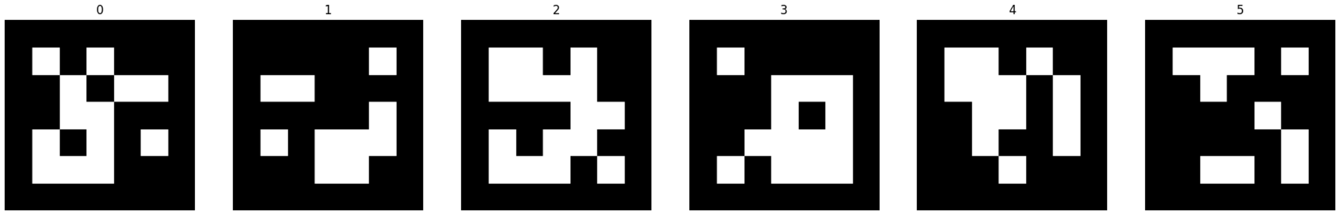
產生ArUco marker

下面範例產生ArUco marker影像，其中DICT_5X5_100表示Marker為5X5的黑白Bit-pattern，一共可有100個，編號0-99號。

In [1]:

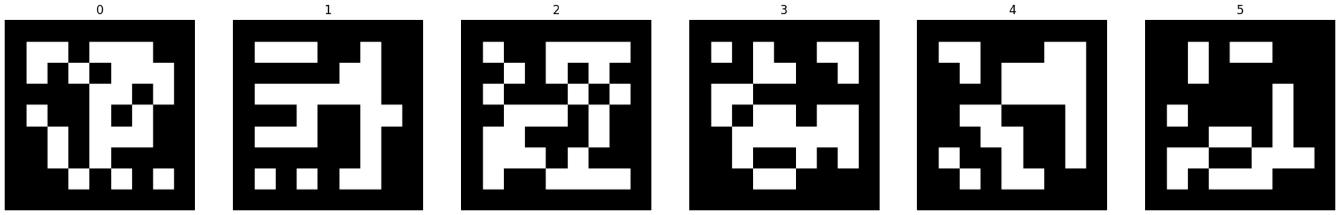
```
import cv2
import cv2.aruco as aruco
import matplotlib.pyplot as plt
arucoDict    = aruco.getPredefinedDictionary(aruco.DICT_5X5_100)
plt.figure(figsize=(24,4))
for i in range(6):
    plt.subplot(1,6,i+1)
    plt.title(i)
    marker_image = aruco.drawMarker(arucoDict,i,200)
    plt.imshow(marker_image,cmap='gray')
    plt.axis(False)
plt.show()
```



下面範例產生ArUco marker影像，其中DICT_7X7_50表示Marker為7X7的黑白Bit-pattern，一共可有50個，編號0-49號。

In [2]:

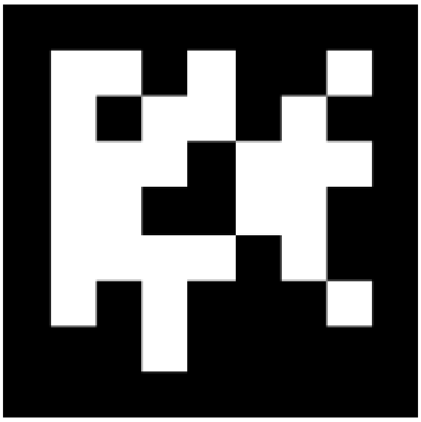
```
import cv2
import cv2.aruco as aruco
import matplotlib.pyplot as plt
arucoDict    = aruco.getPredefinedDictionary(aruco.DICT_7X7_50)

plt.figure(figsize=(24,4))
for i in range(0,6):
    plt.subplot(1,6,1+i)
    plt.title(i)
    marker_image = aruco.drawMarker(arucoDict,i,200)
    plt.imshow(marker_image,cmap='gray')
    plt.axis(False)
plt.show()
```



到這裡或是用下面程式，產生特定尺寸(6cmX6cm)的ArUco Marker。

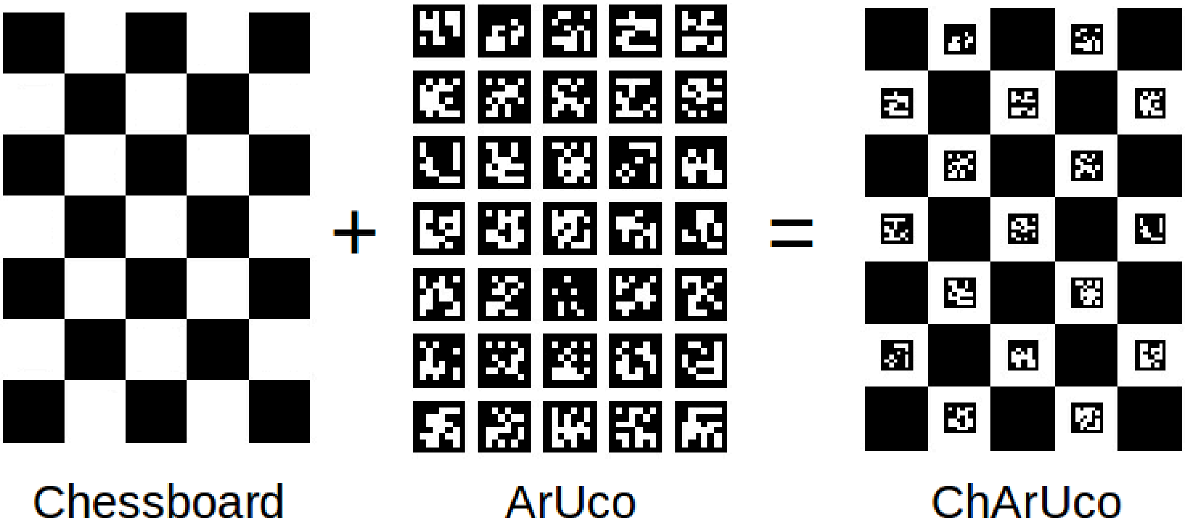
In [3]:

```
import cv2
import cv2.aruco as aruco
import matplotlib.pyplot as plt
arucoDict      = aruco.getPredefinedDictionary(aruco.DICT_7X7_50)
markerSize     = 6 # cm
markerId       = 6
plt.figure(figsize=(markerSize/2.54,markerSize/2.54))
marker_image = aruco.drawMarker(arucoDict,markerId,200)
plt.grid(False)
plt.axis(False)
plt.tight_layout()
plt.imshow(marker_image,cmap='gray')
plt.savefig('aruco_marker.svg')
plt.show()
```



產生ChArUco Marker

什麼是ChArUco board?詳細說明看這裡?



In [4]:

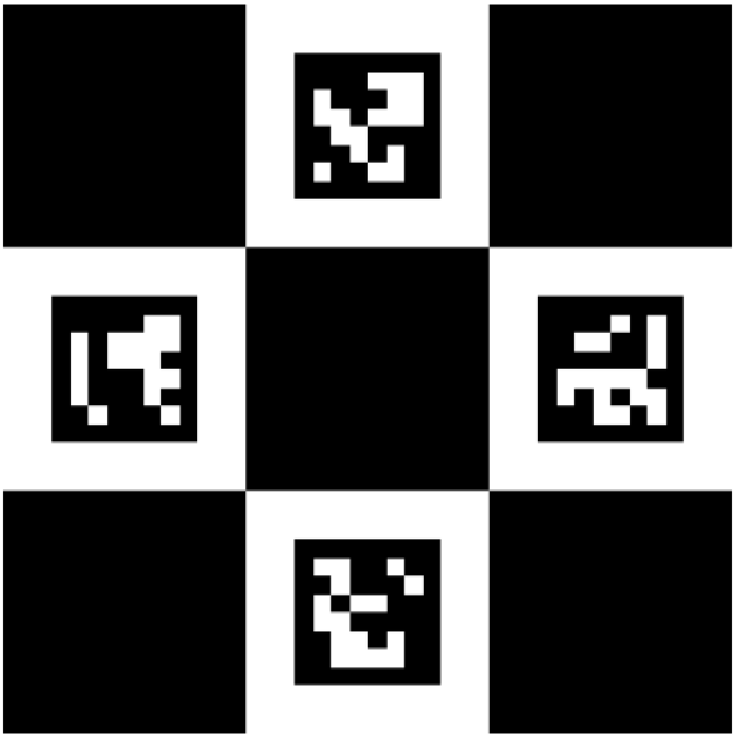
```
help(aruco.CharucoBoard_create)
```

```
Help on built-in function CharucoBoard_create:

CharucoBoard_create(...)
    CharucoBoard_create(squaresX, squaresY, squareLength, markerLength, dictionary) -> retval
    .   * @brief Create a CharucoBoard object
    .        *
    .        * @param squaresX number of chessboard squares in X direction
    .        * @param squaresY number of chessboard squares in Y direction
    .        * @param squareLength chessboard square side length (normally in meters)
    .        * @param markerLength marker side length (same unit than squareLength)
    .        * @param dictionary dictionary of markers indicating the type of markers.
    .        * The first markers in the dictionary are used to fill the white chessboard squa
res.
    .        * @return the output CharucoBoard object
    .        *
    .        * This functions creates a CharucoBoard object given the number of squares in ea
ch direction
    .        * and the size of the markers and chessboard squares.
```

In [5]:

```
import numpy as np
arucoDict = aruco.getPredefinedDictionary(aruco.DICT_6X6_250)
```

```
arucoIds   = np.array([13,29,47,97])
squareLength= 200
markerLength= 120
markerSize  = 10 # cm
charucoBoard = aruco.CharucoBoard_create(3,3,squareLength,markerLength,arucoDict)
markerImage = charucoBoard.draw((3*100,3*100),0,0) # Square 100x100 pixels
#markerImage = aruco.drawCharucoDiamond(arucoDict,arucoIds,squareLength,markerLength)
plt.figure(figsize=(markerSize/2.54,markerSize/2.54))
plt.axis(False)
plt.grid(False)
plt.tight_layout()
plt.imshow(markerImage,cmap='gray')
plt.savefig('ChArUco_marker.svg')
plt.show()
```

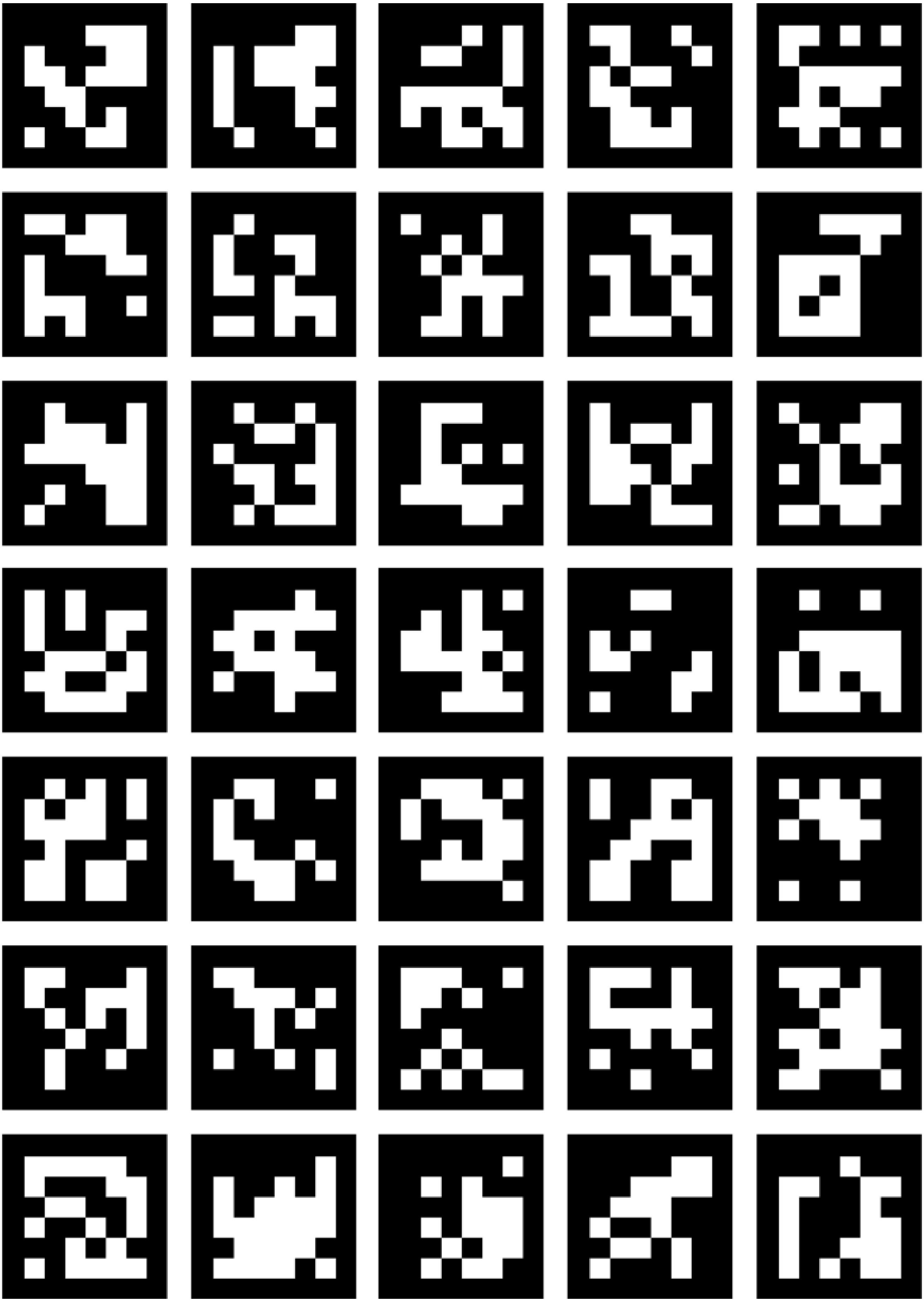


使用ChArUco或ArUco Marker做相機校正

產生ArUco Board。

In [6]:

```
import numpy as np
arucoDict     = aruco.Dictionary_get(aruco.DICT_6X6_250)
gridX         = 5
gridY         = 7
markerSize    = 3.5 #cm
markerGap     = 0.5 #cm
arucoBoard    = aruco.GridBoard_create(gridX,gridY,markerSize,markerGap,arucoDict) # marker:3..
boardImage    = arucoBoard.draw((gridX*100,gridY*100),0,0) #5*100,7*100
boardHeight   = gridY*markerSize+(gridY+1)*markerGap #cm
boardWidth    = gridX*markerSize+(gridX+1)*markerGap
plt.figure(figsize=(boardWidth/2.54,boardHeight/2.54))
plt.grid(False)
plt.axis(False)
plt.tight_layout()
plt.imshow(boardImage,cmap='gray')
plt.savefig('ArUco_board.svg')
plt.show()
```



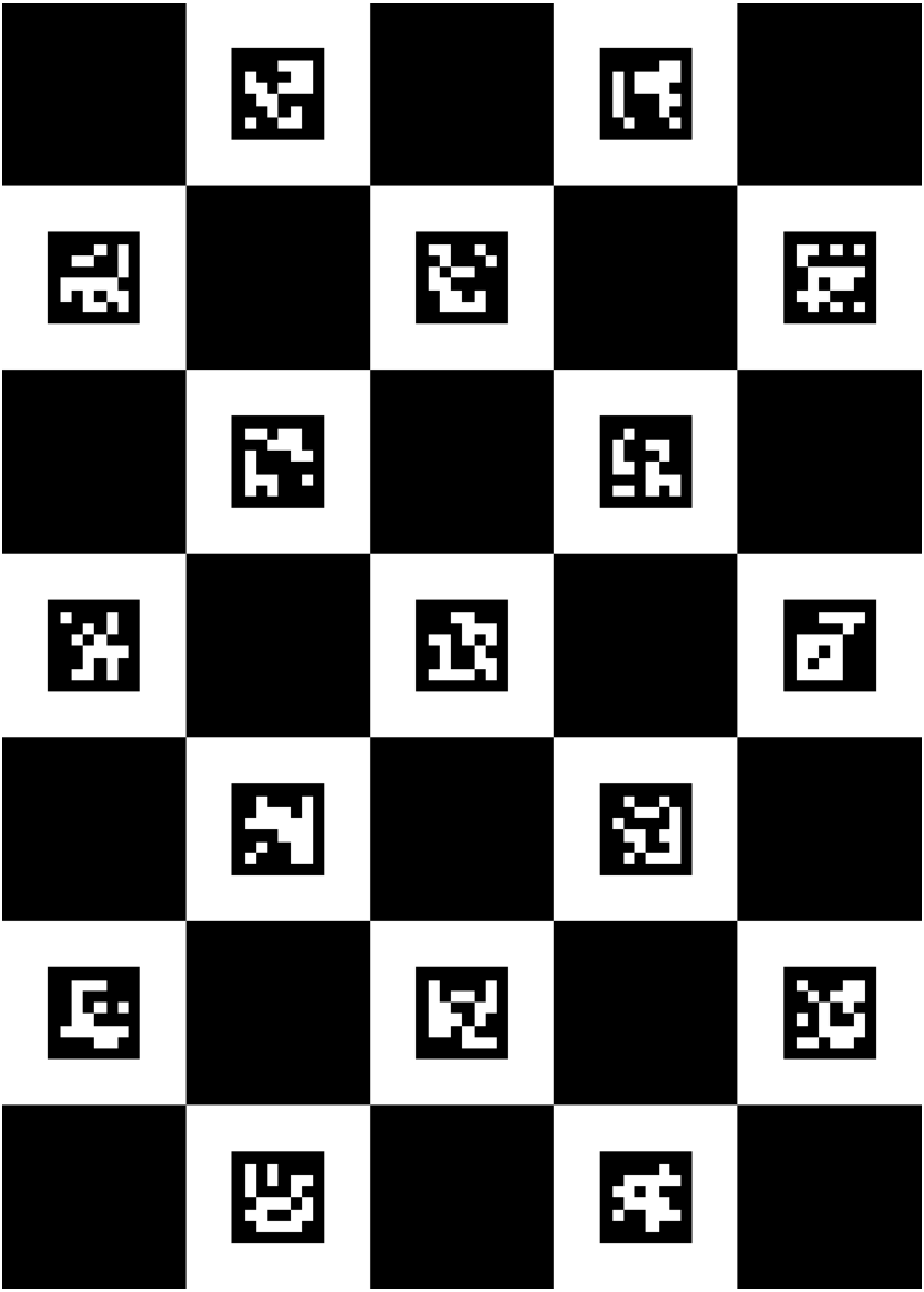
產生ChArUco Board。

根據官方說明，偵測ChArUco board比較準。

In [7]:

```
import numpy as np
arucoDict     = aruco.Dictionary_get(aruco.DICT_6X6_250)
gridX         = 5
gridY         = 7
```

```
squareSize   = 4 #cm
charucoBoard = aruco.CharucoBoard_create(gridX,gridY,squareSize,squareSize/2,arucoDict)
boardImage   = charucoBoard.draw((gridX*100,gridY*100),0,0) # Square 100x100 pixels
plt.figure(figsize=(gridX*squareSize/2.54,gridY*squareSize/2.54)) #Board 5*4cm X 7*4cm
plt.grid(False)
plt.axis(False)
plt.tight_layout()
plt.imshow(boardImage,cmap='gray')
plt.savefig('ChArUco_board.svg')
plt.show()
```



偵測ArUco Marker

使用前先準備有關aruco影像處理與marker編碼的參數。有必要，可以調整影像處理的參數arucoParams:

```
arucoParams = aruco.DetectorParameters_create()
arucoDict   = aruco.Dictionary_get(aruco.DICT_7X7_50)
```

然後呼叫偵測aruco marker函式:

```
    (corners, ids, rejected) = aruco.detectMarkers(frame, arucoDict,
parameters=arucoParams)
```

若要顯示偵測結果，可以呼叫drawDetectedMarkers

```
    aruco.drawDetectedMarkers(frame, corners, ids))
```

corners依照順時針排，但是沒說哪一個角是第一個點。

In [8]:

```
import cv2
import cv2.aruco as aruco

cap = cv2.VideoCapture('arUco_marker.mp4')
#原始畫面有點大，為了有利於顯示這份講義所以縮小。
frameWidth   = int(cap.get(cv2.CAP_PROP_FRAME_WIDTH))//2
frameHeight  = int(cap.get(cv2.CAP_PROP_FRAME_HEIGHT))//2

arucoParams = aruco.DetectorParameters_create()
arucoDict   = aruco.Dictionary_get(aruco.DICT_7X7_50)

print('height {}, width {}'.format(cap.get(cv2.CAP_PROP_FRAME_HEIGHT),cap.get(cv2.CAP_PROP_FR

while True:
    ret, frame = cap.read()
    if not ret:
        break

    frame = cv2.resize(frame,(frameWidth,frameHeight))
    (corners, ids, rejected) = aruco.detectMarkers(frame, arucoDict, parameters=arucoParams)
    if len(corners) > 0:
        aruco.drawDetectedMarkers(frame, corners, ids)

    cv2.imshow('arUco marker',frame)
    if cv2.waitKey(20) != -1:
        break

cv2.destroyAllWindows()
cap.release()
```

```
height 1080.0, width 1920.0
```

使用未校正相機估計ChArUco Board姿態

相機內部參數用猜的。

In [9]:

```
dir(aruco)
```

```
Out[9]: ['Board',
         'Board_create',
         'CCW_CENTER',
         'CCW_center',
         'CORNER_REFINE_APRILTAG',
         'CORNER_REFINE_CONTOUR',
         'CORNER_REFINE_NONE',
         'CORNER_REFINE_SUBPIX',
         'CW_TOP_LEFT_CORNER',
         'CW_top_left_corner',
         'CharucoBoard',
         'CharucoBoard_create',
         'DICT_4X4_100',
         'DICT_4X4_1000',
         'DICT_4X4_250',
         'DICT_4X4_50',
         'DICT_5X5_100',
         'DICT_5X5_1000',
         'DICT_5X5_250',
         'DICT_5X5_50',
         'DICT_6X6_100',
         'DICT_6X6_1000',
         'DICT_6X6_250',
         'DICT_6X6_50',
         'DICT_7X7_100',
         'DICT_7X7_1000',
         'DICT_7X7_250',
         'DICT_7X7_50',
         'DICT_APRILTAG_16H5',
         'DICT_APRILTAG_16h5',
         'DICT_APRILTAG_25H9',
         'DICT_APRILTAG_25h9',
         'DICT_APRILTAG_36H10',
         'DICT_APRILTAG_36H11',
         'DICT_APRILTAG_36h10',
         'DICT_APRILTAG_36h11',
         'DICT_ARUCO_ORIGINAL',
         'DetectorParameters',
         'DetectorParameters_create',
         'Dictionary',
         'Dictionary_create',
         'Dictionary_create_from',
         'Dictionary_get',
         'Dictionary_getBitsFromByteList',
         'Dictionary_getByteListFromBits',
         'EstimateParameters',
         'EstimateParameters_create',
         'GridBoard',
         'GridBoard_create',
         '__doc__',
         '__loader__',
         '__name__',
         '__package__',
         '__spec__',
         'calibrateCameraAruco',
         'calibrateCameraArucoExtended',
         'calibrateCameraCharuco',
         'calibrateCameraCharucoExtended',
         'custom_dictionary',
         'custom_dictionary_from',
         'detectCharucoDiamond',
         'detectMarkers',
         'drawCharucoDiamond',
         'drawDetectedCornersCharuco',
         'drawDetectedDiamonds',
         'drawDetectedMarkers',
         'drawMarker',
         'drawPlanarBoard',
         'estimatePoseBoard',
         'estimatePoseCharucoBoard',
         'estimatePoseSingleMarkers',
         'getBoardObjectAndImagePoints',
         'getPredefinedDictionary',
         'interpolateCornersCharuco',
         'refineDetectedMarkers',
         'testCharucoCornersCollinear']
```

In [10]:

```python
import cv2
import cv2.aruco as aruco

cap = cv2.VideoCapture('CharUco_board.mp4')
print('height {}, width {}'.format(cap.get(cv2.CAP_PROP_FRAME_HEIGHT),cap.get(cv2.CAP_PROP_FR
#原始畫面有點大，為了有利於顯示這份講義所以縮小。
totalFrame   = int(cap.get(cv2.CAP_PROP_FRAME_COUNT))
frameWidth   = int(cap.get(cv2.CAP_PROP_FRAME_WIDTH))//2
frameHeight  = int(cap.get(cv2.CAP_PROP_FRAME_HEIGHT))//2

arucoParams  = aruco.DetectorParameters_create()
arucoParams.cornerRefinementMethod = aruco.CORNER_REFINE_SUBPIX
arucoDict    = aruco.Dictionary_get(aruco.DICT_6X6_250)
gridX        = 5
gridY        = 7
squareSize   = 4 #cm
charucoBoard = aruco.CharucoBoard_create(gridX,gridY,squareSize,squareSize/2,arucoDict)
cameraMatrixInit = np.array([[ frameWidth/2.,    0., frameWidth/2.],[    0., frameWidth/2., f
distCoeffsInit   = np.zeros((5,1))

while True:
    ret, frame = cap.read()
    if not ret:
        break

    frame = cv2.resize(frame,(frameWidth,frameHeight))
    (corners, ids, rejected) = aruco.detectMarkers(frame, arucoDict, parameters=arucoParams)

    if ids is not None and len(ids)>0:
        aruco.drawDetectedMarkers(frame, corners, ids)
        ret, rvect, tvect = aruco.estimatePoseBoard(corners, ids, charucoBoard, cameraMatrixI
#          if ret:
#              aruco.drawAxis(frame, cameraMatrixInit, distCoeffsInit, rvect, tvect, squareSiz

    cv2.imshow('Estimation of the pose of a ChArUco board with inarrurate intrinic camera para
    if cv2.waitKey(20) != -1:
        break

cv2.destroyAllWindows()
cap.release()
```

```
height 1080.0, width 1920.0
```

使用ChArUco Board做相機校正

In [11]:

```python
import cv2
import cv2.aruco as aruco

cap = cv2.VideoCapture('CharUco_board.mp4')
#原始畫面有點大，為了有利於顯示這份講義所以縮小。
totalFrame   = int(cap.get(cv2.CAP_PROP_FRAME_COUNT))
frameWidth   = int(cap.get(cv2.CAP_PROP_FRAME_WIDTH))//2
frameHeight  = int(cap.get(cv2.CAP_PROP_FRAME_HEIGHT))//2
```

```
arucoParams  = aruco.DetectorParameters_create()
arucoParams.cornerRefinementMethod = aruco.CORNER_REFINE_SUBPIX

arucoDict    = aruco.Dictionary_get(aruco.DICT_6X6_250)

# 必須描述ChArUco board的尺寸規格
gridX        = 5 # 水平方向5格
gridY        = 7 # 垂直方向7格
squareSize   = 4 # 每格為4cmX4cm
# ArUco marker為2cmX2cm
charucoBoard = aruco.CharucoBoard_create(gridX,gridY,squareSize,squareSize/2,arucoDict)

print('height {}, width {}'.format(cap.get(cv2.CAP_PROP_FRAME_HEIGHT),cap.get(cv2.CAP_PROP_FR
refinedStrategy = True
criteria        = (cv2.TERM_CRITERIA_EPS + cv2.TERM_CRITERIA_MAX_ITER, 100, 0.00001)
frameId        = 0
collectCorners = []
collectIds     = []
collectFrames  = []
while True:
    ret, frame = cap.read()
    if not ret:
        break

    frame = cv2.resize(frame,(frameWidth,frameHeight))
    (corners, ids, rejected) = aruco.detectMarkers(frame, arucoDict, parameters=arucoParams)

    if refinedStrategy:
        corners, ids, _, _ = aruco.refineDetectedMarkers(frame,charucoBoard,corners,ids,rejec

    if frameId % 100 == 50 and ids is not None and len(ids)==17: # 17 ArUco markers
        collectCorners.append(corners)
        collectIds.append(ids.ravel())
        collectFrames.append(frame)

    if len(corners) > 0:
        aruco.drawDetectedMarkers(frame, corners, ids)

    cv2.imshow('Analysis of a CharUco board for camera calibration',frame)
    if cv2.waitKey(20) != -1:
        break

    frameId += 1

cv2.destroyAllWindows()
cap.release()
```

```
height 1080.0, width 1920.0
```

先使用calibrateCameraAruco

In [12]:

```
caliCorners=np.concatenate([np.array(x).reshape(-1,4,2) for x in collectCorners],axis=0)
counter=np.array([len(x) for x in collectIds])
caliIds=np.array(collectIds).ravel()
cameraMatrixInit = np.array([[ 1000.,    0., frameWidth/2.],[    0., 1000., frameHeight/2.],[
distCoeffsInit   = np.zeros((5,1))
ret, aruco_cameraMatrix, aruco_distCoeffs, aruco_rvects, aruco_tvects = aruco.calibrateCamera
print(aruco_cameraMatrix)
print(aruco_distCoeffs)
# print(aruco_rvects)
# print(aruco_tvects)
```

```
[[913.8106975    0.         479.55867775]
 [  0.         921.09144892 293.00946535]
 [  0.           0.           1.        ]]
[[ 0.06739157]
 [-0.11176168]
 [-0.00446193]
 [-0.00266387]
 [-0.01974242]]
```

接續使用calibriateCameraChAruco

In [13]:

```
caliCorners=[]
caliIds    =[]
for corners, ids, frame in zip(collectCorners,collectIds,collectFrames):
    ret, charucoCorners, charucoIds = aruco.interpolateCornersCharuco(corners,ids,frame,charu
    caliCorners.append(charucoCorners)
    caliIds.append(charucoIds)

ret, charuco_cameraMatrix, charuco_distCoeffs, charuco_rvects, charuco_tvects = aruco.calibra
print(charuco_cameraMatrix)
print(charuco_distCoeffs)
# print(charuco_rvects)
# print(charuco_tvects)
```

```
[[888.25445081   0.         482.34262729]
 [  0.         896.25259096 305.57037135]
 [  0.           0.           1.        ]]
[[ 0.08518852]
 [-0.41241413]
 [-0.0023548 ]
 [-0.00228344]
 [ 1.08101268]]
```

使用校正的相機估計ChArUco Board姿態

In [14]:

```
import cv2
import cv2.aruco as aruco

cap = cv2.VideoCapture('CharUco_board.mp4')
print('height {}, width {}'.format(cap.get(cv2.CAP_PROP_FRAME_HEIGHT),cap.get(cv2.CAP_PROP_FR

#原始畫面有點大，為了有利於顯示這份講義所以縮小。
totalFrame   = int(cap.get(cv2.CAP_PROP_FRAME_COUNT))
frameWidth   = int(cap.get(cv2.CAP_PROP_FRAME_WIDTH))//2
frameHeight  = int(cap.get(cv2.CAP_PROP_FRAME_HEIGHT))//2

arucoParams  = aruco.DetectorParameters_create()
arucoParams.cornerRefinementMethod = aruco.CORNER_REFINE_SUBPIX
arucoDict    = aruco.Dictionary_get(aruco.DICT_6X6_250)
gridX        = 5
gridY        = 7
squareSize   = 4 #cm
charucoBoard = aruco.CharucoBoard_create(gridX,gridY,squareSize,squareSize/2,arucoDict)

while True:
    ret, frame = cap.read()
    if not ret:
        break

    frame = cv2.resize(frame,(frameWidth,frameHeight))
    (corners, ids, rejected) = aruco.detectMarkers(frame, arucoDict, parameters=arucoParams)

    if ids is not None and len(ids)>0:
        aruco.drawDetectedMarkers(frame, corners, ids)
        ret, rvect, tvect = aruco.estimatePoseBoard(corners, ids, charucoBoard, charuco_camer
#         if ret:
#             aruco.drawAxis(frame, charuco_cameraMatrix, charuco_distCoeffs, rvect, tvect, sc

    cv2.imshow('Estimation of the pose of a CharUco board with intrinsic camera parameters',f
    if cv2.waitKey(20) != -1:
        break

cv2.destroyAllWindows()
cap.release()
```

```
height 1080.0, width 1920.0
```

估計Marker姿態

In [15]:

```
import cv2
import cv2.aruco as aruco

cap = cv2.VideoCapture('arUco_marker.mp4')
markerSize  = 6 #6cm

#原始畫面有點大，為了有利於顯示這份講義所以縮小。
frameWidth   = int(cap.get(cv2.CAP_PROP_FRAME_WIDTH))//2
frameHeight  = int(cap.get(cv2.CAP_PROP_FRAME_HEIGHT))//2

arucoParams = aruco.DetectorParameters_create()
arucoParams.cornerRefinementMethod = aruco.CORNER_REFINE_SUBPIX
arucoDict   = aruco.Dictionary_get(aruco.DICT_7X7_50)

print('height {}, width {}'.format(cap.get(cv2.CAP_PROP_FRAME_HEIGHT),cap.get(cv2.CAP_PROP_FR

while True:
    ret, frame = cap.read()
    if not ret:
        break

    frame = cv2.resize(frame,(frameWidth,frameHeight))
    (corners, ids, rejected) = aruco.detectMarkers(frame, arucoDict, parameters=arucoParams)
    if len(corners) > 0:
        aruco.drawDetectedMarkers(frame, corners, ids)
        rvects, tvects, _ = aruco.estimatePoseSingleMarkers(corners, markerSize, charuco_came
#         for rvec,tvec in zip(rvects,tvects):
#             aruco.drawAxis(frame, charuco_cameraMatrix, charuco_distCoeffs, rvec, tvec, mar

    cv2.imshow('Estimation of the pose of arUco marker with intrinsic camera parameters',fram
    if cv2.waitKey(20) != -1:
        break

cv2.destroyAllWindows()
cap.release()
```

```
height 1080.0, width 1920.0
```

世界座標系統⇒影像座標系統

將Marker的4角點透過projectPoints計算其影像座標。

In [16]:

```
import cv2
import cv2.aruco as aruco

cap = cv2.VideoCapture('arUco_marker.mp4')
markerSize  = 6 #6cm

#原始畫面有點大，為了有利於顯示這份講義所以縮小。
```

```
frameWidth   = int(cap.get(cv2.CAP_PROP_FRAME_WIDTH))//2
frameHeight  = int(cap.get(cv2.CAP_PROP_FRAME_HEIGHT))//2

arucoParams = aruco.DetectorParameters_create()
arucoParams.cornerRefinementMethod = aruco.CORNER_REFINE_SUBPIX
arucoDict   = aruco.Dictionary_get(aruco.DICT_7X7_50)

print('height {}, width {}'.format(cap.get(cv2.CAP_PROP_FRAME_HEIGHT),cap.get(cv2.CAP_PROP_FRA
markerCorners3D = np.array([[3,3,0],[-3,3,0],[-3,-3,0],[3,-3,0]],dtype=float)
while True:
    ret, frame = cap.read()
    if not ret:
        break

    frame = cv2.resize(frame,(frameWidth,frameHeight))
    (corners, ids, rejected) = aruco.detectMarkers(frame, arucoDict, parameters=arucoParams)
    if len(corners) > 0:
        aruco.drawDetectedMarkers(frame, corners, ids)
        for corner in corners:
            for pt in corner[0]:
                cv2.drawMarker(frame,tuple(pt.astype(int).ravel()),(0,0,255),cv2.MARKER_CROSS

        rvects, tvects, _ = aruco.estimatePoseSingleMarkers(corners, markerSize, charuco_came


        for rvec,tvec in zip(rvects,tvects):
            proj_pt_with_dist,_ = cv2.projectPoints(markerCorners3D, rvec, tvec, charuco_came
#             aruco.drawAxis(frame, charuco_cameraMatrix, charuco_distCoeffs, rvec, tvec, mar
            for pt in proj_pt_with_dist:
                cv2.drawMarker(frame,tuple(pt.astype(int).ravel()),(0,255,0),cv2.MARKER_CROSS

    cv2.imshow('Estimation of the pose of arUco marker with intrinsic camera parameters',fram
    if cv2.waitKey(20) != -1:
        break

cv2.destroyAllWindows()
cap.release()
```

```
height 1080.0, width 1920.0
```

In [ ]: