Original image (b) Generated image

Figure 9: Examples of failure cases produced by our method.

Despite its general effectiveness, our method exhibits notable failure cases, particularly in scenes with dense vegetation. As seen in Fig. 9, the plant-covered regions appear visually noisy and aesthetically unpleasing. This issue arises primarily due to the dominant green hue of vegetation, which leads to large regions being assigned the same screentone pattern during the color-to-pattern mapping process (Sec 3.4). Additionally, vegetation typically contains complex high-frequency textures. When mapped to a uniform tone, the result becomes flattened and cluttered, failing to convey the natural richness of the original content.

### 4.4 The Effect of Histogram Equalization



(a) Original image (b) Generated w/o histogram equalization (c) Generated w/ histogram equalization

Figure 10: Effect of histogram equalization in scenes with extreme lighting conditions.

As discussed in Sec 3.2, enhancing contrast by scaling the intensity values of all pixels is a critical preprocessing step to achieve visually appealing manga-style output. While this approach is effective for most natural images, it may fall short in scenes with extreme lighting conditions—such as low contrast or uneven illumination.

In such cases, we incorporate an additional step of histogram equalization to improve tonal distribution and enhance local contrast. As shown in Fig. 10, applying histogram equalization significantly improves the output quality by recovering detail in dark or overexposed regions, thus preserving the visual balance necessary for stylized manga rendering.

### 4.5 Making Our Own Manga: NTU to Treasure Hill Artist Village

Following the suggestion of Prof. Ming-Sui Lee, we created a manga using photographs taken during a personal excursion. These images were processed with our proposed method to generate manga-style illustrations. The resulting comic-style work are shown in Fig 11.

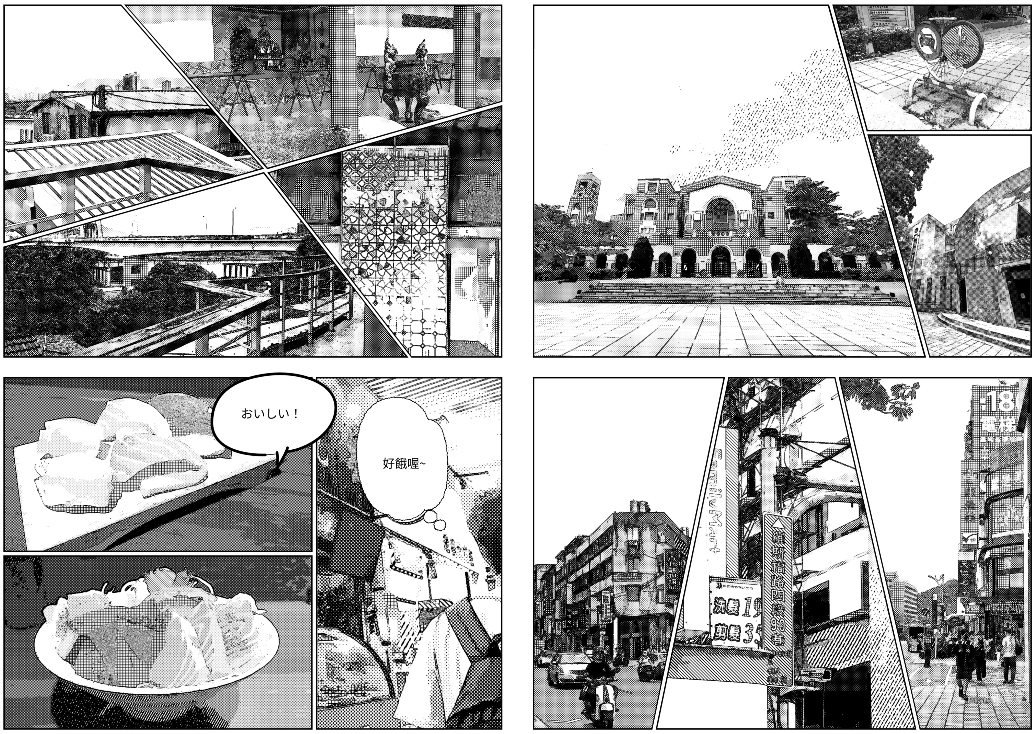



Figure 11: Selected pages from our manga created using the proposed method.

All photographic content used in this manga was captured by the authors during a walking tour from National Taiwan University (NTU), through Gongguan, and ending at the Treasure Hill Artist Village. We applied our manga conversion pipeline to casual street photography taken along the route to generate stylized screentone illustrations. These were then arranged into manga panel layouts using an online comic composition tool[1].

## 5 Conclusion

In this work, we presented a fully automatic pipeline for converting natural photographs into manga-style images by leveraging adaptive screentone generation, perceptual color-to-pattern mapping, and tone-preserving density selection. Our method introduces a procedural screentone library with controllable pattern types and densities, enabling flexible and expressive visual representations that align with the aesthetic principles of traditional manga.

Through preprocessing techniques such as brightness scaling and histogram equalization, we improve visual contrast and compatibility with manga conventions. Our segmentation and matching strategy ensures that perceptual color differences in the original image are preserved via distinct screentone patterns, while luminance consistency is maintained across tone densities. The final result, obtained by combining tone-mapped screentones with Sobel edge detection, produces stylized illustrations reminiscent of hand-drawn manga.

Experimental results demonstrate that our approach is capable of achieving visually compelling results on a wide range of natural images. In particular, it performs well in urban and structured scenes where chromatic regions and strong contours are prevalent. Nonetheless, failure cases in dense vegetation scenes reveal limitations in handling high-frequency textures with uniform screentone patterns, suggesting opportunities for future improvements. Potential extensions include semantic-aware segmentation, perceptual refinement through user input, and deep-learning-based pattern adaptation.

[1] `https://new-sankaku.github.io/manga-editor-desu/`

Overall, our system offers a novel and interpretable framework for manga-style rendering that bridges traditional aesthetics and computational techniques, opening possibilities for creative applications in comics, illustration, and stylized visual storytelling.

## 6 Contribution Ratio

- **Jih-Kang Hsieh** (R13922A03) – 50%
  Screentone generation algorithm design, finding proper image preprocessing methods, experiment and analysis, video presentation, report writting, images capturing.
- **Li-Cheng Shen** (R13922098) – 50%
  Finding proper image segmentation methods, color-to-pattern mapping and tone matching implementation, video presentation, report writting, images capturing.

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