VuMark Design Guide

Version: 7/27/2016

1 OVERVIEW

A VuMark is a new kind of Vuforia target that can be customized to closely reflect a company's brand identity.

It can both store encoded data as well as initialize an AR experience. One example of VuMark usage is for enterprises: by affixing VuMarks to their manufactured equipment, enterprises can both identify the piece of equipment and overlay augmentation that indicates how to use it.

This document will help you create your own VuMark design. It provides guidelines to help you design a VuMark that conforms to the requirements for making a functional VuMark that will perform well.

Figure 1 - Example VuMarks

2 THE PARTS OF A VUMARK

VuMarks have five major parts that you will need to understand when designing your own.

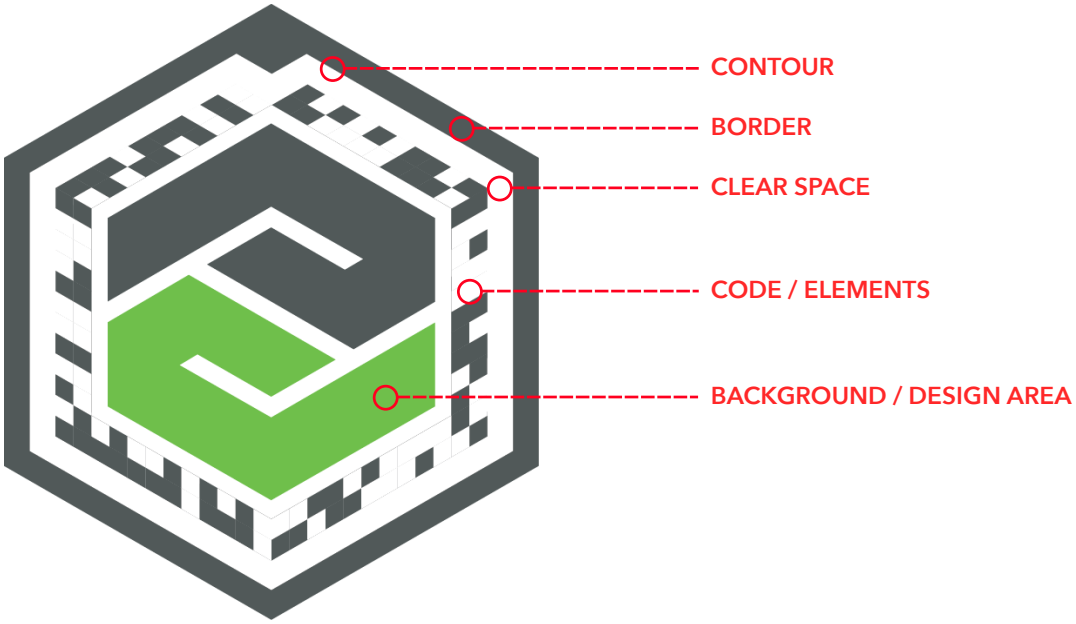


Figure 2 - VuMark Parts

2.1 Contour

The Contour is what the Vuforia computer vision algorithm first detects. After finding the contour, the algorithm looks for the code and “reads” it to identify the value or “ID” that is encoded within the VuMark.

The Contour is not explicitly drawn or visible in a VuMark design. Rather, the Contour is the line that appears where two other parts of the VuMark meet – the Border and the Clear Space. Essentially the Contour is defined by the contrast between the two different colors of the Border and Clear Space.

2.2 Border

The Border is typically the most identifiable and defining shape within the VuMark. In FIGURE 2, the Border is the outermost shape made of six straight lines forming a hexagon.

2.3 Clear Space

The Clear Space is the mandatory blank area that appears adjacent to the border along its entire length. The Clear Space can be either inside or outside of the border and is required in order to guarantee there is enough contrast for the algorithm to detect the Contour.

2.4 Code / Elements

Every individual VuMark contains a unique Code, which is a visual representation of the ID encoded in the VuMark.

The Code consists of Elements and the type of data and length of the value/ID that is encoded determine the number of Elements. The larger the value length, the larger number of elements that are required.

Every Element has 2 states: a “Dark” and “Bright” state. A unique code is generated by setting some of the elements in the Dark vs. Bright state (roughly 50% of Elements in each state).

2.5 Background / Design Area

The Background or Design Area is a layer where you can put any parts of the VuMark that are not used for detection. There is a lot of freedom in designing and placing the Background. We recommend to add graphically rich background if you plan to use VuMark for tracking as well.

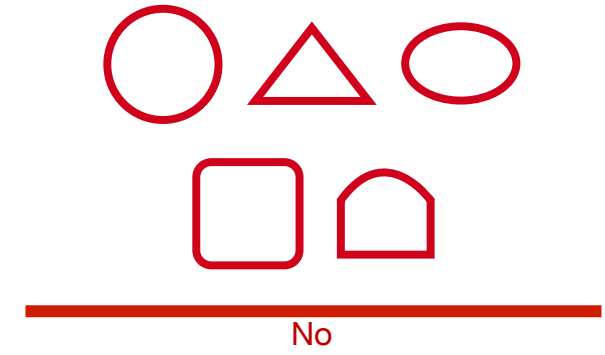
3 DESIGN REQUIREMENTS

This section will help you design a VuMark that performs well in a variety of conditions. To do that you'll need to take into account the following considerations and requirements.

3.1 Contour

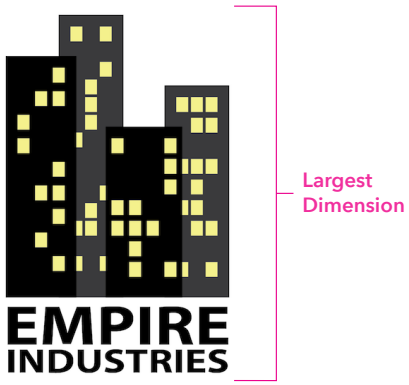
The Contour is a part of the VuMark that is implied by the line created when placing the Border and the Clear Space next to each other.

- The Contour must consist of straight lines that form a closed path.
- The Contour must have at least 4 sides, and a maximum of 20 sides.
- The Contour shall ideally not be rotational symmetric (as shown in lower row). If you decide to do, additional steps are necessary during design.

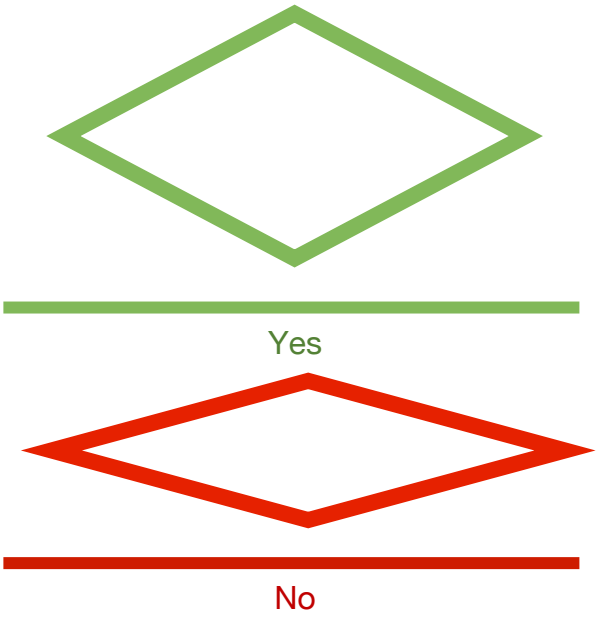


ILLUSTRATOR TIP: Create the Contour directly on the "VuMark-Contour" layer using Illustrator's "Pen Tool", by manually rendering the underlying contrast border between the Border and the Clear Space anchor-by-anchor.

- The length of smallest side of the Contour must be at least 10% of the length of the largest dimension of the overall VuMark.
    - The largest dimension is the larger of either the height or width.
    - The overall size of a VuMark will comprise all parts of the VuMark, including the Background.



- Maximum angle limit between contour segments is 150°. If you have designs where the angle is bigger, the VuMark may not work. Make sure to create less flat corners. Example ('No' example has top and bottom corner with very flat angles):

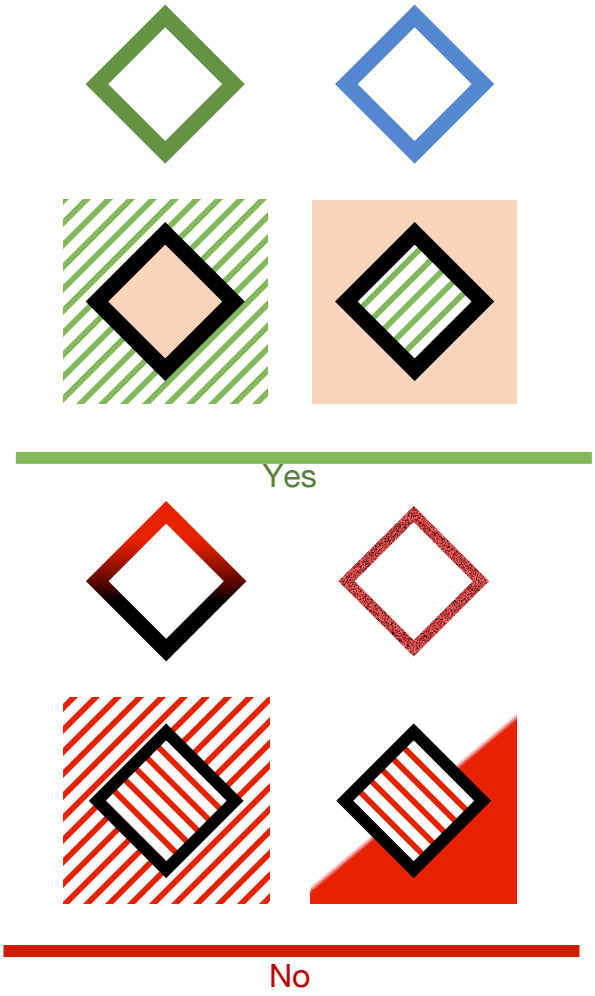


3.2 Border & Clear Space

The Border and Clear Space share the same design requirements. These requirements guarantee that the Contour becomes a good quality contrast edge.

- The width of the Border & Clear Space must be at least 5% of the length of the largest dimension of the overall VuMark.

- The Border and Clear Space must be filled with a solid/uniform color; they can't be transparent or set to 'No fill, and can't have a gradient or pattern fill.
- Make sure these elements don't use Appearance Attributes.



- There must be high contrast between the colors of the Border & Clear.

  To ensure that there is enough contrast between the colors used for the Border and Clear Space, you should convert those colors to grayscale, and then inspect the "K" value of each color. There should be a "K" value difference of at least 30-40%, but more is better.

  ILLUSTRATOR TIP: To find out the "K" value: Select an object, then from the Illustrator menu choose: Edit → Edit Colors → Convert to Grayscale. Then using the Color panel, check the "K" value (your color space must be set to CMYK).

- The Clear Space can be placed either inside or outside of the Border, so that the Contour is formed inside or outside of the Border.

3.2.1 Advanced Techniques

Only the edge of the Clear Space that faces the Border must consist of straight lines and meet the length requirements described above.

3.3 Code / Elements

Determining the number of elements that your VuMark design must accommodate is an important detail to figure out up front. Your choice of what type of data and the length of that data or "ID" will determine how many elements will be needed in your VuMark.

There are 3 types of data that can be encoded:

String – Use this if an ID will consist of printable ASCII characters[1].
Numeric – Use this if an ID will only use numeric digits 0 - 9.
Byte – Use this for data in byte format.

The section 'Using the Setup script' later in this document explains how to calculate the number of elements that your design must have based on your data type and ID length. Following design requirements apply to the Elements:

- Every Element must have a Bright and Dark state defined.
- An Element's Bright and Dark state are represented by different colors that have high contrast to each other. Ideally all Bright Elements have the same color, slight variation is acceptable. Same applies for Dark Elements.
- When placing the elements brighter elements must go on the "VuMark-BrightElements" layer.

  ILLUSTRATOR TIP: To ensure that there is enough contrast between the colors used for the Dark and Bright states, you should convert those colors to grayscale, and then inspect the "K" value of each color. There should be a "K" value difference of at least 30-40%, but more is better.

- The Bright and Dark states of any element must be in the exact same position (perfectly overlapping).

- An Element's size (both the height and width) must be at least 3% of the length of the largest dimension of the overall VuMark.

- Each Element can be a unique size and shape provided the element meets the size requirement. Use filled paths or compound paths only. Strokes only will not work. Also don't use grouped or layered items as Elements. Don't use Appearance Attributes.

- Elements don't need to be adjacent – they can be scattered anywhere within the VuMark.

- Elements can overlap with the Background/Design Area. They cannot overlap the Border, Clear

[1] Printable ASCII characters: https://en.wikipedia.org/wiki/ASCII#ASCII_printable_characters

Space or other Elements.

- Elements can be placed inside or outside of the Border and Clear Space but the farthest Element must be no more than approximately 50% of the VuMark's width from the border.

3.3.1 Design Tip – Using 'Fake' Elements

Sometimes it can be challenging to design your VuMark such that it has the exact number of required Elements, but there is a technique to make this easier to accomplish.

This technique involves creating more than the required number of Elements, and designating some of them as "fake" elements. They are "fake" in that they look like real elements but are actually not included in the Bright or Dark Elements layers – instead they are placed in the Background layer. Since anything in the Background layer is ignored by the Vuforia algorithm, your VuMark design technically has the exact number of required elements that the algorithm expects.

For example: Your VuMark requires 122 Elements, but from a design perspective it is hard to arrange your Elements in an aesthetically pleasing way such that you have exactly 122 elements, but 128 elements fit nicely into your design. You would select any 6 elements that you want to be considered "fake" and move them to the Background layer.
In the example below, this particular VuMark only required 122 Elements in its design, but the element layout worked best with 128 Elements. You can see that 6 of the Elements have been set to look like "Dark" Elements but have actually been placed in the VuMark-Background layer where they will not technically be treated as real Elements.

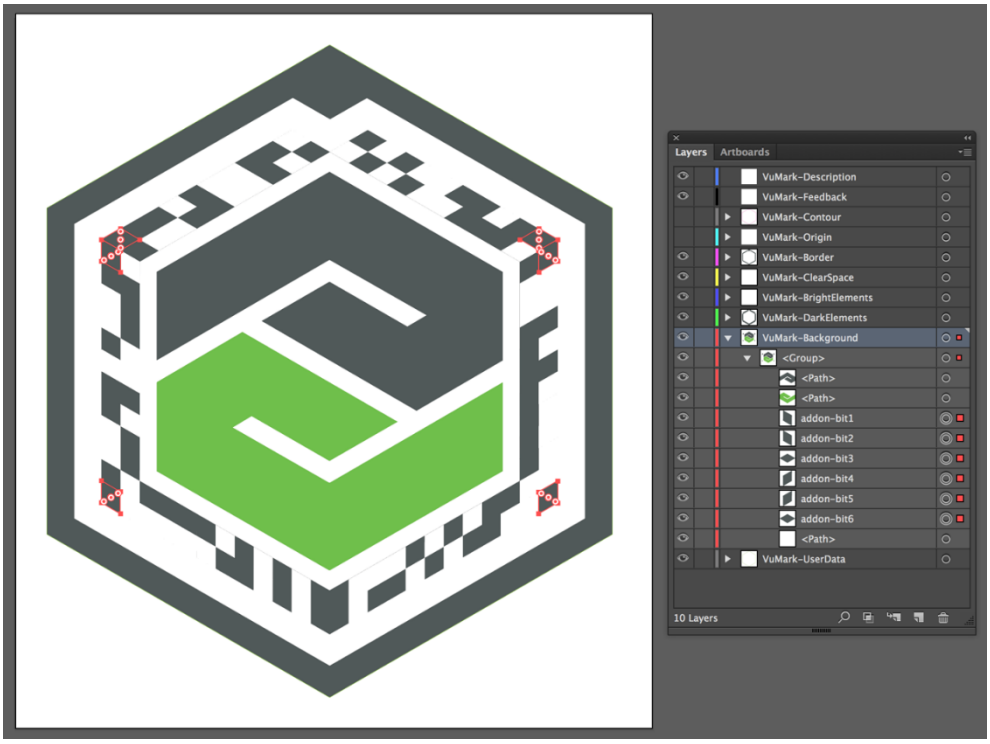


Figure 3 – Adding 'fake'-Elements to the design

3.4 Background / Design Area

Since the Background / Design Area is not used for detection, there aren't many requirements or limitations for what you place there. You have a lot of freedom to create a VuMark that expresses your brand or identity. Background can be empty; it's assumed to be white. Note that the background can influence the size of your VuMark which affects minimal size of Elements, and Border & Clear Space width requirements.

4 INSTALLATION OF VUMARK SCRIPTS IN ILLUSTRATOR

The recommended tool for designing VuMarks is Adobe Illustrator. There are three custom scripts for use with Illustrator that will help you create, verify and export your VuMark design.

4.1 Setup script

This script creates a new Illustrator file for your VuMark, which we refer to as the VuMark template. It automatically creates the layers that you will place various parts of your VuMark design into.

4.2 Verify script

This script helps you test your VuMark design by providing a list of design requirements, Pass/Fail results for each requirement and suggestions for resolving any issues that may have been found. You will typically run this script multiple times during the design process as you make changes to correct failed conditions.

4.3 Export script

Once your design has been run through the Verify script and is determined to be “ready for export”, this script will export your VuMark template as a Scalable Vector Graphics (SVG) file. You will upload this SVG file into the Vuforia Developer Portal Target Manager to create the dataset that will be used within your iOS, Android, Unity, or Windows 10 application.

4.4 Installing and using the Illustrator Scripts

Download the VuMark Illustrator scripts from the Vuforia Developer Portal.

4.4.1 Mac

Open the **/Applications/Adobe Illustrator CC 2015 folder/Presets/en_US/Scripts** folder and copy the VuMark folder containing all the scripts into it.

4.4.2 Windows

Open the **C:\Program Files\Adobe\Adobe Illustrator CC\Presets\en_US\Scripts** folder and VuMark folder containing all the scripts into it.

If you have Illustrator open, you must quit the application and re-open it to use the newly installed scripts.

You can now run the scripts from the Illustrator menu: **File > Scripts > VuMark**

5 CREATING A VUMARK IN ILLUSTRATOR

5.1 Using the Setup script

When you run the Setup script a dialog will appear that asks you to enter in a Name, Type and ID Length for your VuMark. The Type and ID Length fields are used to choose what type of data that you want to encode in your VuMark and this determines how many Elements that your VuMark template must have. Given these inputs, the script will configure your template accordingly.

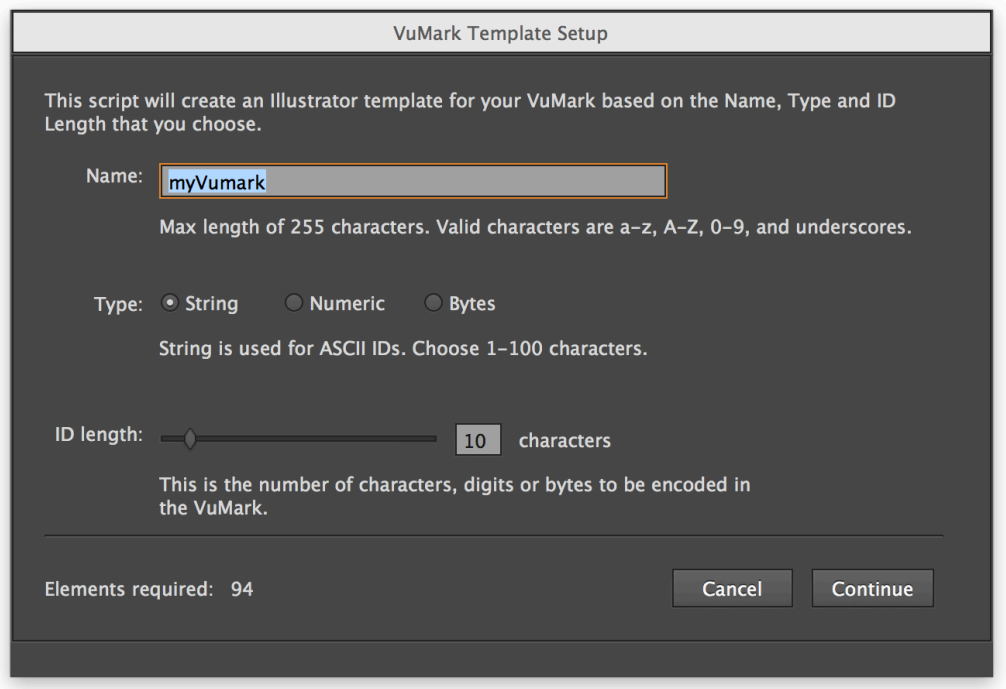


Figure 4 – VuMark Template Setup

Type		ID Length
String	Use this if an ID will consist of printable ASCII characters.	If you choose String type, ID Length is the number of characters that your value will have.
Numeric	Use this if an ID will only use numeric digits 0 - 9.	If you choose Numeric type, you have to enter the maximum numeric value that your VuMark will encode. For example, if you want a VuMark that supports numeric values from 0 to 20,000 you would enter '20,000' in the Maximum ID field.
Byte	Use this for data in a byte format.	If you choose Byte type, the ID Length is the number of bytes that your value will have.

5.2 Template Layers

After running the Setup script you will have a new Illustrator file containing the layers meant to hold the various parts of a VuMark, as well as several additional layers that are also used in the design process. During the design process you may change order of the layers, but make sure other layers don't hide Border and ClearSpace graphics. Also ensure Bright and Dark Elements are always visible in your design and not covered by other graphics.

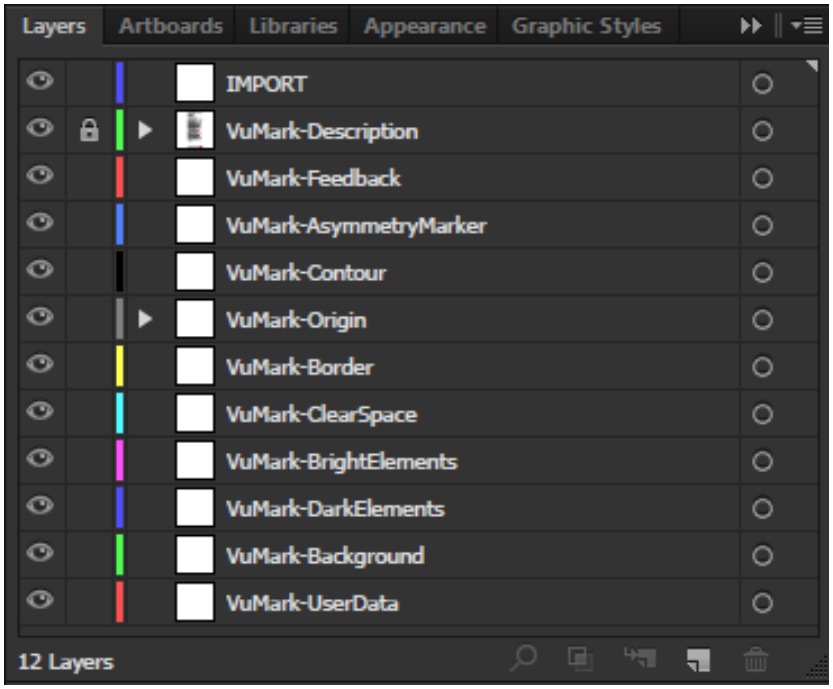


Figure 5 - VuMark Layer Setup

IMPORT

It is not required that you use this layer, but we have found it helpful to have a "work space" where you can paste your VuMark design. From this layer, you can begin separating the various parts of your VuMark design by moving them to the corresponding layers.

VuMark-Description

INFORMATIONAL, LOCKED – DO NOT ATTEMPT TO MODIFY THIS LAYER

This layer contains the details of your VuMark such as the Name, Type, Length and number of required Elements.

The Exporter script uses the information contained in this layer and that is why it is locked by default to prevent accidental deletion.

VuMark-Feedback

This layer is empty at first, but after you run the Verify script, it will be populated with feedback presented on top of your VuMark design to help you verify that it meets the design requirements.

VuMark-AsymmetryMarker

CAN BE EMPTY

When creating a rotational symmetric Contour, this layer can be used to add Assymetry Markers that prevent from accidental wrong ID readout. See section TODO on more details.

VuMark-Contour

This layer shall only contain one closed path with 4-20 straight edges. Once you have placed your Border and Clear Space parts into their corresponding layers, you must use the Pen tool in Illustrator to draw a

	closed path along the invisible “line” that is formed where these two parts touch. This path must be placed in the VuMark-Contour layer.
VuMark-Origin	This layer contains a circle shaped object that represents a point that will be considered the “origin” on your VuMark design. Augmentations that will appear registered to the VuMark relative to this point. Move them in your design to match required origin. Circle can be scaled.
VuMark-Border	This layer should only contain the object representing your VuMark’s Border.
VuMark-ClearSpace	This layer should only contain the object representing your VuMark’s Clear Space.
VuMark-BrightElements	This layer will contain the Elements in their Bright state. The number of objects placed in this layer must match the number of required Elements exactly. Make sure Elements are actually brighter than Dark state.
VuMark-DarkElements	This layer will contain the Elements in their Dark state. The number of objects placed in this layer must match the number of required Elements exactly. Make sure Elements are actually darker than Bright state.
VuMark-Background	CAN BE EMPTY Contains background design. Use rich background if you intend to track VuMark in Vuforia.

VuMark-UserData

CAN BE EMPTY

This layer can contain graphical elements for various purposes, e.g. UI overlays, printing marks, metadata, etc. The graphic placed in this layer will be exported as part of the VuMark template SVG file and provided with `VuMarkTemplate::getUserData()` method inside the SDK when the VuMark is loaded.

The VuMark native public sample shows an example of a detection highlight graphic displayed over the VuMark. The blue line is a path we added to the VuMark-UserData layer. Using this method you can build UI that is agnostic to the actual VuMark-shape.

5.3 Separating the parts of your VuMark

A common design workflow starts a conceptual phase where you experiment with various VuMark design concepts. Once you have chosen a design to move forward with, you can copy and paste it into the IMPORT layer of your newly created template. We have found it useful to place the design concept in the IMPORT layer and then start moving each part of the VuMark design into their corresponding layers in the Illustrator template.

5.4 Drawing the Contour

As described earlier, the Contour is normally not explicitly defined in your VuMark's design up to this point!

Now that you have placed the Border and Clear Space parts into their corresponding layers, you must use the Pen tool in Illustrator to draw a path along the length of the invisible "line" that is formed where these two parts touch. Make sure that this path is placed in the VuMark-Contour layer!

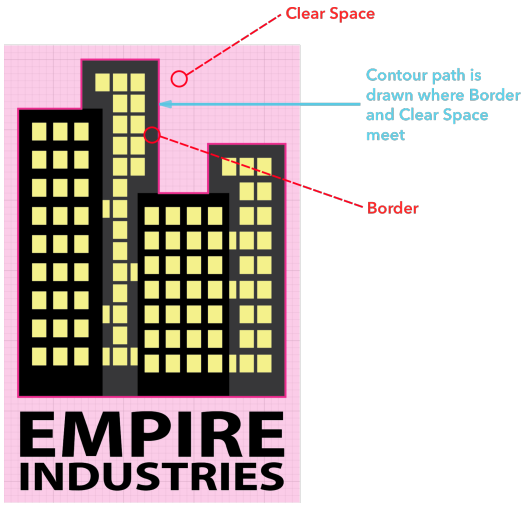


Figure 6 – Drawing the Contour path

NOTES:

- The Contour path will not be visible in real instances of your VuMark.
- The Clear Space in above example has been filled in pink to help show its boundaries – it is normally filled in white in this design.

It is helpful to give the path a 1-2 point stroke in a highly visible highlight color like Magenta or Cyan so that you can easily see where the Contour has been defined.

5.5 Using the Verify script

After you have assembled the parts of your VuMark into their respective layers, you are ready to test your VuMark design.
The Verify script will first check that your VuMark conforms to the design requirements and then provides feedback in the form of a Pass, Fail, or Verify status message in an artboard adjacent to your main artboard in Illustrator.

Feedback Artboard in Illustrator
After running the Setup script, you will have two artboards: your main design artboard, and a Feedback artboard adjacent to it.

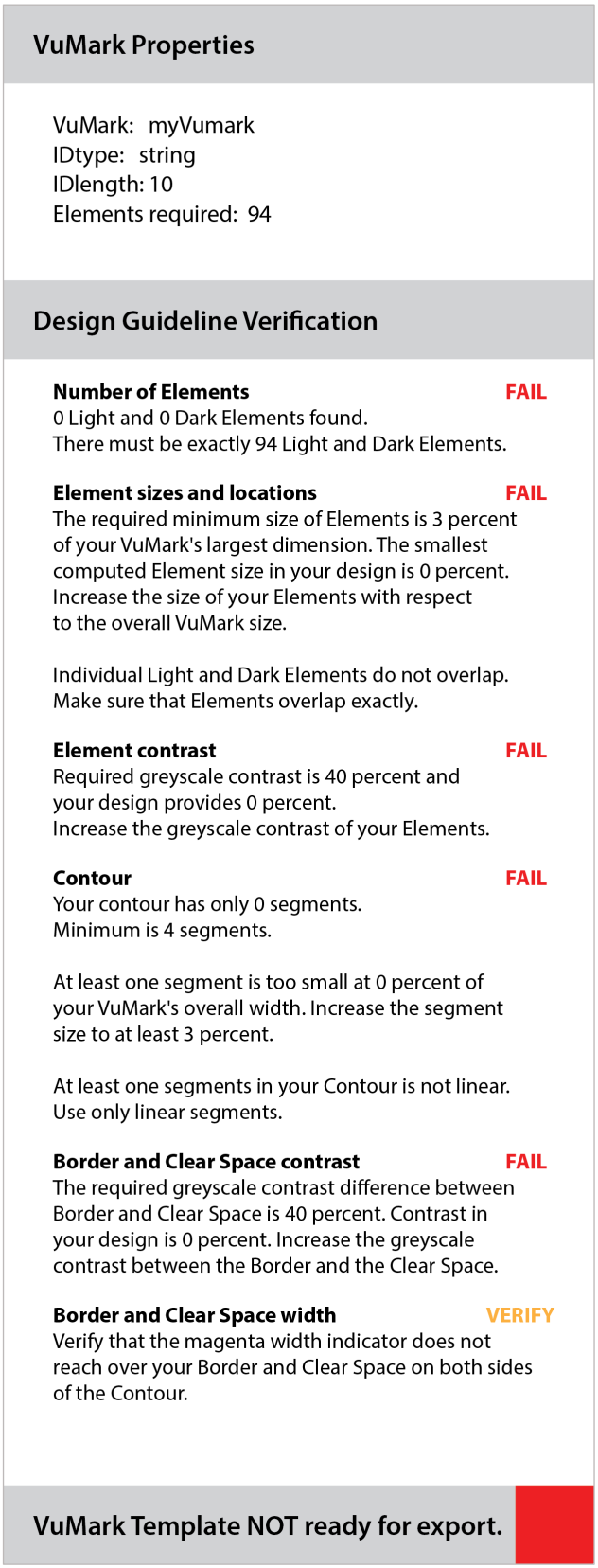
The Feedback artboard provides a quick summary of the VuMark properties you have chosen, as well as a checklist of what will be verified by the script.

Before you have run the Verify script, the Design Guideline Verification section of the Feedback artboard will show a “FAIL” status for each item. It is useful to refer back to these status messages since they provide a reminder of the key design requirements your VuMark must adhere to.

Once you run the Verify script, the Feedback artboard will update to display the latest verification results.

What the script verifies

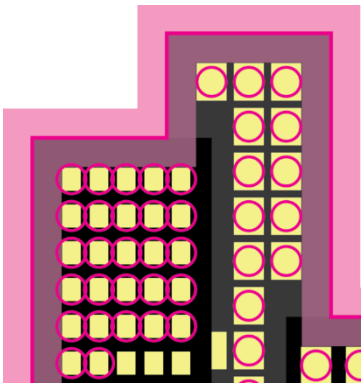
- Number of Elements
- Element sizes and locations
- Element contrast
- Contour segments
- Border and Clear Space contrast
- Border and Clear Space width
  (visual verification by user is required)



5.6 Understanding the Feedback layer overlays

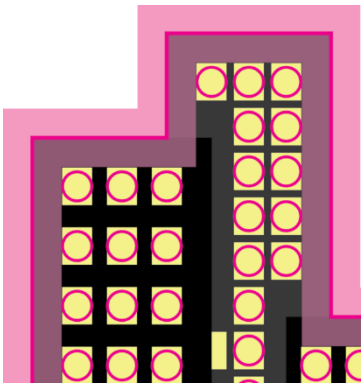
5.6.1 Element sizes

The Verify script provide a Pass/Fail result for Element sizes. It draws on the VuMark-Feedback layer magenta circles on top of every Element it finds. You should inspect the Elements in your design to make sure that they occupy or fill at least the same size and area as the circles. This visualization also helps to identify which Element cases the script to fail.



FAIL

- Some of the magenta circles touch or overlap with each other.
- The size of some of the Elements are smaller than the size of the magenta circles. Notice how some of the yellow “windows” in the design do not completely fill the area indicated by circles.
- Some of the magenta circles overlap the Border area.

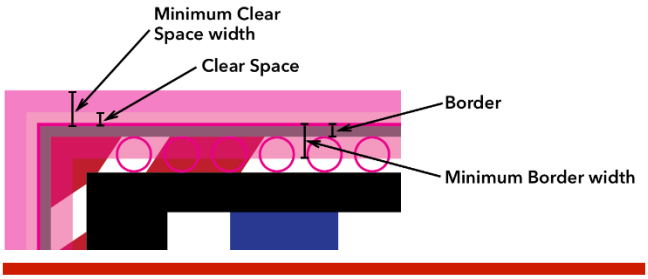


PASS

- All Elements are at least the same or larger size/area as the magenta circles.
- None of the magenta circles touch each other.
- The magenta circles don’t overlap the Border area.

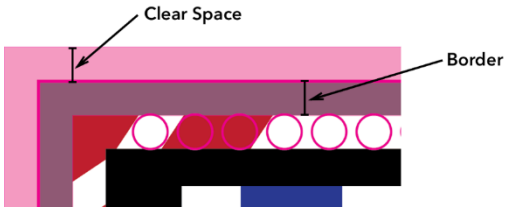
5.6.2 Border & Clear Space width

The Verify script doesn’t automatically provide a Pass/Fail result for the Border and Clear Space widths but the feedback layer will display overlays that indicate the required Border and Clear Space sizes on each side of the Contour. In the examples below you can see how a magenta fill is overlaid on each side of the Contour to indicate the minimum width required for the Border and Clear Space.



FAIL

- Border width is too small. Notice how the minimum Border width extends past the actual Border.
- Clear Space width is too small. Notice how the minimum Clear Space width extends past the actual Clear Space.



PASS

- Border is at least the same width as the minimum Border width indicated by the magenta overlay.
- Clear Space is at least the same width as the minimum Clear Space width indicated by the magenta overlay.

Both the Border and Clear Space must be filled paths or compound paths.

ILLUSTRATOR TIP: If you've designed your Border or Clear Space with a path that has a simple stroke width, you can use Illustrator's "Object->Expand…" or "Object->Expand Appearance" to convert it to a compound path.
Any "Appearance Attributes" that are assigned to your shapes, paths, or objects in your VuMark must be removed prior to exporting as an SVG.

ILLUSTRATOR TIP: You can use the Appearance Panel's menu option "Reduce to Basic Appearance" to remove the Appearance Attributes.

The VuMark-Border and VuMark-ClearSpace layers should only contain a single path or compound path each. The VuMark-Contour should contain only a single path that has exactly as many anchor-points as corners there are in your Contour. Make sure there is no overlapping anchors in your path. Use the "Document Info->Object" panel to list the anchor points by selecting the Contour path only.

5.7 Using the Export script

5.7.1 Export Script

When your VuMark design receives a “Pass” status for each of the items in the Design Guidelines Verification section and the message “VuMark Template ready for export” appears on the Feedback artboard, you can now run the Export script.

The Export script will again run verification, create a new file in Illustrator, and move contents from your VuMark template file gradually over. It will automatically trim your design artboard so that it is exactly the size of your VuMark design. It will then prompt you to save your VuMark template as an SVG file.

5.7.2 Common problems

Occasionally you may find that the artboard trimming doesn’t work correctly, and your artboard still appears larger than your VuMark design. Typically, the reason this happens is that there are one or more objects on your artboard that may be invisible to you, but are still there and the script interprets these as being part of your VuMark design. To fix this, you should inspect each of your layers looking for any objects that aren’t part of your intended design and remove them. Sometimes there are invisible elements in Compound Paths or Sub-Layers preventing correct clipping. After cleanup you can run the Export script again and check that the artboard is trimmed correctly.

5.8 Target Generation in the Vuforia Developer Portal

In the Vuforia Developer Portal create a VuMark database. Since VuMark databases need to be associated to licenses, they cannot contain other target types. If you need to use different target types in your application download them as separate Device Databases and load them as simultaneous datasets.

Upload the VuMark SVG Template to create a VuMark target dataset on “Add Target”. The Device Database download process of the VuMark target is identical to other targets.

Additionally, you have the possibility to directly generate instances of the VuMark in the Vuforia Developer portal UI.

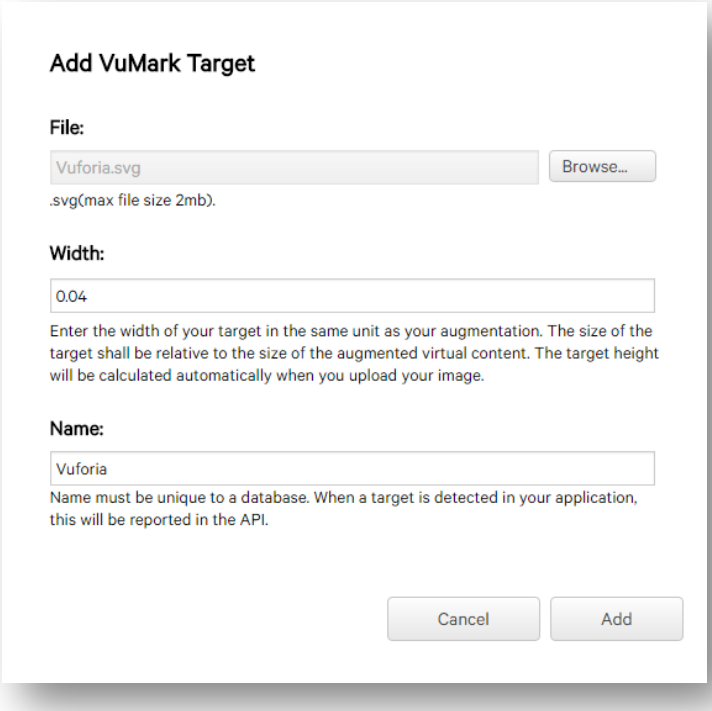


Figure 7 - VuMark Template Upload

6 ADVANCED TOPICS

6.1 Rotational Symmetry – Asymmetry Markers

We recommend to create designs that are not rotational symmetric, compare below:

Non-rotational symmetric

Rotational symmetric
[orders: 6, 5, 5, 5]

Figure 8 – Rotational symmetry examples

When contours are used that are rotational symmetric, there is a minimal, theoretical chance that a Code contained in a certain specific instance may not be read out correctly. If you want to assure that this never happens you will need to add Asymmetry Markers to your design.
Asymmetry Markers are little circles manually added to the "VuMark-AsymmetryMarkers" layer, named in order "a0000", "a0001", "a0002", … . Their purpose is to markup one arbitrary, rotational symmetric location in your design with respect to the Contour rotation, that fulfills following criteria (see Figure 10 and Figure 11 for examples):

- The number of Asymmetry Markers must be identical to the symmetry order of your Contour (see Figure 8 for examples).
- When rotated around the symmetry center, individual Asymmetry Markers need to fall onto each-other. Basically they need to be on rotational symmetric locations (as shown in Figure 9).
- One, and only one out of the multiple Asymmetry Markers must have in its center a different color than the other markers. The reason for that is that this specific marker is used to 'lock' the orientation to a specific rotation. The contrast between the one and the other markers should be similar to what is used for Dark/Bright elements.

Figure 9 - Asymmetry Marker Placement Example

Figure 10 – Order 2 asymmetry marked up in "ACME" design

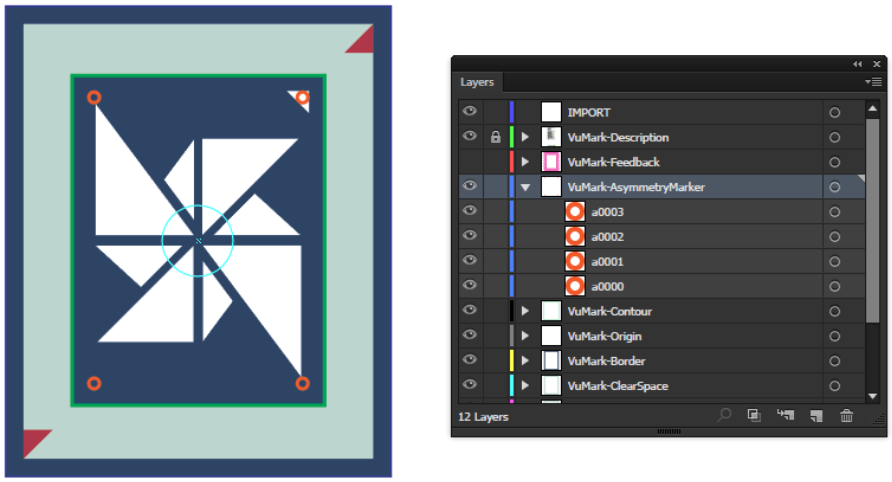


Figure 11 - Order 4 asymmetry marked up in "EAP" design

7 OTHER CONSIDERATIONS

7.1 Physical Size

VuMark instances are generated in PNG, PDF, or SVG formats by Vuforia. Printing PDF documents will create the VuMark printouts in exactly the same size as you have designed them in Illustrator. When creating printout based on PNG or SVG files you should manage the print size correctly.

7.2 Detection Range

The detection range of a VuMark is limited by its apparent size in the mobile applications live camera viewfinder. The VuMark shall cover around 1/4-1/16th of the live camera view in your application. This means, in a typical use scenario the user of your app shall be able to hold the mobile device camera pointing to a VuMark, so that the VuMark appears to cover 1/4-1/16th of the screen.
The recommended smallest physical size of a VuMark shall be not smaller than a dime (~1 inch or 25mm). In case of a small VuMark when you move the device closer to the VuMark to fulfil above coverage requirement, at some point the camera will fail to focus.

7.3 Printing

VuMarks should be printed on paper and other media that ideally has a matte surface. Avoid glossy and reflective surfaces. The VuMark must be flat to be detected and tracked accurately.

8 TIPS & TROUBLESHOOTING

8.1 Troubleshooting VuMark creation/detection fails

Due to the variety of ways how a VuMark design can be created there may be still cases when verification and export of the VuMark succeeds, but the VuMark generation upon upload to the Developer Portal fails, or even that a downloaded VuMark dataset is not capable of detecting instances (e.g. the “0” instance displayed in the VuMark Target detail panel.
Try to apply one of the recommended fixes based on the below listed possible reasons. We will work on improving the Illustrator toolchain over time to catch these issues and either provide feedback or automatically fix/bypass below mentioned cases:

- **Overlapping points in Contour path causing more points than actual corners in contour**. When the Contour is not created carefully using the Pen-Tool as recommended, more points end up in contour path than your visual design actually has. Please **verify using Document Info>Objects** that you have as many points in the closed path as your design actually has when counting corners of contour visually.

- Check **maximum angle limit** between contour segments is 150°.

- **Shape transformation** in Contour/Border/Clear Space elements. Move/rotation/scale of an object results in an update to the anchor points of a path/compound path. Shapes however can store above changes either as update to their width/height and position coordinates OR in a separate transformation. If you find in your failed VuMark SVG Template file *transform="matrix(…* attributes, use the **Object>Shape>Expand Shape** command to flatten them as paths.

- **Don’t use appearance attributes for Elements/Contour/ClearSpace/Border!** When listed objects have appearance attributes their export to SVG is not always properly rendered and verification may provide incorrect results. You can easily identify the issue, as appearance attributes are displayed with a filled dot in Layers panel:

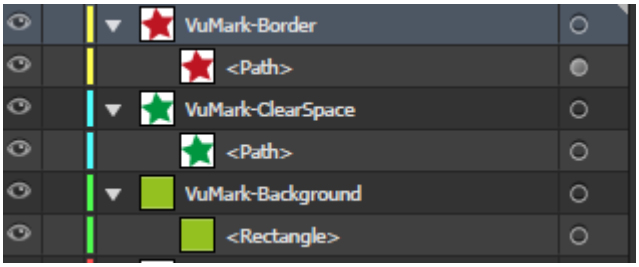


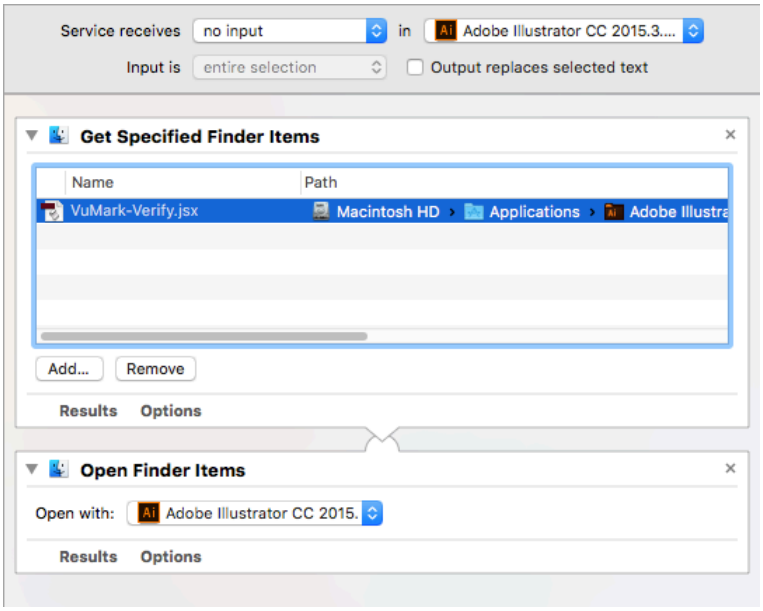
Figure 12 - Appearance attribute is used in VuMark-Border layer

To fix this issue select the object and use **Object>Expand Appearance**.

8.2 Calling Scripts with Keyboard-Shortcuts on MacOS

To save time during iterative checks using the VuMark Verify script, you might want to setup a keyboard shortcut to run the script. Shortcuts are OS platform-specific and techniques will vary. As a convenience, instructions for one way to do so on the Mac version of Illustrator are provided below:

1. Launch Mac Automator
2. Select “Service” and click the “Choose” button to accept
3. Set the following values: Service receives “no input” in “Adobe Illustrator”
4. Add a “Get Specified Finder Items” and click “Add” to select Vumark-Verify.jsx script located in the “Presets/en_US/Scripts/” folder of Illustrator app
5. Add an “Open Finder Items” and set it to the Illustrator app
6. Save your new workflow service with name such as “VuMark-Verify”



7. Open Keyboard in Settings and select Shortcuts tab

8. With “Services” selected, scroll till you find “VuMark-Verify” and then click “add shortcut” and choose an available key combination.
9. Restart Illustrator and check Services for your script with assigned hotkey.