TopologyPracticum

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2 Lower Star Image Filtrations for Scanning

Here I take the notebook Lower Star Image Filtrations from ripser.py and adjust it to create a left-to-right scan on a letter from letters.csv and I would also perform a right-to-left scan on each letter. Then I plan on inverting the image and performing an up-to-down scan follwed by a down-to-up scan. First let's import everything they imported. I also import csv to read our csv file.

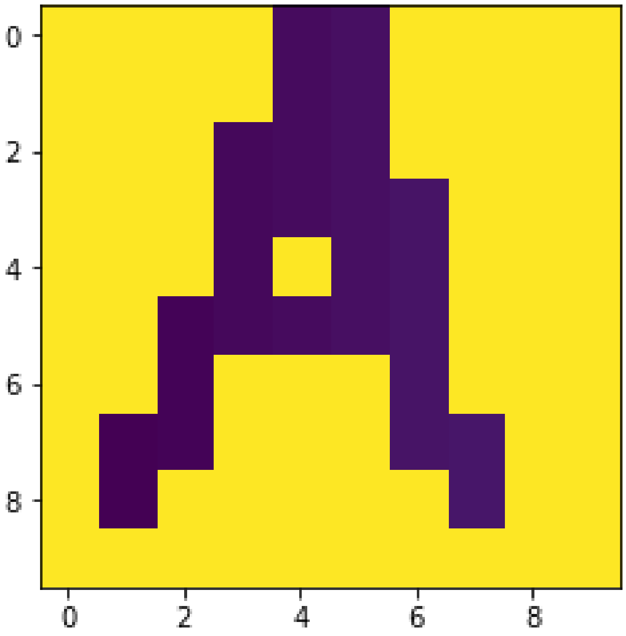
[1]:
```
import numpy as np
import matplotlib.pyplot as plt
import scipy
from scipy import ndimage
import PIL
from persim import plot_diagrams
from ripser import ripser, lower_star_img
import csv
```

2.1 Left-to-right Scanning Example

Our function on the image will be very simple: if the value we see in the corresponding row is 0 then the value on the pixel is 100, if the value is 1 then the value is the x1 coordinate. I'll be scanning the leters in sequential order from A-Z first left-to-right.

[2]:
```
from numpy import genfromtxt
import numpy as np
# read in file of letters

# read in file of letters
letters = genfromtxt('letters.csv', delimiter=',') # take first letter
letter_one_line=letters[0,:]

# initialize matrix of size 10x10 with all values 100
letter=np.full((10, 10), 100)

# convert one line letter to 10x10 matrix replacing zeros with 100
for k in range(1,101):
    if letter_one_line[k]==1.0:
        row=int((k-1)/10)
        column=(k-1)%10
        letter[row,column]=k%10
print(letter.shape)
print(letter)

plt.imshow(letter)
plt.show()
```

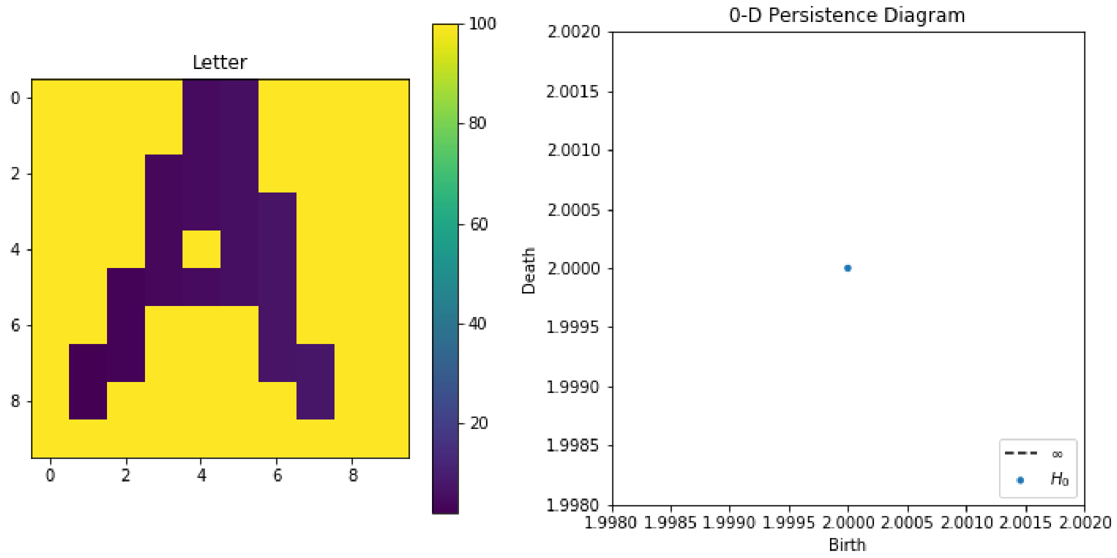
```
(10, 10)
[[100 100 100 100   5   6 100 100 100 100]
 [100 100 100 100   5   6 100 100 100 100]
 [100 100 100   4   5   6 100 100 100 100]
 [100 100 100   4   5   6   7 100 100 100]
 [100 100 100   4 100   6   7 100 100 100]
 [100 100   3   4   5   6   7 100 100 100]
 [100 100   3 100 100 100   7 100 100 100]
 [100   2   3 100 100 100   7   8 100 100]
 [100   2 100 100 100 100 100   8 100 100]
 [100 100 100 100 100 100 100 100 100 100]]
```



[3]:

```
dgm = lower_star_img(letter)
print(dgm)
plt.figure(figsize=(10, 5))
plt.subplot(121)
plt.imshow(letter)
plt.colorbar()
plt.title("Letter")
plt.subplot(122)
plot_diagrams(dgm)
plt.title("0-D Persistence Diagram")
plt.tight_layout()
plt.show()
```

```
[[ 2. inf]]

/Users/enzo/anaconda2/lib/python2.7/site-packages/matplotlib/axes/_base.py:3152:
UserWarning: Attempting to set identical left==right results
in singular transformations; automatically expanding.
left=2.0, right=2.0
  'left=%s, right=%s') % (left, right))
/Users/enzo/anaconda2/lib/python2.7/site-packages/matplotlib/axes/_base.py:3471:
UserWarning: Attempting to set identical bottom==top results
in singular transformations; automatically expanding.
bottom=2.0, top=2.0
  'bottom=%s, top=%s') % (bottom, top))
```

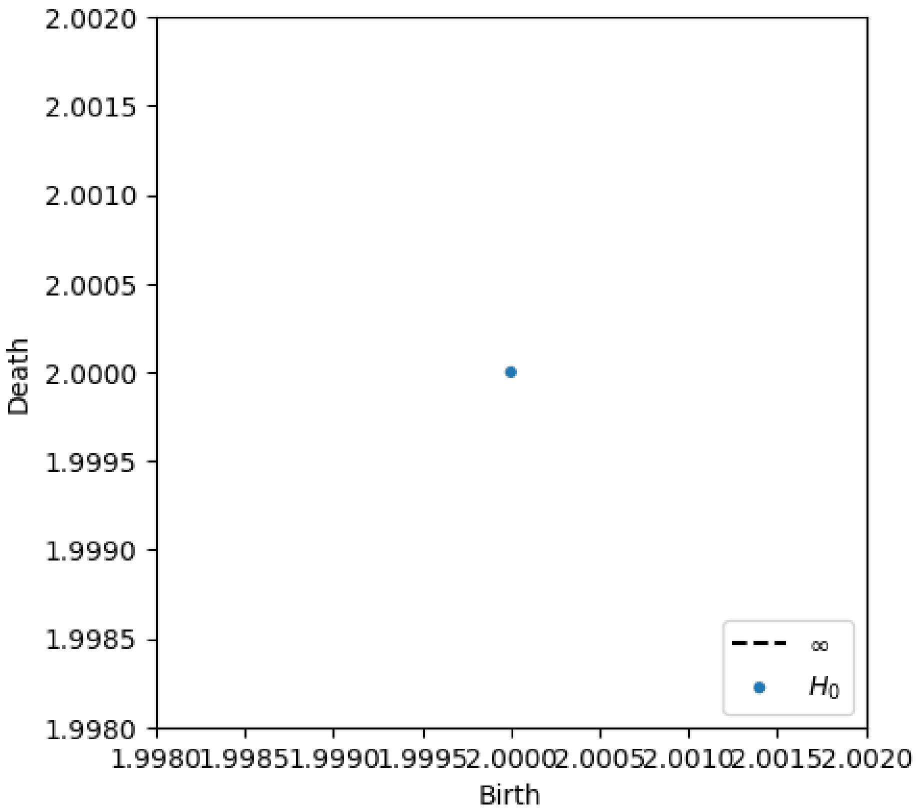


[4]:
```
help(lower_star_img)
```

```
Help on function lower_star_img in module ripser.ripser:

lower_star_img(img)
    Construct a lower star filtration on an image
    Parameters
    ----------
    img: ndarray (M, N)
        An array of single channel image data

    Returns
    -------
    I: ndarray (K, 2)
        A 0-dimensional persistence diagram corresponding to the sublevelset
filtration
```

[5]:
```
dgm = lower_star_img(letter)
print(dgm.shape)
print(dgm)
plot_diagrams(dgm)

plt.show()
```

```
(1, 2)
[[ 2. inf]]
```

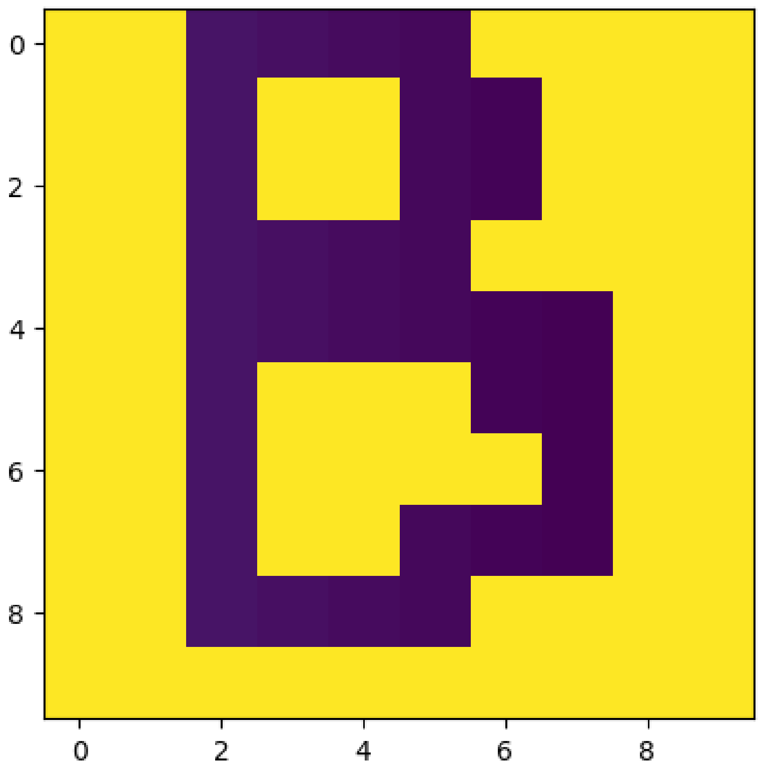


2.2 Right-to-left Scanning Example

Our function on the image will be very simple: if the value we see in the corresponding row is 0 then the value on the pixel is 100, if the value is 1 then the value is the x1 coordinate. I'll be scanning the leters in sequential order from A-Z right-to-left.

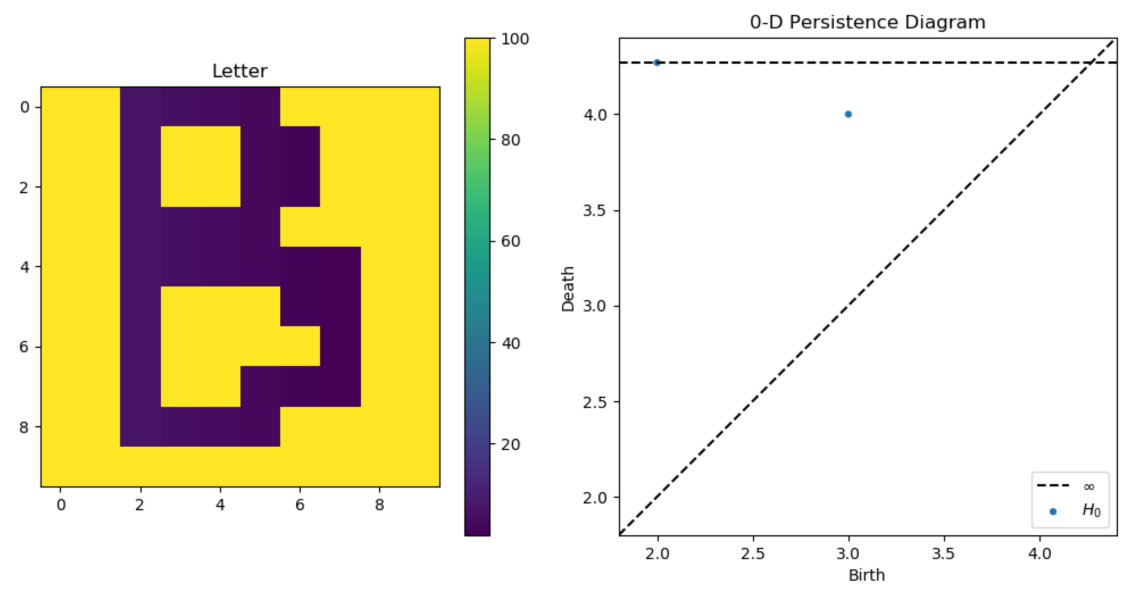
[6]:
```
from numpy import genfromtxt
import numpy as np
# read in file of letters

# read in file of letters
letters = genfromtxt('letters.csv', delimiter=',') # take first letter
letter_one_line=letters[1,:]

# initialize matrix of size 10x10 with all values 100
letter=np.full((10, 10), 100)

# convert one line letter to 10x10 matrix replacing zeros with 100
for k in range(1,101):
    if letter_one_line[k]==1.0:
        row=int((k-1)/10)
        column=(k-1)%10
        letter[row,column]=10-k%10 #this portion is how to scan the images␣
 ↪right-to-left
print(letter.shape)
print(letter)

plt.imshow(letter)
plt.show()
```

```
(10, 10)
[[100 100   7   6   5   4 100 100 100 100]
 [100 100   7 100 100   4   3 100 100 100]
 [100 100   7 100 100   4   3 100 100 100]
 [100 100   7   6   5   4 100 100 100 100]
 [100 100   7   6   5   4   3   2 100 100]
 [100 100   7 100 100 100   3   2 100 100]
 [100 100   7 100 100 100 100   2 100 100]
 [100 100   7 100 100   4   3   2 100 100]
 [100 100   7   6   5   4 100 100 100 100]
 [100 100 100 100 100 100 100 100 100 100]]
```



[7]:
```
dgm = lower_star_img(letter)
print(dgm)
plt.figure(figsize=(10, 5))
plt.subplot(121)
plt.imshow(letter)
plt.colorbar()
plt.title("Letter")
plt.subplot(122)
plot_diagrams(dgm)
plt.title("0-D Persistence Diagram")
plt.tight_layout()
plt.show()
```

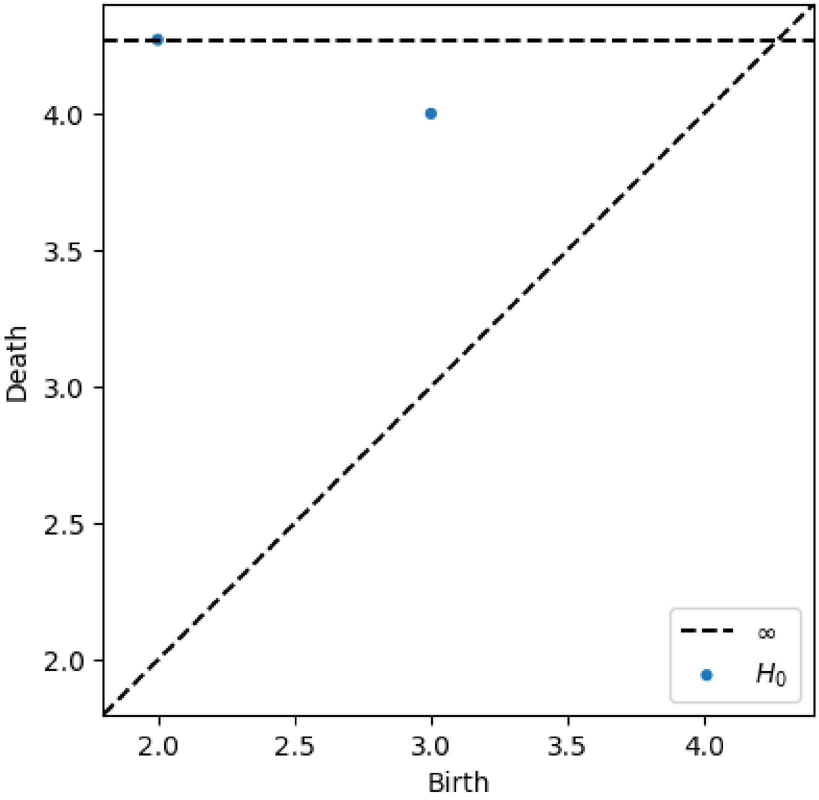
```
[[ 3.  4.]
 [ 2. inf]]
```



[8]:

```
dgm = lower_star_img(letter)
print(dgm.shape)
print(dgm)
plot_diagrams(dgm)

plt.show()
```

```
(2, 2)
[[ 3.   4.]
 [ 2. inf]]
```

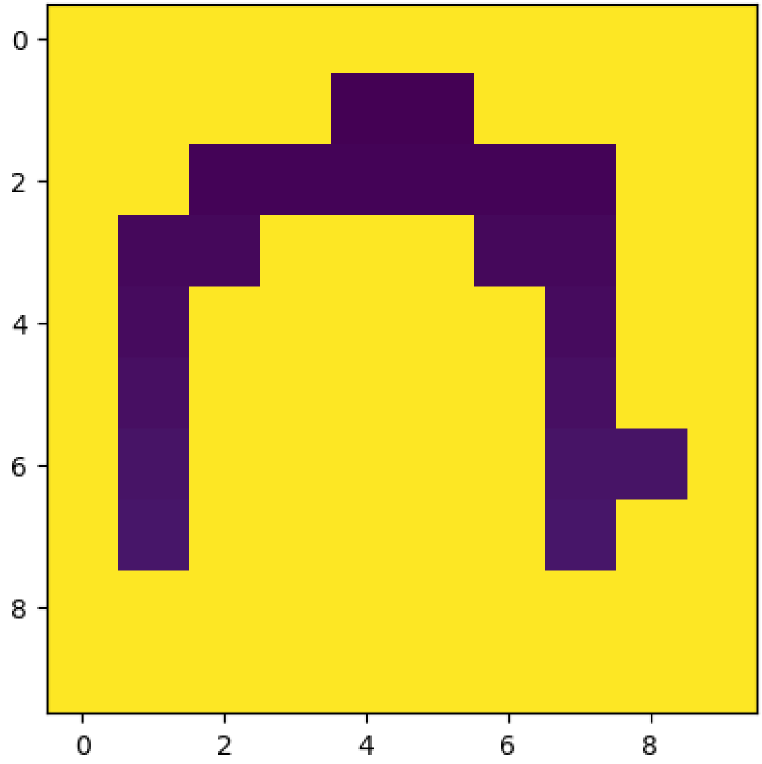


2.3 Down-to-up Scanning Example

Our function on the image will be very simple: if the value we see in the corresponding row is 0 then the value on the pixel is 100, if the value is 1 then the value is the x1 coordinate. I'll be scanning the leters in sequential order from A-Z first left-to-right inverted, which is down-to-up.

[9]:
```
from numpy import genfromtxt
import numpy as np
# read in file of letters

# read in file of letters
letters = genfromtxt('letters.csv', delimiter=',') # take first letter
letter_one_line=letters[2,:]

# initialize matrix of size 10x10 with all values 100
letter=np.full((10, 10), 100)

# convert one line letter to 10x10 matrix replacing zeros with 100
for k in range(1,101):
    if letter_one_line[k]==1.0:
        row=int((k-1)%10)
        column=(k-1)/10
        letter[row,column]=k%10
print(letter.shape)
print(letter)

plt.imshow(letter)
plt.show()
```

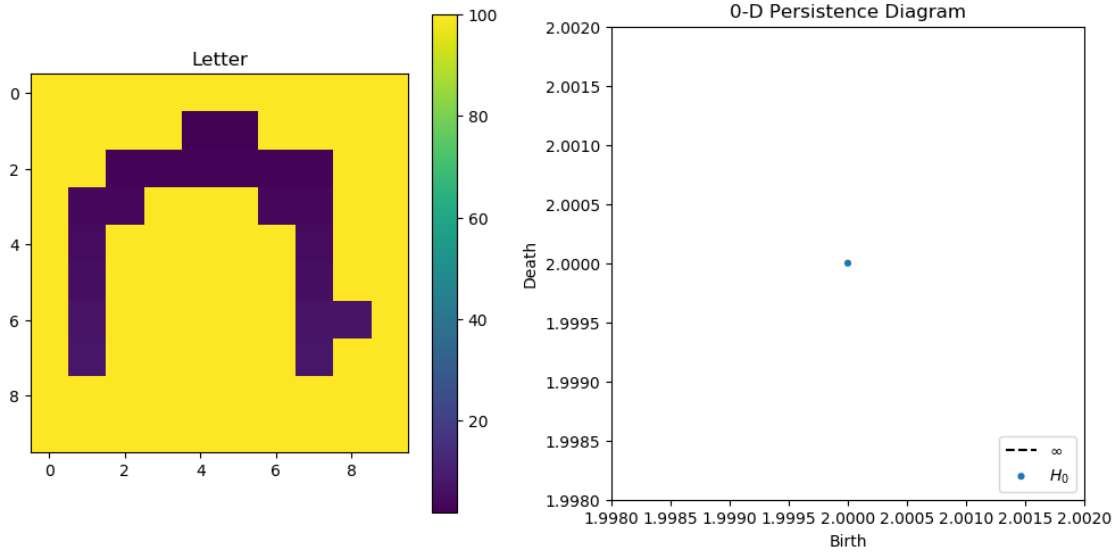
```
(10, 10)
[[100 100 100 100 100 100 100 100 100 100]
 [100 100 100 100   2   2 100 100 100 100]
 [100 100   3   3   3   3   3   3 100 100]
 [100   4   4 100 100 100   4   4 100 100]
 [100   5 100 100 100 100 100   5 100 100]
 [100   6 100 100 100 100 100   6 100 100]
 [100   7 100 100 100 100 100   7   7 100]
 [100   8 100 100 100 100 100   8 100 100]
 [100 100 100 100 100 100 100 100 100 100]
 [100 100 100 100 100 100 100 100 100 100]]
```



[10]:
```
dgm = lower_star_img(letter)
print(dgm)
```

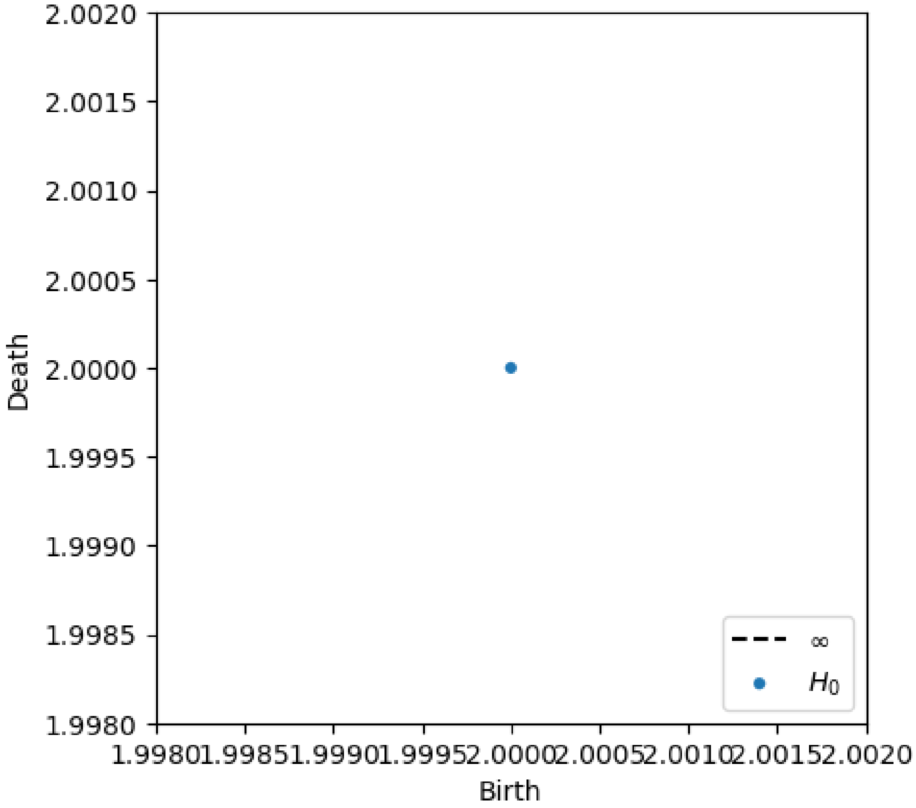
```
plt.figure(figsize=(10, 5))
plt.subplot(121)
plt.imshow(letter)
plt.colorbar()
plt.title("Letter")
plt.subplot(122)
plot_diagrams(dgm)
plt.title("0-D Persistence Diagram")
plt.tight_layout()
plt.show()
```

```
[[ 2. inf]]
```



[11]:
```
dgm = lower_star_img(letter)
print(dgm.shape)
print(dgm)
plot_diagrams(dgm)

plt.show()
```

```
(1, 2)
[[ 2. inf]]
```

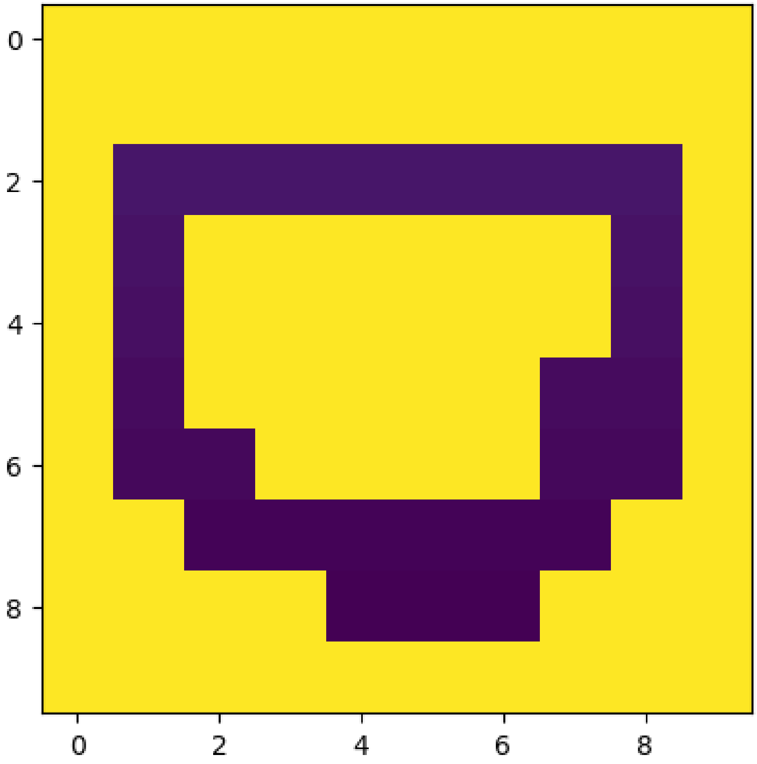


2.4 Up-to-down Inverted Scanning Example

Our function on the image will be very simple: if the value we see in the corresponding row is 0 then the value on the pixel is 100, if the value is 1 then the value is the x1 coordinate. I'll be scanning the leters in sequential order from A-Z right-to-left inverted, which is up-to-down.

[12]:
```
from numpy import genfromtxt
import numpy as np
# read in file of letters

# read in file of letters
letters = genfromtxt('letters.csv', delimiter=',') # take first letter
letter_one_line=letters[3,:]

# initialize matrix of size 10x10 with all values 100
letter=np.full((10, 10), 100)

# convert one line letter to 10x10 matrix replacing zeros with 100
for k in range(1,101):
    if letter_one_line[k]==1.0:
        row=int((k-1)%10)
        column=(k-1)/10
        letter[row,column]=10-k%10
print(letter.shape)
print(letter)

plt.imshow(letter)
plt.show()
```

```
(10, 10)
[[100 100 100 100 100 100 100 100 100 100]
 [100 100 100 100 100 100 100 100 100 100]
 [100   7   7   7   7   7   7   7   7 100]
 [100   6 100 100 100 100 100 100   6 100]
 [100   5 100 100 100 100 100 100   5 100]
 [100   4 100 100 100 100 100   4   4 100]
 [100   3   3 100 100 100 100   3   3 100]
 [100 100   2   2   2   2   2   2 100 100]
 [100 100 100 100   1   1   1 100 100 100]
 [100 100 100 100 100 100 100 100 100 100]]
```

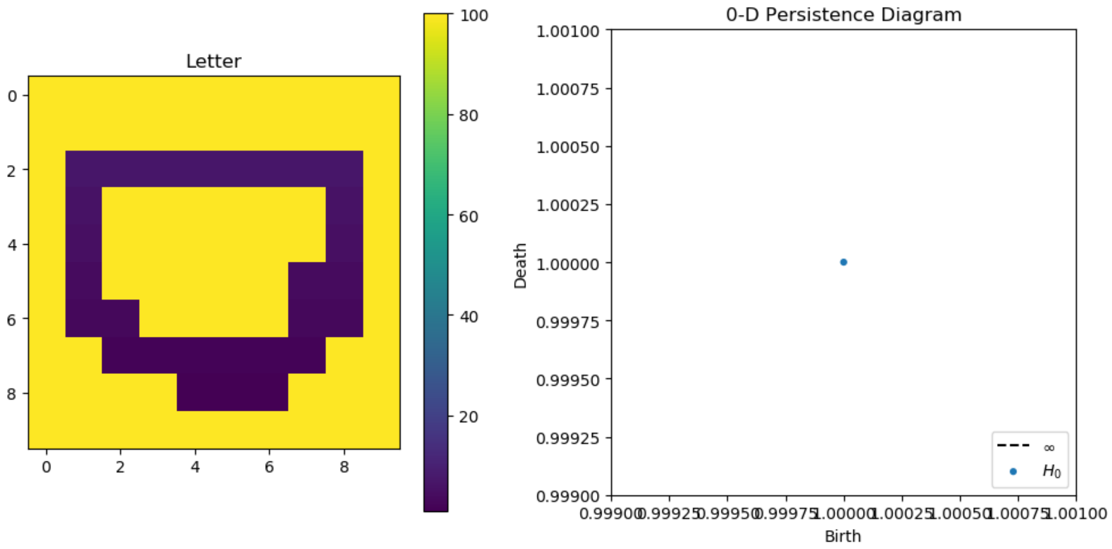


[13]:
```
dgm = lower_star_img(letter)
print(dgm)
```

```
plt.figure(figsize=(10, 5))
plt.subplot(121)
plt.imshow(letter)
plt.colorbar()
plt.title("Letter")
plt.subplot(122)
plot_diagrams(dgm)
plt.title("0-D Persistence Diagram")
plt.tight_layout()
plt.show()
```

```
[[ 1. inf]]
```

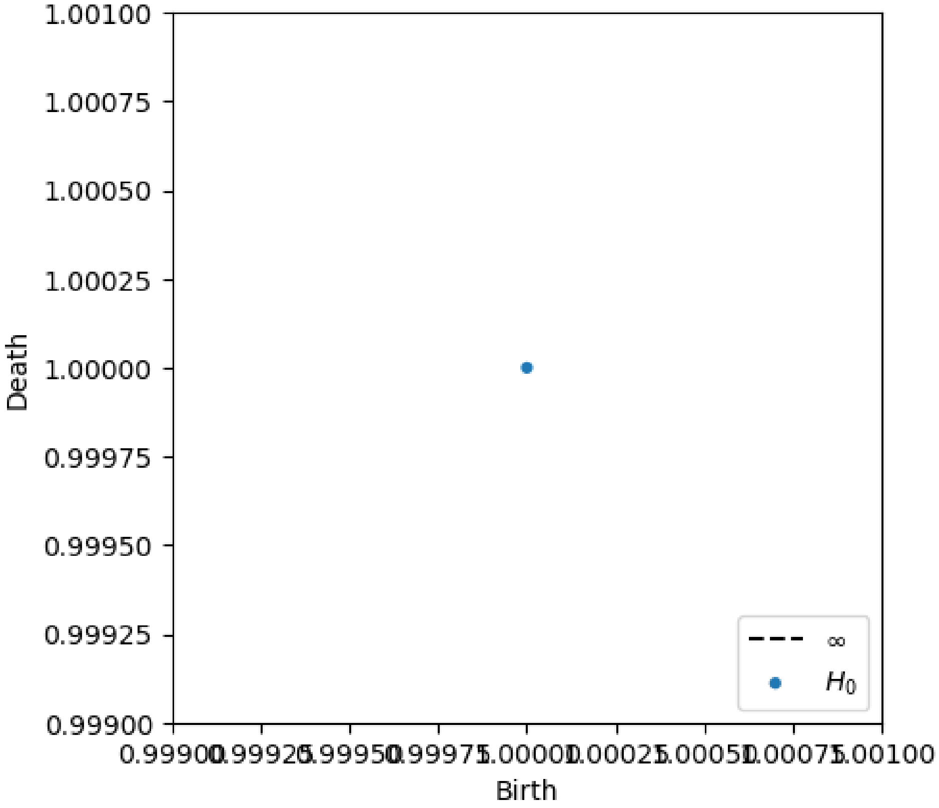
```
/Users/enzo/anaconda2/lib/python2.7/site-packages/matplotlib/axes/_base.py:3152:
UserWarning: Attempting to set identical left==right results
in singular transformations; automatically expanding.
left=1.0, right=1.0
  'left=%s, right=%s') % (left, right))
/Users/enzo/anaconda2/lib/python2.7/site-packages/matplotlib/axes/_base.py:3471:
UserWarning: Attempting to set identical bottom==top results
in singular transformations; automatically expanding.
bottom=1.0, top=1.0
  'bottom=%s, top=%s') % (bottom, top))
```



[14]:
```
dgm = lower_star_img(letter)
print(dgm.shape)
print(dgm)
plot_diagrams(dgm)
```

```
plt.show()
```

```
(1, 2)
[[ 1. inf]]
```

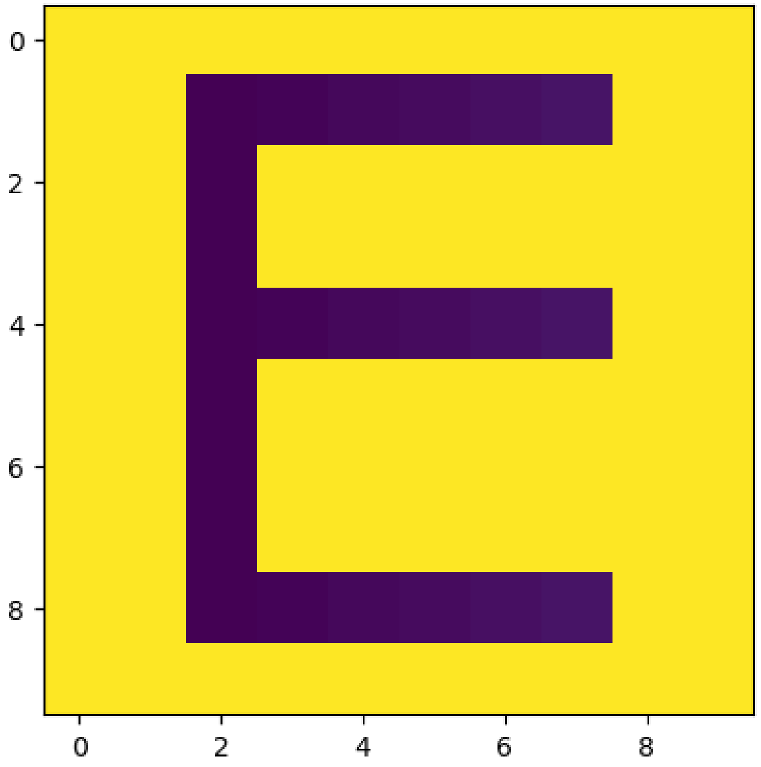


2.5 Angle Scanning Example

[15]:

```
from numpy import genfromtxt
import numpy as np
# read in file of letters

# read in file of letters
letters = genfromtxt('letters.csv', delimiter=',') # take first letter
letter_one_line=letters[4,:]

# initialize matrix of size 10x10 with all values 100
letter=np.full((10, 10), 100)

# convert one line letter to 10x10 matrix replacing zeros with 100
for k in range(1,101):
    if letter_one_line[k]==1.0:
        row=int((k-1)/10)
        column=(k-1)%10
        letter[row,column]=max(k%10,int(k-1)%10)
print(letter.shape)
print(letter)

plt.imshow(letter)
plt.show()
```

```
(10, 10)
[[100 100 100 100 100 100 100 100 100 100]
 [100 100   3   4   5   6   7   8 100 100]
 [100 100   3 100 100 100 100 100 100 100]
 [100 100   3 100 100 100 100 100 100 100]
 [100 100   3   4   5   6   7   8 100 100]
 [100 100   3 100 100 100 100 100 100 100]
 [100 100   3 100 100 100 100 100 100 100]
 [100 100   3 100 100 100 100 100 100 100]
 [100 100   3   4   5   6   7   8 100 100]
 [100 100 100 100 100 100 100 100 100 100]]
```

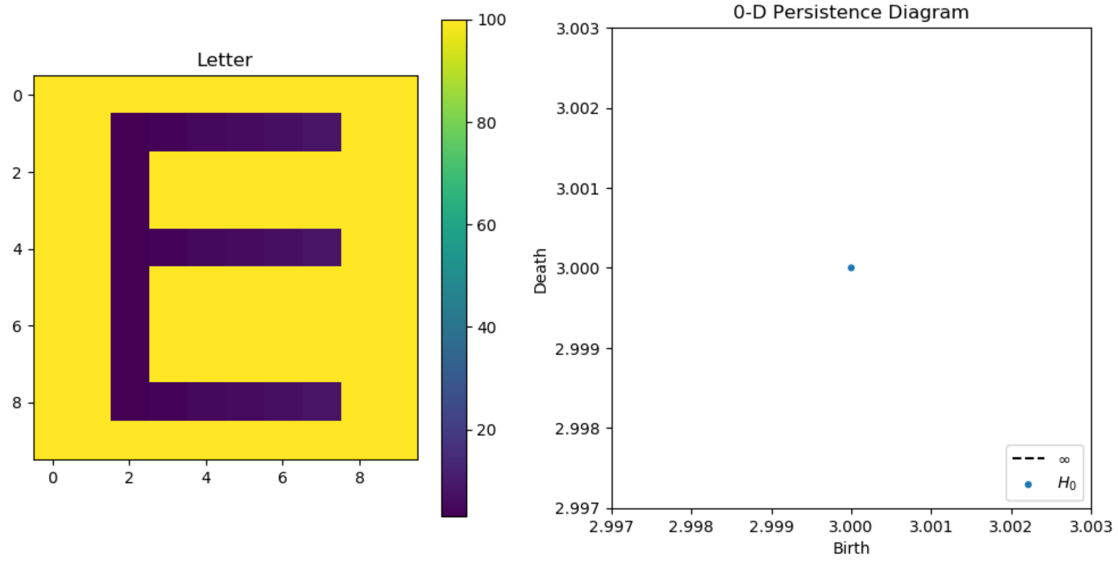


[16]:

```
dgm = lower_star_img(letter)
print(dgm)
plt.figure(figsize=(10, 5))
plt.subplot(121)
plt.imshow(letter)
plt.colorbar()
plt.title("Letter")
plt.subplot(122)
plot_diagrams(dgm)
plt.title("0-D Persistence Diagram")
plt.tight_layout()
plt.show()
```

```
[[ 3. inf]]
```

```
/Users/enzo/anaconda2/lib/python2.7/site-packages/matplotlib/axes/_base.py:3152:
UserWarning: Attempting to set identical left==right results
in singular transformations; automatically expanding.
left=3.0, right=3.0
  'left=%s, right=%s') % (left, right))
/Users/enzo/anaconda2/lib/python2.7/site-packages/matplotlib/axes/_base.py:3471:
UserWarning: Attempting to set identical bottom==top results
in singular transformations; automatically expanding.
bottom=3.0, top=3.0
  'bottom=%s, top=%s') % (bottom, top))
```

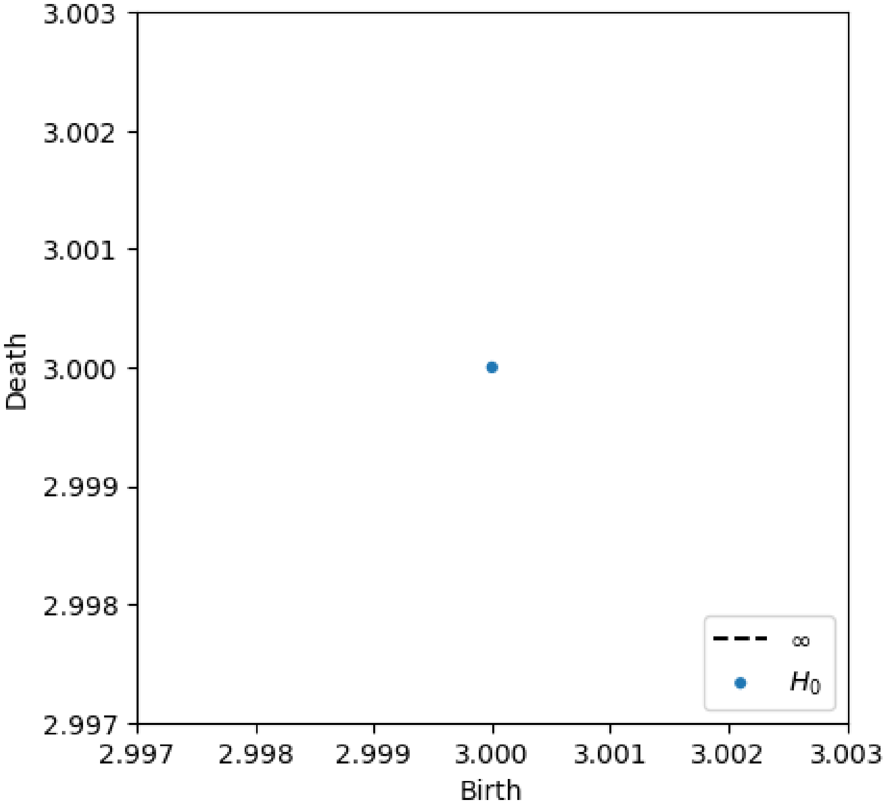


[17]:

```
dgm = lower_star_img(letter)
print(dgm.shape)
print(dgm)
```

```
plot_diagrams(dgm)

plt.show()
```

```
(1, 2)
[[ 3. inf]]
```

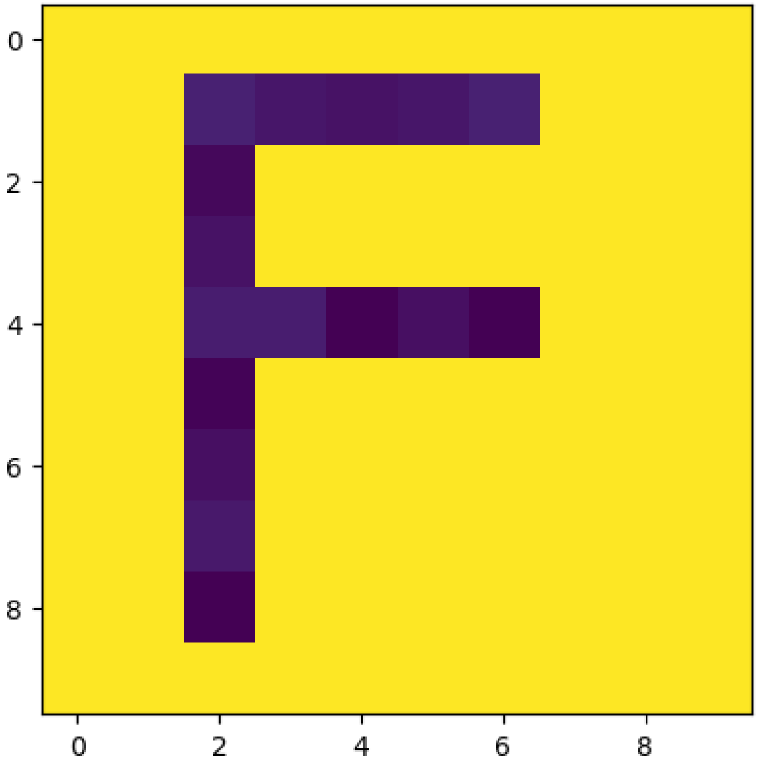


2.6 Diagonal Scanning Example

[18]:
```
from numpy import genfromtxt
import numpy as np
# read in file of letters

# read in file of letters
letters = genfromtxt('letters.csv', delimiter=',') # take first letter
letter_one_line=letters[5,:]

# initialize matrix of size 10x10 with all values 100
letter=np.full((10, 10), 100)
```

```
# convert one line letter to 10x10 matrix replacing zeros with 100
for k in range(1,101):
    if letter_one_line[k]==1.0:
        row=int((k-1)/10)
        column=(k-1)%10
        letter[row,column]=(column+row)*k%10
print(letter.shape)
print(letter)

plt.imshow(letter)
plt.show()
```

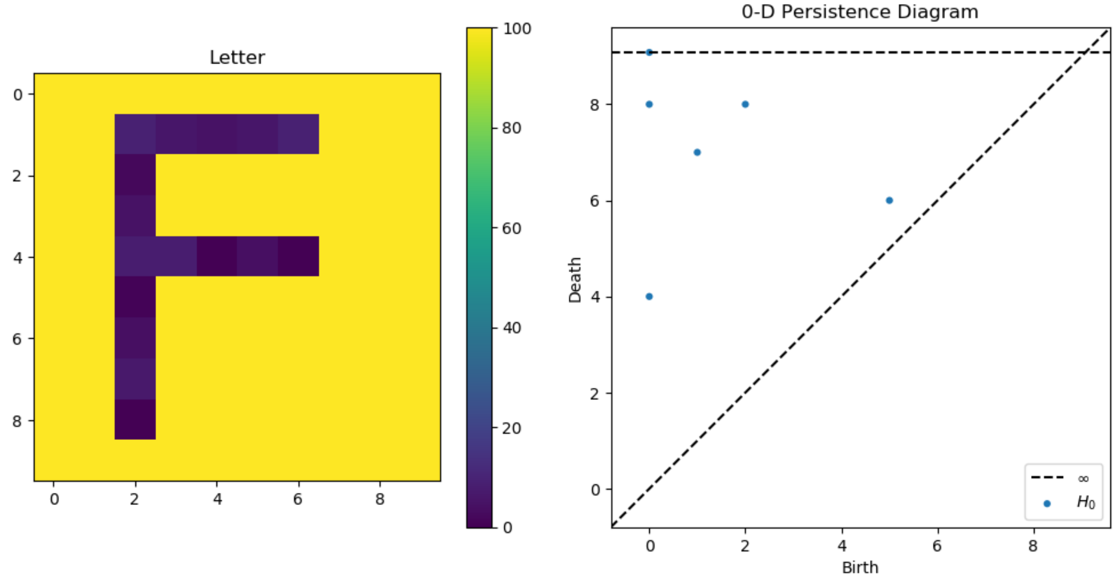
```
(10, 10)
[[100 100 100 100 100 100 100 100 100 100]
 [100 100   9   6   5   6   9 100 100 100]
 [100 100   2 100 100 100 100 100 100 100]
 [100 100   5 100 100 100 100 100 100 100]
 [100 100   8   8   0   4   0 100 100 100]
 [100 100   1 100 100 100 100 100 100 100]
 [100 100   4 100 100 100 100 100 100 100]
 [100 100   7 100 100 100 100 100 100 100]
 [100 100   0 100 100 100 100 100 100 100]
 [100 100 100 100 100 100 100 100 100 100]]
```



[19]:

```
dgm = lower_star_img(letter)
print(dgm)
plt.figure(figsize=(10, 5))
plt.subplot(121)
plt.imshow(letter)
plt.colorbar()
plt.title("Letter")
plt.subplot(122)
plot_diagrams(dgm)
plt.title("0-D Persistence Diagram")
plt.tight_layout()
plt.show()
```

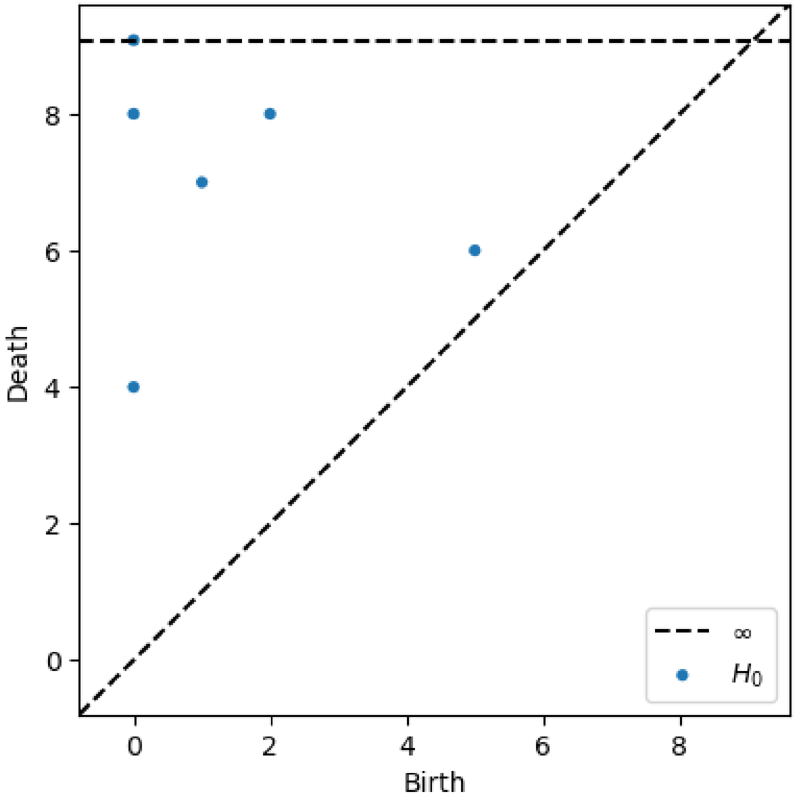
```
[[ 0.   4.]
 [ 5.   6.]
 [ 1.   7.]
 [ 0.   8.]
 [ 2.   8.]
 [ 0.  inf]]
```



[20]:

```
dgm = lower_star_img(letter)
print(dgm.shape)
print(dgm)
plot_diagrams(dgm)

plt.show()
```

```
(6, 2)
[[ 0.   4.]
 [ 5.   6.]
 [ 1.   7.]
 [ 0.   8.]
 [ 2.   8.]
 [ 0. inf]]
```



3 Looping through all the letters in every direction

[21]:
```
# Left-to-right scanning through loops
letters = genfromtxt('letters.csv', delimiter=',') # Upload the file

dgmLR = [None]*26 #Initialize an empty list
for i in range(26):
    letter_one_line=letters[i,:]

    # initialize matrix of size 10x10 with all values 100
    letter=np.full((10, 10), 100)
    # convert one line letter to 10x10 matrix replacing zeros with 100
    for k in range(1,101):
        if letter_one_line[k]==1.0:
            row=int((k-1)/10)
            column=(k-1)%10
            letter[row,column]=k%10
    dgmLR[i] = lower_star_img(letter)
```

[22]:
```
# Print A-Z diagrams
print(dgmLR[0:25])
```

```
[array([[ 2., inf]]), array([[ 3., inf]]), array([[ 2., inf]]), array([[ 3.,
inf]]), array([[ 3., inf]]), array([[ 3., inf]]), array([[ 2., inf]]), array([[
3., inf]]), array([[ 4.,  5.],
       [ 4., inf]]), array([[ 4.,  6.],
       [ 4., inf]]), array([[ 3., inf]]), array([[ 3., inf]]), array([[ 2.,
inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[ 3., inf]]), array([[
6.,  7.],
       [ 2., inf]]), array([[ 3., inf]]), array([[ 3.,  8.],
       [ 3., inf]]), array([[ 2., inf]]), array([[ 3., inf]]), array([[ 2.,
inf]]), array([[ 2., inf]]), array([[ 3.,  4.],
       [ 3., inf]]), array([[ 3., inf]])]
```

[23]:
```
# Print A digram
print(dgmLR[0])
```

```
[[ 2. inf]]
```

[24]:
```
# Print z diagram
print(dgmLR[25])
```

```
[[ 3.  7.]
 [ 2. inf]]
```

[25]:
```
# Right-to-left scanning through loops
letters = genfromtxt('letters.csv', delimiter=',') # Upload the file

dgmRL = [None]*26 #Initialize an empty list
for i in range(26):
    letter_one_line=letters[i,:]

    # initialize matrix of size 10x10 with all values 100
    letter=np.full((10, 10), 100)

    # convert one line letter to 10x10 matrix replacing zeros with 100
    for k in range(1,101):
        if letter_one_line[k]==1.0:
            row=int((k-1)/10)
            column=(k-1)%10
            letter[row,column]=10-k%10
    dgmRL[i] = lower_star_img(letter)
```

[26]:
```
# Print A-Z diagrams
print(dgmRL[0:25])
```

```
[array([[ 2., inf]]), array([[ 3.,  4.],
       [ 2., inf]]), array([[ 2.,  7.],
       [ 2., inf]]), array([[ 1., inf]]), array([[ 2.,  7.],
       [ 2.,  7.],
       [ 2., inf]]), array([[ 3.,  7.],
       [ 3., inf]]), array([[ 3.,  7.],
       [ 3., inf]]), array([[ 3., inf]]), array([[ 4.,  5.],
       [ 4., inf]]), array([[ 4., inf]]), array([[ 3.,  6.],
       [ 3., inf]]), array([[ 3., inf]]), array([[ 2., inf]]), array([[ 3.,
inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[
3.,  5.],
       [ 3., inf]]), array([[ 2.,  7.],
       [ 2., inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[ 2.,
inf]]), array([[ 1., inf]]), array([[ 3.,  5.],
       [ 3., inf]]), array([[ 3., inf]])]
```

[27]:
```
# Print A diagram
print(dgmRL[0])
```

```
[[ 2. inf]]
```

[28]:
```
# Print Z diagram
print(dgmRL[25])
```

```
[[ 2.  6.]
 [ 2. inf]]
```

[29]:
```
# Down-to-up scanning through loops
letters = genfromtxt('letters.csv', delimiter=',') # Upload the file

dgmDU = [None]*26 #Initialize an empty list
for i in range(26):
    letter_one_line=letters[i,:]

    # initialize matrix of size 10x10 with all values 100
    letter=np.full((10, 10), 100)

    # convert one line letter to 10x10 matrix replacing zeros with 100
    for k in range(1,101):
        if letter_one_line[k]==1.0:
            row=int((k-1)%10)
            column=(k-1)/10
            letter[row,column]=k%10
    dgmDU[i] = lower_star_img(letter)
```

[30]:

```
# Print A-Z diagrams
print(dgmDU[0:25])
```

```
[array([[ 2., inf]]), array([[ 3., inf]]), array([[ 2., inf]]), array([[ 3.,
inf]]), array([[ 3., inf]]), array([[ 3., inf]]), array([[ 2., inf]]), array([[
3., inf]]), array([[ 4.,  5.],
       [ 4., inf]]), array([[ 4.,  6.],
       [ 4., inf]]), array([[ 3., inf]]), array([[ 3., inf]]), array([[ 2.,
inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[ 3., inf]]), array([[
6.,  7.],
       [ 2., inf]]), array([[ 3., inf]]), array([[ 3.,  8.],
       [ 3., inf]]), array([[ 2., inf]]), array([[ 3., inf]]), array([[ 2.,
inf]]), array([[ 2., inf]]), array([[ 3.,  4.],
       [ 3., inf]]), array([[ 3., inf]])]
```

[31]:

```
# Print A diagram
print(dgmDU[0])
```

```
[[ 2. inf]]
```

[32]:

```
# Print Z diagram
print(dgmDU[25])
```

```
[[ 3.  7.]
 [ 2. inf]]
```

[33]:

```
# Up-to-down scanning through loops
letters = genfromtxt('letters.csv', delimiter=',') # Upload the file

dgmUD = [None]*26 #Initialize an empty list
for i in range(26):
    letter_one_line=letters[i,:]

    # initialize matrix of size 10x10 with all values 100
    letter=np.full((10, 10), 100)

    # convert one line letter to 10x10 matrix replacing zeros with 100
    for k in range(1,101):
        if letter_one_line[k]==1.0:
            row=int((k-1)%10)
            column=(k-1)/10
            letter[row,column]=10-k%10
    dgmUD[i] = lower_star_img(letter)
```

[34]:

```
# Print A-Z diagrams
print(dgmUD[0:25])
```

```
[array([[ 2., inf]]), array([[ 3.,  4.],
       [ 2., inf]]), array([[ 2.,  7.],
       [ 2., inf]]), array([[ 1., inf]]), array([[ 2.,  7.],
       [ 2.,  7.],
       [ 2., inf]]), array([[ 3.,  7.],
       [ 3., inf]]), array([[ 3.,  7.],
       [ 3., inf]]), array([[ 3., inf]]), array([[ 4.,  5.],
       [ 4., inf]]), array([[ 4., inf]]), array([[ 3.,  6.],
       [ 3., inf]]), array([[ 3., inf]]), array([[ 2., inf]]), array([[ 3.,
inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[
3.,  5.],
       [ 3., inf]]), array([[ 2.,  7.],
       [ 2., inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[ 2.,
inf]]), array([[ 1., inf]]), array([[ 3.,  5.],
       [ 3., inf]]), array([[ 3., inf]])]
```

[35]:

```
# Print A diagram
print(dgmUD[0])
```

```
[[ 2. inf]]
```

[36]:

```
# Print Z diagram
print(dgmUD[25])
```

```
[[ 2.  6.]
 [ 2. inf]]
```

[37]:

```
# Angle scanning through loops
letters = genfromtxt('letters.csv', delimiter=',') # Upload the file

dgmAngle = [None]*26 #Initialize an empty list
for i in range(26):
    letter_one_line=letters[i,:]

    # initialize matrix of size 10x10 with all values 100
    letter=np.full((10, 10), 100)

    # convert one line letter to 10x10 matrix replacing zeros with 100
    for k in range(1,101):
        if letter_one_line[k]==1.0:
            row=int((k-1)/10)
            column=(k-1)%10
            letter[row,column]=max(k%10,int(k-1)%10)
    dgmAngle[i] = lower_star_img(letter)
```

[38]:
```
# Print A-Z diagrams
print(dgmAngle[0:25])
```

```
[array([[ 2., inf]]), array([[ 3., inf]]), array([[ 2., inf]]), array([[ 3.,
inf]]), array([[ 3., inf]]), array([[ 3., inf]]), array([[ 2., inf]]), array([[
3., inf]]), array([[ 4.,  5.],
       [ 4., inf]]), array([[ 4.,  6.],
       [ 4., inf]]), array([[ 3., inf]]), array([[ 3., inf]]), array([[ 2.,
inf]]), array([[ 2., inf]]), array([[ 2., inf]]), array([[ 3., inf]]), array([[
6.,  7.],
       [ 2., inf]]), array([[ 3., inf]]), array([[ 3.,  8.],
       [ 3., inf]]), array([[ 2., inf]]), array([[ 3., inf]]), array([[ 2.,
inf]]), array([[ 2., inf]]), array([[ 3.,  4.],
       [ 3., inf]]), array([[ 3., inf]])]
```

[39]:
```
# Print A digram
print(dgmAngle[0])
```

```
[[ 2. inf]]
```

[40]:
```
# Print z diagram
print(dgmAngle[25])
```

```
[[ 3.  7.]
 [ 2. inf]]
```

[41]:
```
# Diagonal scanning through loops
letters = genfromtxt('letters.csv', delimiter=',') # Upload the file

dgmDiagonal = [None]*26 #Initialize an empty list
for i in range(26):
    letter_one_line=letters[i,:]

    # initialize matrix of size 10x10 with all values 100
    letter=np.full((10, 10), 100)

    # convert one line letter to 10x10 matrix replacing zeros with 100
    for k in range(1,101):
        if letter_one_line[k]==1.0:
            row=int((k-1)/10)
            column=(k-1)%10
            letter[row,column]=(column+row)*k%10
    dgmDiagonal[i] = lower_star_img(letter)
```

[42]:

```
# Print A-Z diagrams
print(dgmDiagonal[0:25])
```

```
[array([[ 0.,  3.],
       [ 0.,  4.],
       [ 1.,  5.],
       [ 0.,  5.],
       [ 0., inf]]), array([[ 1.,  2.],
       [ 0.,  4.],
       [ 0.,  4.],
       [ 2.,  4.],
       [ 2.,  5.],
       [ 0.,  6.],
       [ 0.,  6.],
       [ 1.,  7.],
       [ 0., inf]]), array([[ 0.,  4.],
       [ 1.,  5.],
       [ 0.,  5.],
       [ 4.,  9.],
       [ 0., inf]]), array([[ 1.,  2.],
       [ 0.,  4.],
       [ 5.,  6.],
       [ 2.,  6.],
       [ 1.,  7.],
       [ 0.,  8.],
       [ 0., inf]]), array([[ 0.,  4.],
       [ 0.,  4.],
       [ 5.,  6.],
       [ 1.,  7.],
       [ 0.,  8.],
       [ 0.,  8.],
       [ 2.,  8.],
       [ 4.,  9.],
       [ 0., inf]]), array([[ 0.,  4.],
       [ 5.,  6.],
       [ 1.,  7.],
       [ 0.,  8.],
       [ 2.,  8.],
       [ 0., inf]]), array([[ 1.,  4.],
       [ 0.,  4.],
       [ 0.,  5.],
       [ 2.,  5.],
       [ 5.,  6.],
       [ 0., inf]]), array([[ 1.,  7.],
       [ 2.,  8.],
       [ 1.,  8.],
       [ 0., inf]]), array([[ 0.,  5.],
       [ 0.,  5.],
       [ 0.,  5.],
       [ 0., inf]]), array([[ 2.,  5.],
       [ 0.,  6.],
       [ 2.,  8.],
       [ 0., inf]]), array([[ 1.,  2.],
       [ 1.,  2.],
       [ 2.,  5.],
       [ 0.,  7.],
       [ 2.,  8.],
       [ 0., inf]]), array([[ 0.,  4.],
       [ 1.,  7.],
       [ 2.,  8.],
       [ 0., inf]]), array([[ 0.,  2.],
       [ 2.,  4.],
       [ 0.,  5.],
       [ 2.,  6.],
       [ 2.,  8.],
       [ 0.,  8.],
       [ 0., inf]]), array([[ 1.,  4.],
       [ 2.,  4.],
       [ 0.,  5.],
       [ 0., inf]]), array([[ 0.,  4.],
       [ 0.,  6.],
       [ 5.,  6.],
       [ 2.,  6.],
       [ 1.,  8.],
       [ 0.,  8.],
       [ 0., inf]]), array([[ 1.,  5.],
       [ 5.,  6.],
       [ 2.,  6.],
       [ 0.,  7.],
       [ 0., inf]]), array([[ 0.,  4.],
       [ 0.,  6.],
       [ 5.,  6.],
       [ 0.,  8.],
       [ 0.,  8.],
       [ 2.,  8.],
       [ 0., inf]]), array([[ 1.,  2.],
       [ 1.,  2.],
       [ 0.,  2.],
       [ 2.,  4.],
       [ 2.,  6.],
       [ 0.,  7.],
       [ 0., inf]]), array([[ 0.,  4.],
       [ 2.,  5.],
       [ 5.,  6.],
       [ 0.,  7.],
       [ 0.,  8.],
       [ 2.,  8.],
       [ 4.,  9.],
       [ 0., inf]]), array([[ 0.,  5.],
       [ 0.,  5.],
       [ 0.,  5.],
       [ 4.,  9.],
       [ 4.,  9.],
       [ 0., inf]]), array([[ 0.,  4.],
       [ 1.,  7.],
       [ 0.,  8.],
       [ 0.,  8.],
       [ 2.,  8.],
       [ 0., inf]]), array([[ 0.,  2.],
       [ 2.,  3.],
       [ 2.,  8.],
       [ 0., inf]]), array([[ 1.,  2.],
       [ 0.,  2.],
       [ 0.,  3.],
       [ 0.,  5.],
       [ 0.,  6.],
       [ 5.,  6.],
       [ 4.,  8.],
       [ 0.,  9.],
       [ 0., inf]]), array([[ 1.,  2.],
       [ 0.,  2.],
       [ 2.,  4.],
       [ 0.,  4.],
       [ 0., inf]]), array([[ 0.,  5.],
       [ 0.,  8.],
       [ 2.,  8.],
       [ 0., inf]])]
```

[43]:

```
# Print A digram
print(dgmDiagonal[0])
```

```
[[ 0.  3.]
 [ 0.  4.]
 [ 1.  5.]
 [ 0.  5.]
 [ 0. inf]]
```

[44]:

```
# Print z diagram
print(dgmDiagonal[25])
```

```
[[ 2.  4.]
 [ 0.  5.]
 [ 5.  6.]
 [ 0.  8.]
 [ 4.  9.]
 [ 0. inf]]
```

[ ]:

```

```