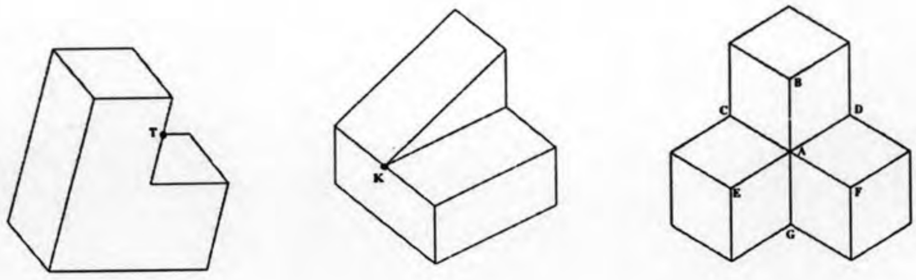
CHAPTER V

EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Test Set

The proposed algorithm is tested with the polyhedral line drawing images from Varley's thesis [2], which is a test set in the reconstruction task. All tested object images have the features of 3D realizable objects as mentioned in Section 3.1. A set of perfect crossing lines of each object image is extracted. Such extracted set of crossing lines is used as the input to the proposed algorithm. If the algorithm can identify an object which is identical to a 3D realizable object image in the test set, we will conclude that such identified 3D realizable object by our algorithm is correct.

By our algorithm, each proposed rule is applied by using the constrain about problem lines as an initial condition in removing the over-identified segments. The problem line is defined as the line that has at least two identified segments and such segments are connected. Therefore, object images in the original test set that have the connected segments along the same line do not cover in our algorithm. This type of object images are not selected for the experiment. Such objects are shown in Fig. 5.1. Figure 5.1(a) is an object image that has T-junction (denoted that point by the capital letter T). It is the type of junction in line drawing object that has T-like shape. The position of T-junction is the break point between two connected segments along the same line. Figure 5.1(b) is an object image that has K-junction (denoted that point by the capital letter K). This is another type of junction in a line drawing object that has a K-like shape. The



(a) (b) (c)

Figure 5.1: Examples of the realizable object in the test set that are not selected for the experiment. (a) An object that has T-junction (point that represent by the capital letter T). (b) An object that has K-junction (point that represent by the capital letter K). (c) An object that has two connected segments on the same line.

position of K-junction is also the break point between two connected segments along the same line. An object image in Fig. 5.1(c) is an example when it does not has T-junction or K-junction but there are three lines which has two connected segments along such lines. Segments AB and AG are the connected segments along the same line. Segments AC and AF are also the connected segments along the same line. On the same way as segments AD and AE along another line.

5.2 Experimental Results

Table 5.1 shows the experimental result after 169 object images are tested. There are three possible cases. In case of successful extraction, it means that only one 3D realizable object is extracted and such object is identical to the original 3D realizable object in the test set. In case of partially successful extraction, it means more than one 3D realizable object can be extracted and one of such extracted objects is identical to the original 3D realizable object in the test set. In case of unsuccessful extraction, it means that none of the possible extracted objects is identical to original 3D realizable object in the test set. The unsuccessful extraction may occur when some segments in the extracted object are unidentified or over-identified compared to the original realizable object in the test set or when the algorithm is failed to extract any object.

Table 5.1: Experimental results

Case of Results	Number of Objects	Percent
Successful Extraction	160	94.68
Partially Successful Extraction	2	1.18
Unsuccessful Extraction	7	4.14
Total	**169**	**100**

The objects with successful extraction are as shown in Fig. 5.2. The first row, Fig. 5.2(a) to Fig. 5.2(e), shows the 3D realizable objects in the test set. The second row, Fig. 5.2(f) to Fig. 5.2(j), shows the set of lines extracted from each of the object in the first row. Whereas, Fig. 5.2(f) is a set of lines extracted from the object in Fig. 5.2(a), Fig. 5.2(g) is a set of lines extracted from the object in Fig. 5.2(b), respectively. Each set of crossing lines in the second row is an input to the algorithm. The third row, Fig. 5.2(k) to Fig. 5.2(o), shows the 3D realizable objects extracted by our algorithm. All objects in the third row are successful extraction because they are identical to the 3D realizable objects in the first row. From 169 tested objects, 160 objects are successful extraction. In Section 5.3, more examples of the objects with successful extraction are also shown.

The results of partially successful extraction are as shown in Fig. 5.3 and Fig. 5.4. Figure 5.3(a) shows the realizable object in the test set. Figure 5.3(b) is a set of lines extracted from the object in Fig. 5.3(a). Figure 5.3(c) shows when the significant junctions

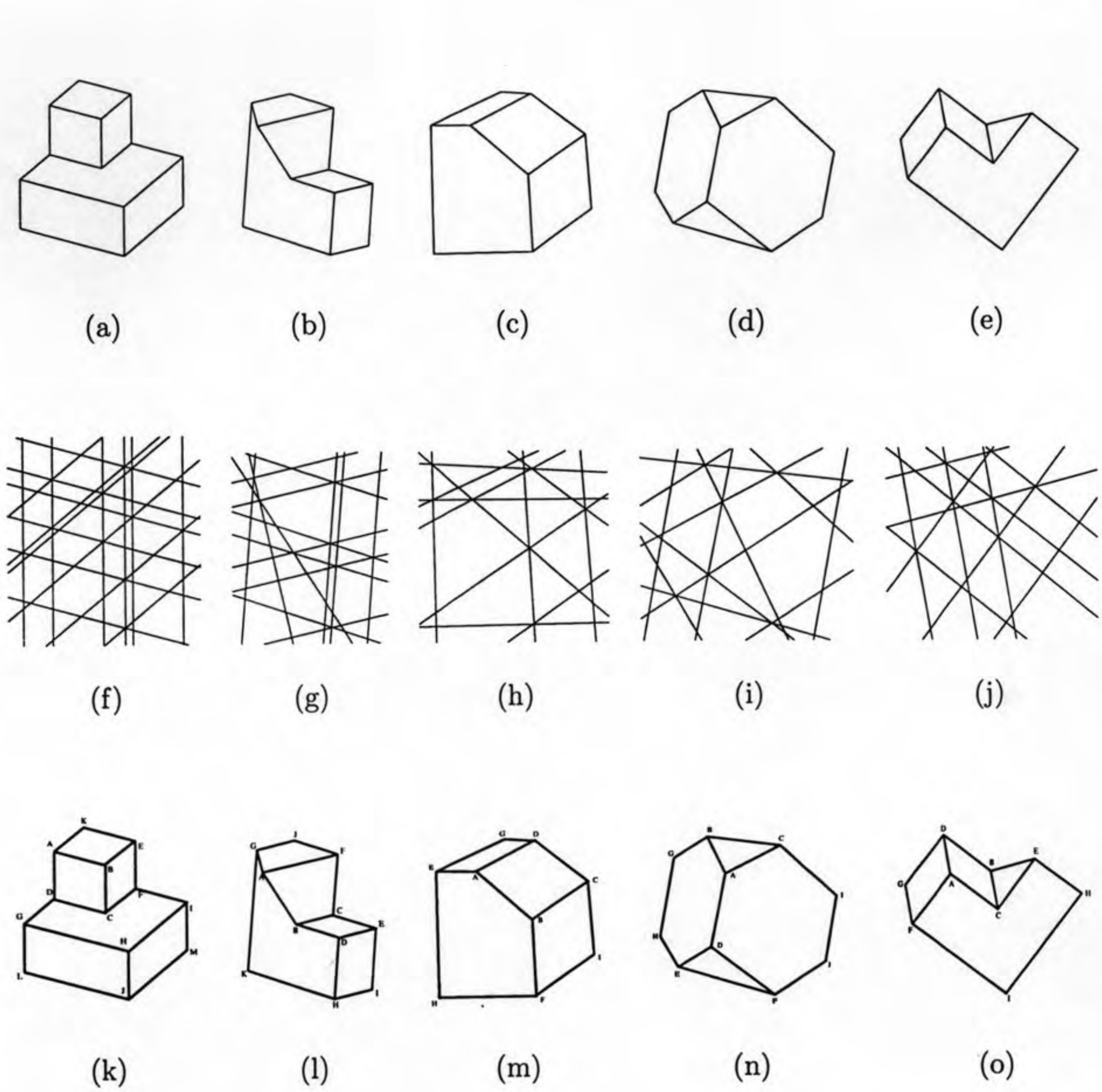


Figure 5.2: Some experimental results of the objects with successful extraction. (a)-(e) The realizable objects in the test set. (f)-(j) Sets of lines extracted from the realizable objects in (a)-(e). Fig. 5.2(f) is the set of lines extracted from the realizable object in Fig. 5.2(a), Fig. 5.2(g) is the set of lines extracted from the realizable object in Fig. 5.2(b), respectively. (k)-(o) The 3D realizable objects extracted by the proposed algorithm. Fig. 5.2(k) is the 3D realizable object extracted from the set of lines in Fig. 5.2(f), Fig. 5.2(l) is the 3D realizable object extracted from the set of lines in Fig. 5.2(g), respectively.

and the significant segments are identified in Process 1 of the algorithm. All segments in the image frame are identified as the significant segments (denoted by the bold solid segments) and there are three problem lines. By the algorithm, if segment AB is first considered and removed by rule $S3$, the result of the final extracted object is as shown in Fig. 5.3(d). Whereas, if segment AC is first considered and also removed by rule $S3$, the result of the final extracted object is shown in Fig. 5.3(e). Therefore, the final object that is extracted by our algorithm can be as in Fig. 5.3(d) or in Fig. 5.3(e). One of such extracted objects is identical to the realizable object in the test set. The extracted object in Fig. 5.3(d) is identical to the realizable object in Fig. 5.3(a).

Another example of the result when partially successful extraction is shown in Fig. 5.4. Figure 5.4(a) shows the realizable object in the test set. Figure 5.3(b) is a set of lines extracted from the object in Fig. 5.4(a). Figure 5.4(c) shows when the essential junctions and the essential segments (denoted by dashed segments) are verified in Process 4 of the algorithm. All essential segments are identified on the problem lines. By the algorithm, if the essential junction a and its related links are first removed by rule $E3$, the result of the final extracted object is shown in Fig. 5.4(d). Whereas, if the essential junction b and its related links are first removed by rule $E3$ as well, the result of the final extracted object is shown in Fig. 5.4(e). The final extracted object by our algorithm, therefore, can be as in Fig. 5.4(d) or in Fig. 5.4(e). The extracted object in Fig. 5.4(d) is identical to the realizable object in Fig. 5.4(a).

A case of the unsuccessful extraction shows in Fig. 5.5 and Fig. 5.6. Figure 5.5 shows the extracted objects when some segments are still over-identified. Segments Aa and ab in Fig. 5.5 are identified as the potential essential segments but they are connected on the same line. Either Aa or ab must be removed but no generated rule in the current proposed method can remove such segments. In the same way as in Fig. 5.6, segments Ab and bc are identified as the potential essential segments on the same line. Segments Bb

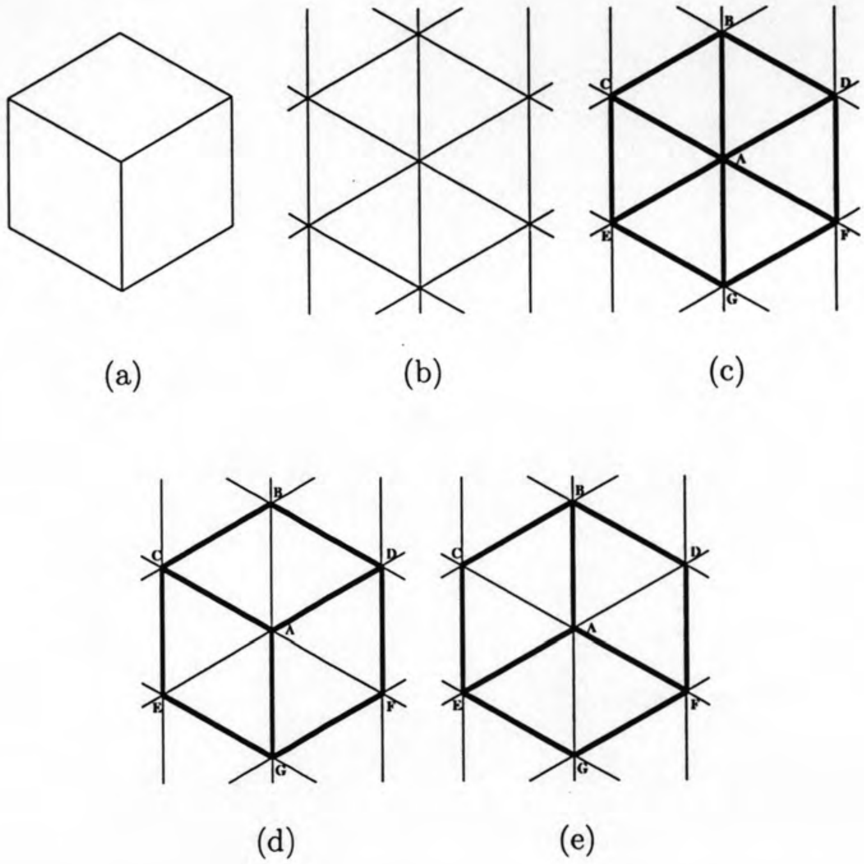


Figure 5.3: Partially successful extraction. Either object in (d) or (e) can be extracted by the proposed algorithm. (a) The realizable object in the test set. (b) Set of lines extracted from the realizable object in (a). (c) Result after the significant junctions and the significant segments are identified in Process 1 of the algorithm. (d) The final extracted object, if segment AB in (c) is removed first by rule $S3$. (e) The final extracted object, if segment AC in (c) is removed first by rule $S3$ as well.

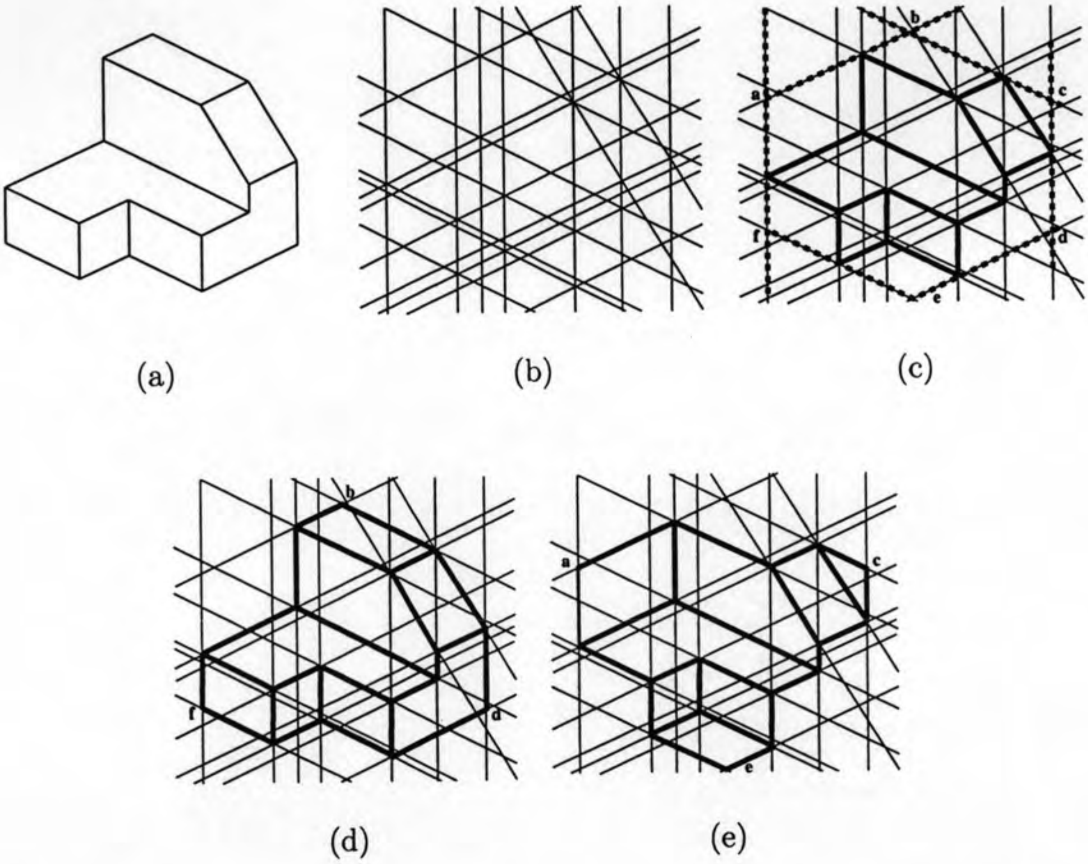


Figure 5.4: Another example of the result when it is partially successful extraction. Either object in (d) or (e) can be extracted by the proposed algorithm. (a) The realizable object in the test set. (b) The set of lines extracted from the object in (a). (c) When the essential junctions and the essential segments (denoted by dashed segments) are verified in Process 4 of the algorithm. (d) The final object is extracted if the essential junction a in (c) and its related links are removed first by rule $E3$. (e) The final object is extracted if the essential junction b in (c) and its related links are removed first by rule $E3$ as well.

and *ba* are identified on another problem line as well. Therefore, each of such segments on each line must be removed.

Figure 5.6 also shows the objects with unsuccessful extraction. Figure 5.6(a), Fig. 5.6(b), and Fig. 5.6(c) are the realizable objects from the test set. Figure 5.6(d) shows the set of lines extracted from the realizable object in Fig. 5.6(a). Figure 5.6(e) shows the set of lines extracted from the realizable object in Fig. 5.6(b). Figure 5.6(f) shows the set of lines extracted from the realizable object in Fig. 5.6(c). Another two realizable objects from the test set shows in Fig. 5.6(g) and Fig. 5.6(h). Figure 5.6(i) is a set of lines that are extracted from the realizable object in Fig. 5.6(g) and Fig. 5.6(j) is a set of lines that are extracted from the realizable object in Fig. 5.6(h), respectively. All objects Fig. 5.6 are failed to extract by our algorithm. The candidates of the significant segments that were identified from Process 1 of the algorithm of each object are incorrectly removed when rule $S1$ is applied to verify such segments in Process 2. The algorithm, therefore, fails to extract the 3D realizable objects in the following processes.

Table 5.2 shows the experimental result of the successful case when rules applying are categorized. The objects from 160 objects are counted for each applied rule. For example, the number of objects applied by rule $S1$ is 42. It means 42 objects from 160 objects use rule $S1$ in Process 2 of the algorithm. From the experiment, rule $E2$ is the most frequently applied. From 160 tested objects, 94 objects need rules $E2$ in removing the over-identified segments. Whereas, rule $SE1$ is the least frequently applied.

Table 5.2: Experimental result of the successful case when rules applying are categorized

Rule applying	***S1***	***S2***	***S3***	***E1***	***E2***	***E3***	***SE1***
Number of objects	42	18	32	17	94	43	9

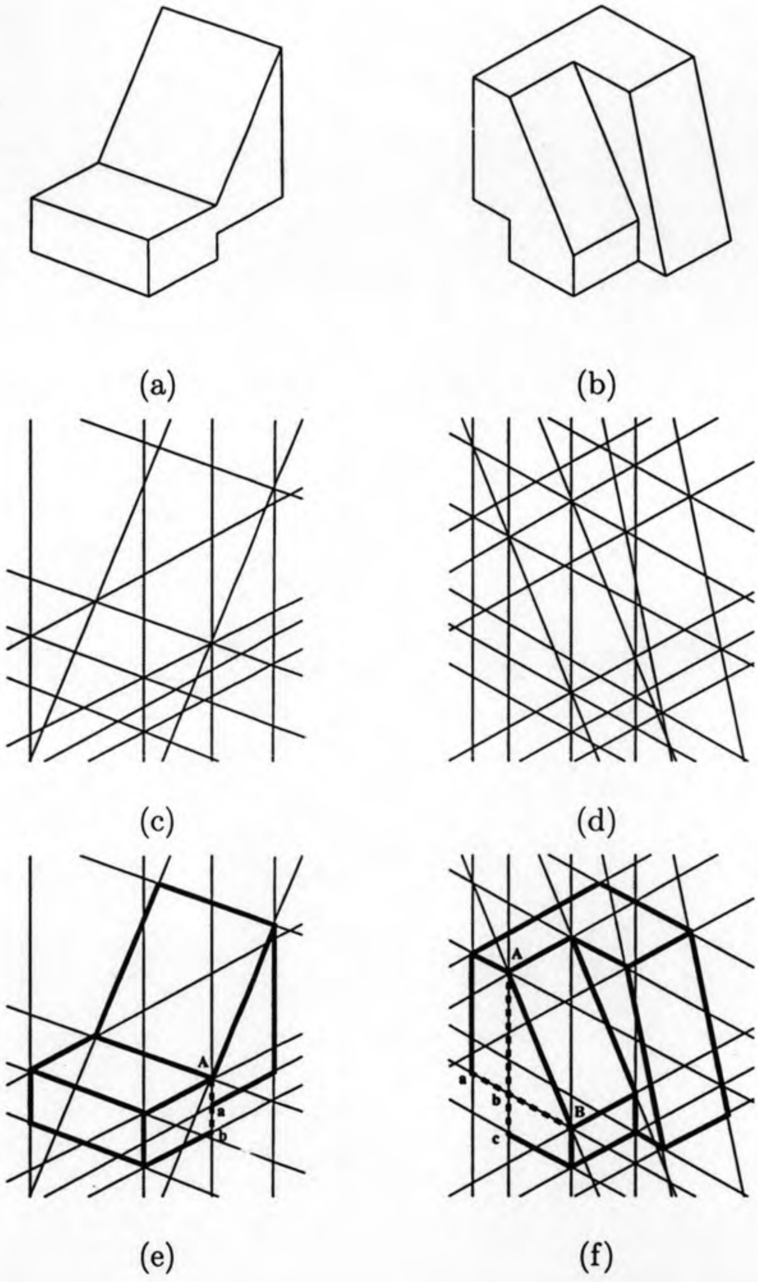


Figure 5.5: The results of unsuccessful extraction. (a)-(b) The realizable objects in the test set. (c)-(d) Sets of line extracted from the realizable objects in (a) and (b), respectively. (e)-(f) The objects extracted by our proposed method with the over-identified segments. No rule in current method can remove some over-identified dashed segments in both objects.

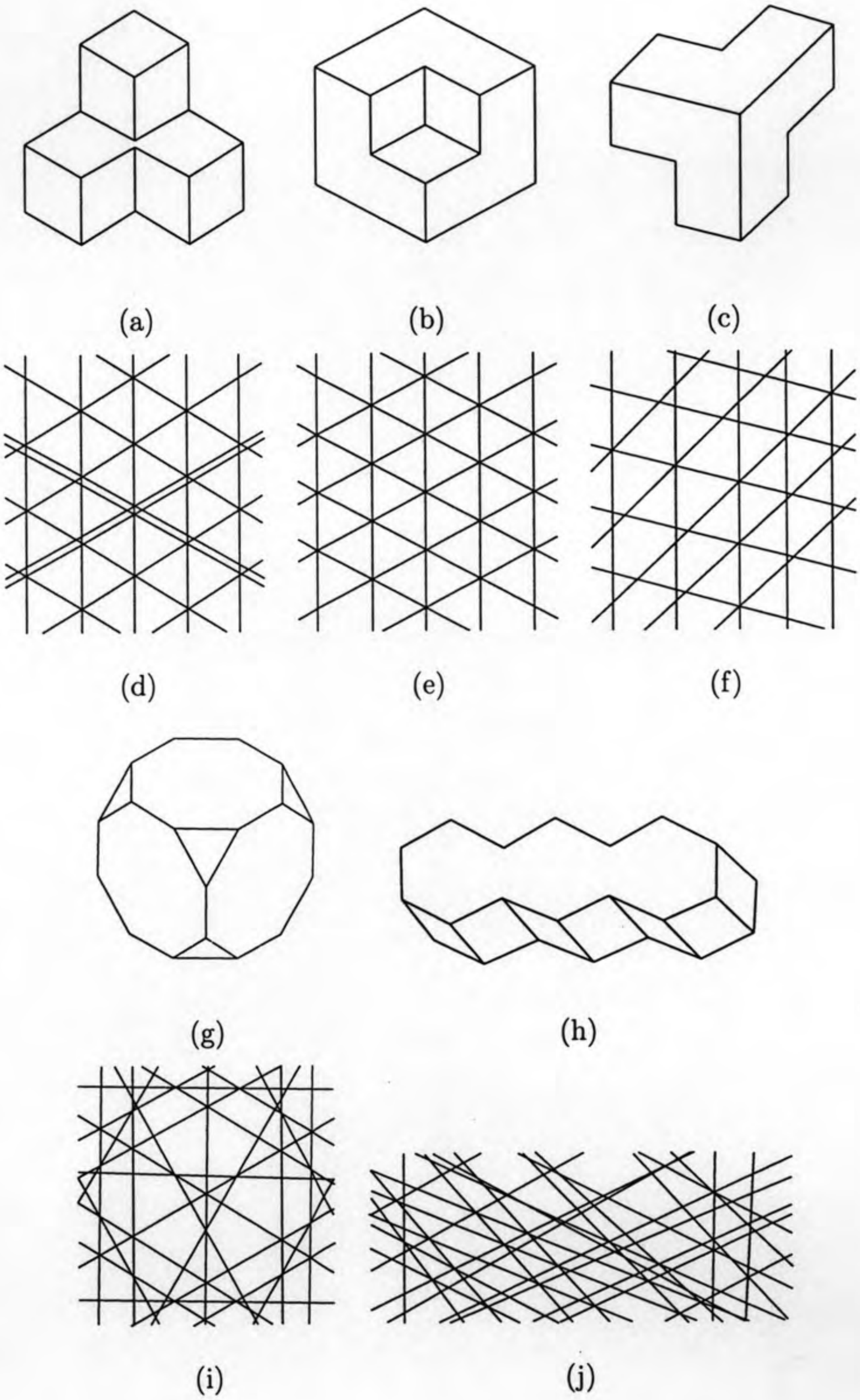
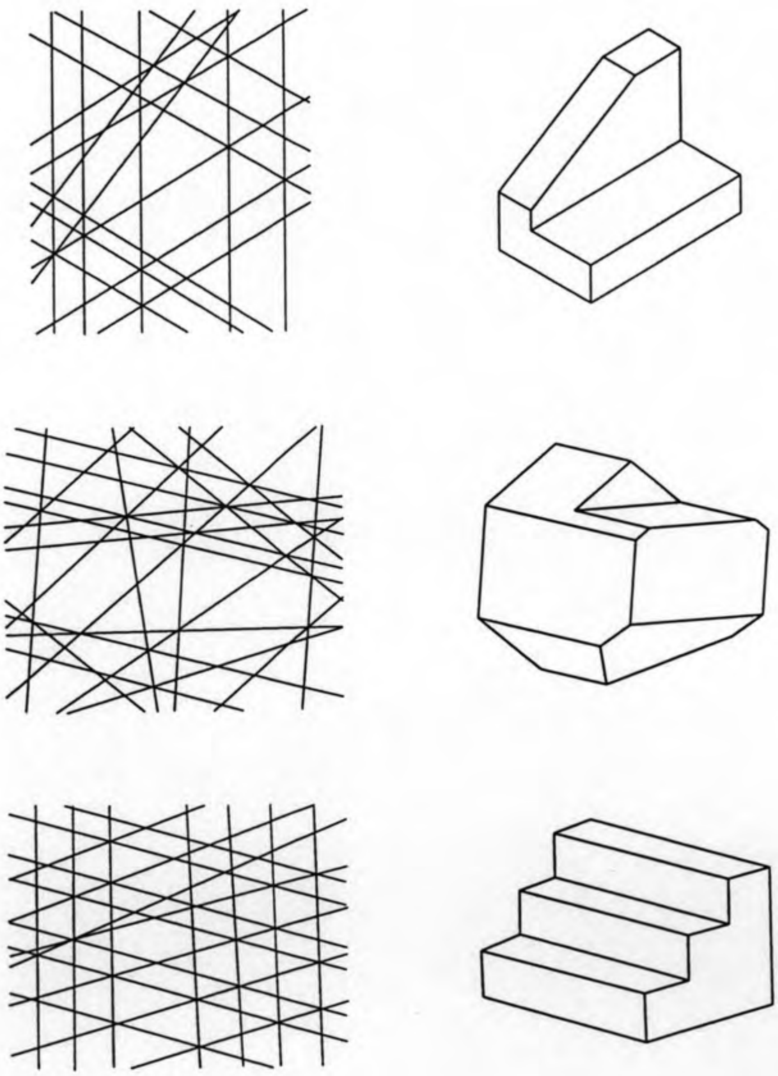
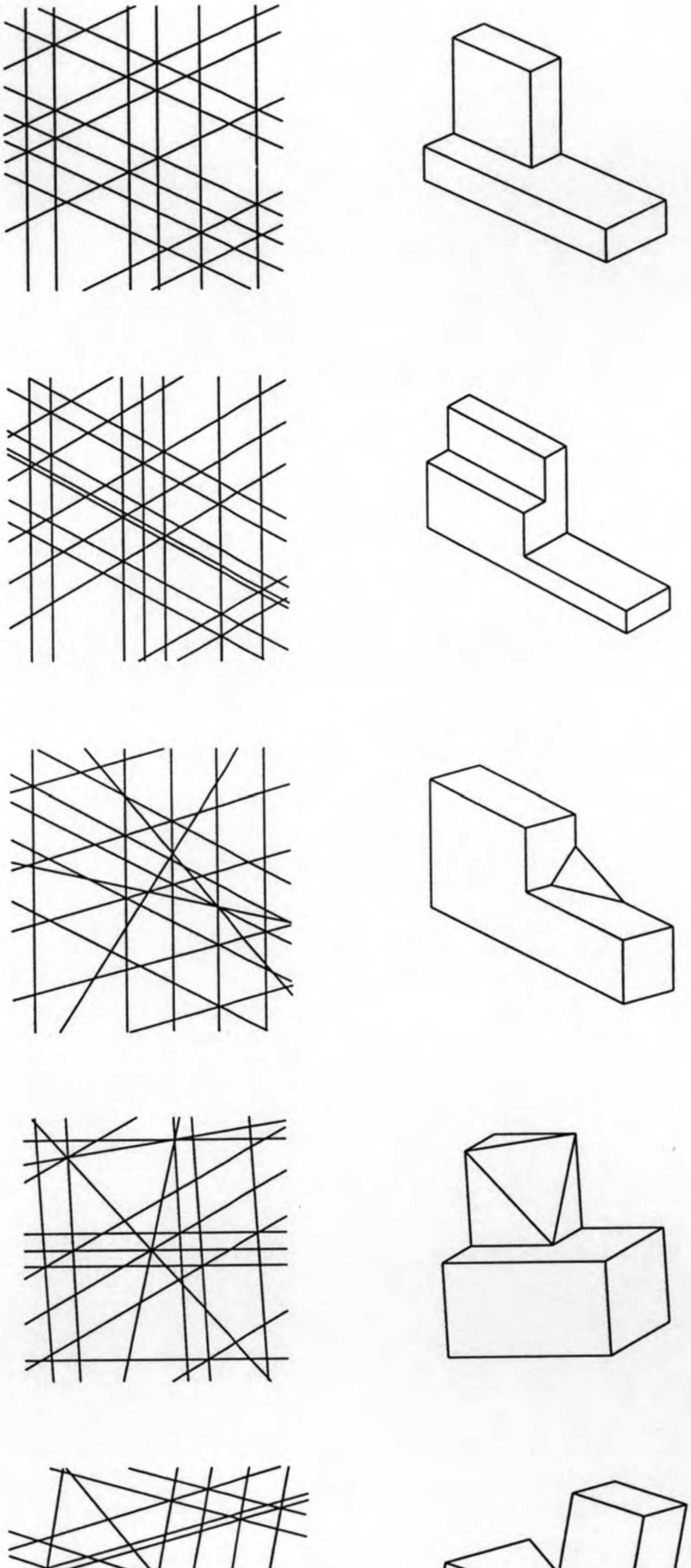


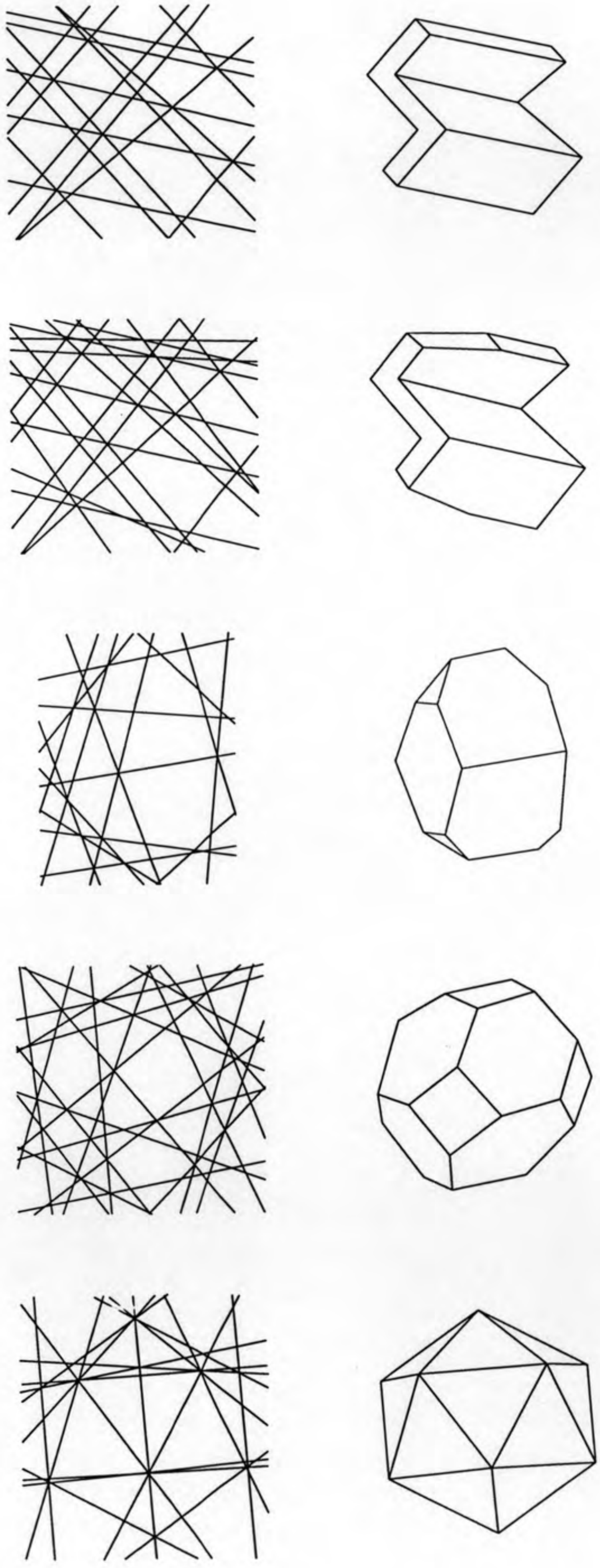
Figure 5.6: Unsuccessful extracted objects. (a)-(c) The 3D realizable objects in the test set. (d)-(f) The set of lines extracted from (a), (b), and (c), respectively. (g)-(h) The 3D realizable objects in the test set. (i)-(j) The set of lines extracted from (g) and (h), respectively.

5.3 Some Objects with Successful Extraction

Some examples of the objects with successful extraction by our proposed method are shown in Fig. 5.7. The column on the left shows the set of crossing lines extracted from the realizable objects in the test set. The column on the right is the 3D realizable objects extracted by our proposed method. All of them are identical to the realizable objects in the test set.







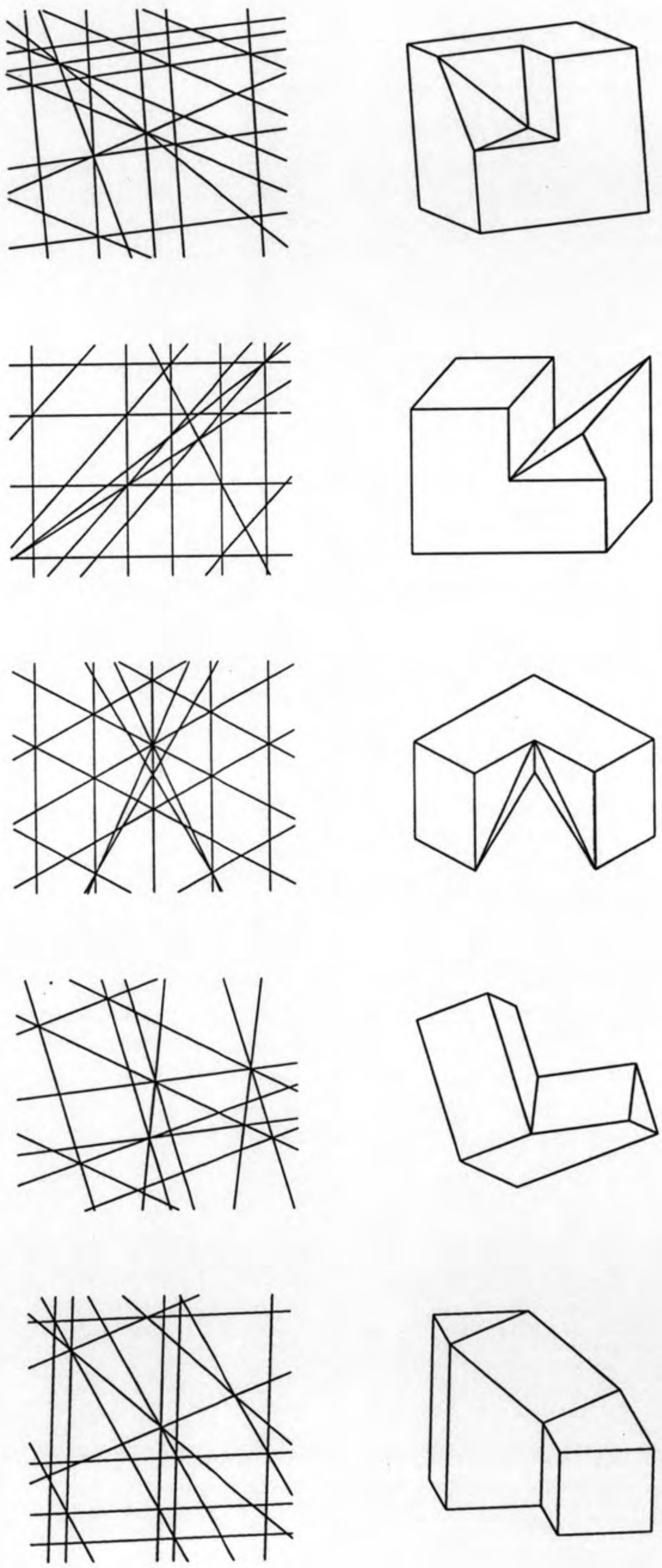


Figure 5.7: Successful extracted objects.

5.4 Discussion

Our rule-based approach algorithm in identifying and extracting a 3D realizable object can mostly identify and extract the tested objects. The accuracy in our experiment is 94.68 percent. There are two objects out of 169 objects that are partially successfully extracted. Such two objects are as previously shown in Fig. 5.3 and Fig. 5.4. From the structure of lines of this kind of objects, if no assumption about the position of view is given, the 3D realizable object can be interpreted into two possible extracted objects. The extracted objects as in Fig. 5.3(d) and in Fig. 5.4(d) can be a unique extracted 3D realizable object if the assumption of the position of view is the top-down view. On the same way, the extracted objects as in Fig. 5.3(e) and in Fig. 5.4(e) can be a unique extracted 3D realizable object if the assumption of the position of view is the bottom-up view.

The unsuccessful extracted objects shown in Fig. 5.5 and Fig. 5.6 are the case when some segments are still over-identified in the final extracted objects but no generated rule in the current proposed method can remove such segments. Therefore, some additional rules are still needed to cover in verifying the over-identified segments as in Fig. 5.5(e) and Fig. 5.5(f).

The group of the unsuccessful extracted objects shown in Fig. 5.6 is a group of objects that are failed to extract by our algorithm. In all objects, the candidates of the significant junctions and significant segments that were identified from Process 1 of the algorithm are incorrectly removed when rule $S1$ is applied to verify such junctions and segments in Process 2. Some real junctions and segments are incorrectly removed when rule $S1$ is applied in Process 1. Therefore, the current algorithm should be improved to cover with the case when the real junctions and segments are incorrectly removed.

Besides, the current algorithm uses the constraint of the problem lines in removing the over-identified segments and junctions, some features of the 3D realizable objects are not covered in the algorithm. Therefore, the algorithm and rules should be developed to cover with more features of the realizable objects. Especially, the features when T-junctions or K-junctions are included.