

# A Visual Programming Language for Soccer

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Abstract: The use of Information Technologies (IT) in high competition sports is an instrument often used. However, the majority of the performers, including technical teams, do not have skills to program those IT tools to their needs. In this paper we present the low level implementation of a visual programming language (VPL) that allows the user without programming expertise to produce relatively complex programs by drawing them on a web application. The VPL tool application is illustrated by applying it to detect programmed situations from a soccer game, using previously obtained tracking data. The tool can be applied to other collective ball sports.

## 1 INTRODUCTION

Aiming for excellence is the keyword to everyone involved in soccer. While players need to show their physical and tactical skills on the pitch, coaches and their remaining staff need to have their own tools so that they can perform at higher levels. Granting to all the parts a multi-functional information system, with the objective of minimizing the adverse effects from the most critical and sensitive points of soccer is then critical. A match analysis, for example, can generate a huge amount of raw data and statistics. Consequently, it is very important to have a way to process that data, providing only the most important information to the coach, as soon as possible. Furthermore, a manual match analysis of soccer games represents a huge amount of work, which whenever possible should be done by an automatic or semi-automatic process.

Footdata (Rodrigues, et al., 2013) is a project in development by the University of the Algarve, Inesting, S.A., and the soccer coach Domingos Paciência. The goal is to build a web application product for soccer, which integrates two fundamental components of this sport's world: i) a social network (FootData-Social), which provides the typical features adapted to the soccer reality, and ii) the professional component (FootData-PRO), which can be considered as a Soccer Resource Planning (SRP), featuring a system for acquisition

and processing of information to meet all the soccer management needs. The latter includes (between other things) an automated platform to gather information from the teams. This platform will be based on a system that will process live images acquired on-site, using a single or a group of cameras placed together in the stands, or images gathered from a Full HD Handycam. One of the main objectives is to automatically collect information and on-the-fly alert the technical staff about specific events. All the above should be presented in a web (browser) environment, accessible from a personal computer or a mobile device (smartphone or tablet).

Furthermore, each technical staff has data that they would like to be treated and analyses but, in the majority of the cases, they do not have the programming skills to implement software capable of such. In order to detect the different game situations from different coaches, we had to develop a tool that allows passing from a visual component to a programming (code) component, i.e., a Visual Programming Language (VPL) framework for soccer (see Figure 1). The main feature consists in the design of an Interface Development Environment (IDE) and a compiler to transform the sketch into a programming language.

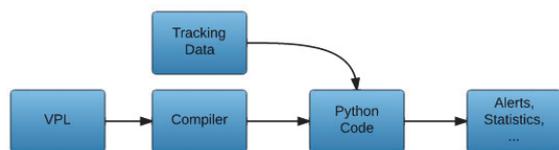


Figure 1: Architecture of the system.

In more detail, a VPL is any programming language that allows users to create programs by using graphical elements rather than specifying them textually. Many VPLs are based on the idea of "boxes and arrows," where boxes or other screen objects are treated as entities, connected by arrows, lines or arcs which represent relations. Usually, VPLs are used in the context where the programmer has limited programming knowledge.

For example the KTechlab (KTechlab, 2014) is a VPL for microcontrollers and electronics that uses flowcharts to program microcontrollers graphically. Another VPL example is Scratch (Scratch, 2014) (Resnick, et al., 2009) which uses an intuitive interface with blocks shaped to fit together only in ways that make syntactic sense, allowing to program various actions easily without having programming knowledge. Because of this features, Scratch is successfully being used to teach new programmers and for educational propose. Another similar web-based VPL application is a Google project called Blockly (Blockly, 2014), which allows making short programs in a web environment by dragging and dropping programming blocks to interact with virtual objects on the computer screen.

Even for more advanced programmers, there are VPLs. For example, Simulink® (Tyagi, 2012) is a block diagram environment for multi-domain simulation and Model-Based Design integrated with Matlab®. Simulink supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. With some similarity we have the Scicos (Scicos, 2014), which is a graphical dynamical system modeler and simulator. With Scicos the user can create block diagrams to model and simulate the dynamics of hybrid dynamical systems and compile models into executable code. Scicos is used for signal processing, systems control, queuing systems, and to study physical and biological systems. Other examples of Visual Processing Languages applied to specific situations are presented in (Dobesova, 2011), (Marchiori & al., 2011) and (Tekli, et al., 2013).

In this paper we describe the low level implementation of a system that aims at creating an interface which allows coaches to "program" their

team's movements and specific game situations using a web-browser VPL environment. Satisfying the prerequisites, and based on the transmitted experience of the consultant technical teams, the interface is prepared to be intuitive and easy to use, providing the necessary tools for the coaches to describe their team procedures. Besides, the developed application is a web application that runs on the majority of the most common web browsers (e.g., Firefox, Chrome, Safari and Internet Explorer). The application includes tools to represent several aspects of soccer, namely areas, movements from players and ball, and passes. In this sense, there are obviously a large number of scenarios where VPL are useful. This paper main focus isn't the design itself (i.e., the IDE building) but passing from the visual representation to code, and further testing in soccer game environment. Our main objective in this paper is to propose our low level implementation off a VPL that can be applied to most collective ball sports.

The remaining document is structured as follows. Section 2 presents our soccer visual programming language. Section 3 and 4 show how the VPL is compiled and executed and Section 5 presents some experimental tests. Finally, we conclude the paper with a brief discussion and the presentation of some future work in Section 6.

## 2 FOOTDATA'S VISUAL PROGRAMMING LANGUAGE

The FootData's development environment interface is called Field Editor (FE), which in the front end can be considered as a visual IDE web-based tool, created using HTML 5, CSS, and Javascript. The FE allows the coaches to draw the desired team movements and other specific situations for future statistical compilation. The features already implemented in the FE include tools to draw and edit the settings of players, ball, areas and distances.

Figure 2 shows an example of a situation drawn in the Field Editor that contains four players (represented by red circles), a ball, three distances lines between the players and two zones. The objective of this drawing is to verify that whenever the ball is inside the green zone, the players should be inside the red zone keeping a distance of 12 meters between them. We should notice that although it is not shown in the picture, the distance between the players admits an error of 3 meters, value configurable in the FE interface. As mentioned

before, the main focus of this paper is not to explore the FE interface, so for more details about the FE interface please refer to (Rodrigues, et al., 2013).



Figure 2: Example of a draw made on the Field Editor representing four players that should be at the red zone when the ball is inside the green one.

When the user completes the draw of the desired team movement, typically the coaches or some other member of the technical team, this has to be passed to the FootData datacenter so that the depicted movement is committed to the database (allowing posterior load and re-edition), and transformed into code which is then matched against the acquired/tracked images.

Also outside the scope of this paper is the tracking framework, developed inside the FootData project. In resume the tracking framework is composed by an application capable of doing the tracking of the players and ball, given images of the full size pitch. Please refer to (Rodrigues, et al., 2013) for further details.

### 3 SERIALIZATION OF THE DRAWN SCHEMAS

Returning to the communication between the FE (web application) and the FootData datacenter, a serialization process was thought tacking into consideration the fact that the FE is implemented over JavaScript and the FootData's libraries used for the verification of the procedures were programmed in Python. In this case, the draw is converted to a JSON document (JSON, 2014), which is a lightweight data-interchange format. Using the JSON type of format allowed us to take advantage of (1) the JavaScript facilities to treat JSON documents, (2) the fact that those documents are very similar to Python dictionaries avoiding intricate parsing procedures, and (3) the fact that the database

used to store the document is MongoDB (MongoDB, 2014). MongoDB is a cross-platform document-oriented database system, classified as a noSQL database, which eschews the traditional table-based relational database structure in favor of JSON-like documents.

Figure 3 shows an example of the JSON document generated by the FE to translate the procedure depicted in Figure 2. The JSON document has a predefined structure, that include the scheme name, the type, the field dimensions, the field scale, the players, the ball, the lines, the distances and a list of conditions.

In more detail, the *name* attribute refers to the name given by the coach to the drawn schema and the *type* is used to categorize the procedures. The attributes *field\_dimension* and *field\_scale* have also to be passed, because the soccer pitch image used in the field editor has been designed to a normalized field dimension, which in general will not match the dimensions of the majority of the stadiums, who have slightly varying sizes. Knowing the field dimensions where the game will occur and drawn the specific game schemas to be detected, it is then possible to adjust the depicted procedure to a particular stadium.

The *players* attribute has an array that takes an embed JSON object, a subdocument, for each player inserted in the field editor, following the structure: `{"id":#, "number":#, "team":"#", "points": [#,#]}`. A different *id* is attributed to each object inserted in the FE, so we can refer to any object by its *id*. The subdocument has also the player's *team*, *number*, field *points* (which is the player's coordinates on the pitch, in pixels) and *radius* (value in meters in which the player position can vary).

```
{
  "name": "schema 1", "description": "EP",
  "type": "DP", "field_dimension": [105, 68],
  "field_scale": [0.1, 0.1],
  "players": [
    { "id": 1, "number": 1, "team": "A", "points": [514, 559], "radius": 3 },
    { "id": 2, "number": 2, "team": "A", "points": [486, 438], "radius": 3 },
    { "id": 3, "number": 3, "team": "A", "points": [483, 314], "radius": 3 },
    { "id": 4, "number": 4, "team": "A", "points": [507, 197], "radius": 3 }
  ],
  "ball": { "id": 5, "points": [762, 320], "owner": "None" },
  "zones": [
    { "id": 7, "name": "Zone 7", "points": [945, 498], [945, 198], [611, 198], [611, 498] },
    { "id": 6, "name": "Zone 6", "points": [546, 603], [546, 103], [409, 103], [409, 603] }
  ],
  "lines": [
    { "id": 10, "objects": [3, 4], "id": 9, "objects": [2, 3], "id": 8, "objects": [1, 2] },
    { "objects": [3, 4], "distance": 12, "margin": 3 },
    { "objects": [2, 3], "distance": 12, "margin": 3 },
    { "objects": [1, 2], "distance": 12, "margin": 3 }
  ],
  "conditions": [
    { "verify_location": [1, "IN", 6] },
    { "verify_location": [2, "IN", 6] },
    { "verify_location": [3, "IN", 6] },
    { "verify_location": [4, "IN", 6] },
    { "verify_location": [5, "IN", 7] },
    { "verify_distances": true },
    { "alert": "True", "msg": "Pressing the ball " },
    { "alert": "False", "msg": "" }
  ]
}
```

Figure 3: Example of JSON document generated at the FE.

When inserting the distances between two players, a line object is created containing a self *id* and the *ids* of the *objects* which define the distance line (start and end). The result is the structure {"id": 8, "objects": [1, 2]} which indicates that there is a line between players with *id* 1 and 2. The distances information is then placed in another attribute called *distances*, which contains an array with objects having the information about the *objects ids*, the *distance* and an error *margin* in meters. For instance, the object with that information has the following structure {"objects": [3, 4], "distance": 12, "margin": 3}, which for the presented case means that objects with *id* 3 and 4 (corresponding to the players with *id* 3 and 4, respectively) should maintain a distance of 12 meters, allowing an error of 3 meters.

The zones inserted in the FE can be elliptical, rectangular or free draws, but they are all treated as polygons. Those polygon vertices, that represent coordinates in the soccer field, are then inserted into a *zones* array in the JSON document. As before, each zone as also an unique *id* and a representation that follows, e.g., the structure {"id": 6, "name": "Zone 6", "points": [[546, 603], [546, 103], [409, 103], [409, 603]]}.

Having all this information gathered, we added one last attribute to the JSON document to allow the program to know what is to be detected. That attribute is called *conditions*. As the name suggest, in this field it is possible to create conditions, more specifically, *if-then-else statements*. To do it, we defined a structure with an array with 3 entries: the first one is the *if* condition, the second one is the *then* statement and the last one is what to do if the condition is false (i.e., the *else* statement).

Some combinations providing more complex programs are also possible. For example: it is possible to program chained *if-then-else* statements, by adding inside the *then* or *else* statements others *if-then-else* statement, i.e., including more “three element arrays” that follow the previously presented structure. There are also some keywords. For example, *verify\_location* will call a function, implemented in the mentioned Python library, which verifies if a certain object is inside or outside a zone. The *verify\_distances* has a similar behavior, i.e., it calls a function which returns a boolean value upon the verification of the distances defined in the JSON document (see Figure 3).

## 4 CONVERTING THE SERIALIZED DOCUMENT

Having the serialization as a JSON structure it is now necessary convert it to Python code. First the variables corresponding to the players, distances, lines and zones are instantiated from the pre-implemented Python classes. These Python instances are saved to a file using a serializer, so that the objects will be simply loaded avoiding their creation every time the verification of the schema is run. This process is also justified by the fact that data from the FE is saved in a MongoDB and having the files with the objects already instantiated will speed up the initialization process. The next step is to convert the conditions to Python code, which is done by recursively accessing the *conditions* array, and creating the *if-then-else* code from the sent statements. The conditions names are matched to their correspondent methods already implemented in our Python library. For example, the matching method to the “*verify\_location*”: [5, "IN", 7]” in the JSON document (Figure 3) corresponds to the function *verify\_location(frame, ['ball', 'IN', zone7])* in our Python code, which receives a *frame* from the tracking system and checks if the ball is inside the region defined as *zone7*. Figure 4 shows the Python code which corresponds to the JSON document presented in Figure 3.

```

from lib import gpm
def run():
    result = False
    if pm.verify_location(frame,['ball','IN',zones7]):
        if
gpm.verify_location(frame,[players2,'IN',zones6]):
        if gpm.verify_location(frame,
[players3,'IN',zones6]):
            if gpm.verify_location(frame,
[players4,'IN',zones6]):
                if gpm.verify_location(frame,
[players1,'IN',zones6]):
                    if gpm.verify_distances(frame,
distances):
                        gpm.sendmsg('Pressing the ball')
                        gpm.sendalert('True')
                        result = True
                    else:
                        gpm.sendmsg('')
                        gpm.sendalert('False')
                        result = False
                return result, gpm

```

Figure 4: Python code generated from the JSON document.

Now that we have the code generated, information about the players and the ball position is needed in order to check the depicted procedures. As already mentioned, this information is obtained using a tracking system (Rodrigues, et al., 2014) that returns, for each frame, the players’ and ball’s positions in meters from the top left corner of the

pitch, using homography (Sebe & Lew, 2003) to place the objects (players and ball) in the model field.

The module *gpm* imported in Figure 4 has a set of pre-implemented methods used to analyze the game and also records the information gathered by each method that is executed. To run the code, first the file name is passed by parameter to a module that is responsible to import the previously generated Python file (Figure 4), and the previously serialized objects. The objects are deserialized and loaded into the already imported module with the code from the drawn movement.

The code can now be run for each frame or for a set of *n* of frames. At the end, a Python dictionary is returned with the result for every frame analyzed. Figure 5 resumes the architecture explained above.

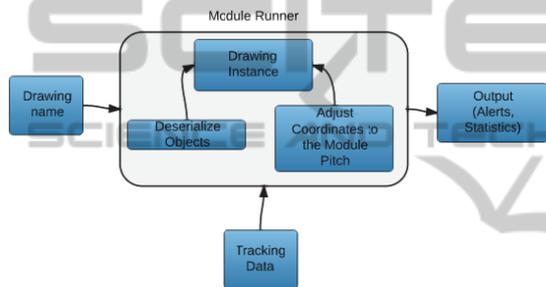


Figure 5: Architecture used to run the game schemas.

In our example, sketched in Figure 4, first it is verified if the ball is in the green zone. If the ball is in the green zone it is then verified individually if the players are in the red zone and at last if the distances are correct. For each frame the verifications result are stored, enabling us to create statistics for what or who is failing in this schema. Figure 6 shows an example of the output obtained from the *verify\_distances* method, which is used to verify the distances between players. The output is composed by an array with a Python dictionary for each distance verified. The dictionary has the players' objects, the defined distance, the distance between the objects in that frame and a key with the name *True* or *False* for easily verify if the distance is correct or not.

```
'verify_distances': [{ 'players': (<Player object>,
                        <Player object>), 'False': None, 'distance_def': 12, 'distance':
                        8.04}, { 'players': (<Player object>, <Player object>), 'True': None, 'distance_def': 12, 'distance':
                        9.95},
                    { 'players': (<Player object>, <Player object>), 'True':
                        None,
                        'distance_def': 12, 'distance': 11.65}]
```

Figure 6: Output from *verify\_distances* function.

## 5 COMPUTATIONAL TESTS

In this section we present some tests and results from the application of the visual programming language. For testing proposes, the data used to analyze the soccer game is returned by the tracking software and has a length of 2:30 minutes.

### 5.1 Test 1



Figure 7: Situation drawn in the FE, player inside a zone.

```
{ "name": "Test1", "description": "", "type": "FO",
  "field_dimension": [105, 68 ], "field_scale": [0.1,
  0.099], "ball": {}, "players": [{"id":2,"number":6,
  "team": "B", "points": [324, 633 ]}], "zones": [{"id":
  1, "name": "Zona 1", "points": [[421,686],[421,571],
  [236,571],[236,686]]}],
  "conditions": [{"verify_location": [2, "IN", 1]}, {"ale
  rt": "True", "msg": "Event Y"}], [{"alert": "False"}
  ]}]
```

Figure 8: JSON document for Test1 example (Figure 8).

The first test is a simple example with a player inside a zone (see Figure 7). Figure 8 shows the corresponding JSON document and the Python code obtained after the compilation is presented in Figure 9. This example shows a simple application for the feature “player inside zone”, in which it will be verified if player number ‘6’, from team ‘B’, is inside that zone.

```
from lib import gpm
def run():
    result = False
    if gpm.verify_location(frame, [players2, 'IN', zones1]):
        gpm.sendmsg('Event Y')
        gpm.sendalert('True')
        result = True
    else:
        gpm.sendalert('False')
        result = False
    return result, gpm
```

Figure 9: Compiled Python code from Test1 example.

Two examples of the output for this situation will be (1){'verify\_location': {False: None, 'first\_arg': 'Number: 6, 'Team': B', 'second\_arg': <Zone object>, 'condition': 'IN'}, 't':258} if the player is outside the defined zone; and (2){'verify\_location': {True: None, 'first\_arg': 'Number: 6, 'Team': B',

'second\_arg': <Zone object>, 'condition': 'IN'}, 't':538} if the player is inside the zone.

In this case, the difference between the two outputs is the existence of a dictionary key with the name *True* or *False* to validate or not the situation. A simple analysis of the output can be the counting of how long the player stayed in the area. In our example of 2:30 minutes, the player was 39,4% of the time in that zone.

## 5.2 Test 2

The second test analyzes the results obtained from the example in Figure 2, explained along the previous sections of this paper.

Figure 10, returned by the tracking software, depicts frame 947 of the analyzed soccer game, along with the zones and distances between players in the pitch. The image is a screenshot from a development tool used for the visualization of what is being processed.



Figure 10: Visual scheme being processed.

As mentioned before, for each frame we will have a Python dictionary with the information gathered by the methods executed to detect if the “drawing” is being accomplished.

```
{'verify_location': [{'True': None, 'first_arg': 'ball',
                    'second_arg': Zones7, 'condition': 'IN'},
                    {'True': None, 'first_arg': 'Number:2, Team:A', 'second_arg':
                    Zones6, 'condition': 'IN'},
                    {'True: None, 'first_arg': 'Number: 3, Team: A',
                    ', 'second_arg': Zones6, 'condition': 'IN'},
                    {'True: None, 'first_arg': 'Number:4, Team:A',
                    'second_arg': Zones6, 'condition': 'IN'},
                    {'True:None, 'first_arg': 'Number:1, Team:A',
                    'second_arg': Zones6, 'condition': 'IN'}], 't': 947,
'verify_distances': [{'players': ('Number:3, Team:A',
'Number:4, Team:A'), 'True':None, 'distance_def':12,
'distance':9.83}, {'players': ('Number:2, Team:A', 'Number:
3, Team:A'), 'True':None, 'distance_def':12, 'distance':11.
44}, {'players': ('Number:1, Team:A', 'Number:2, Team:A'),
'True': None, 'distance_def': 12, 'distance': 14.14}]}
```

Figure 11: Output from frame 947.

Figure 11 shows the output for frame 947, in which is presented the result from the *verify\_location* and *verify\_distances*. In *verify\_location* each array element contains the

result from one object, in our case the ball and four players, each element has a key with the name *True*, that means that the players and the ball are inside their predefined zone. The *verify\_distances* follows the same principle, having one element of the array for each distance verified. As all the players are complying the distances between them, being inside the predefined zone when the ball is at the other zone, the output from Figure 11 confirms that they are doing what was drawn in the Field Editor.

## 6 CONCLUSIONS

This paper presented our implementation aspects of a VPL for soccer analysis, built to help the coaches and technical teams in the improvement of their players and team’s performance by allowing them to draw the expected procedures and verifying if the players are complying with them. This VPL can also be applied to other collective ball sports.

This web tool allows, without previous programming knowledge, to make fairly complex analysis just by using some of the implemented features. The tool analyses the pretended procedures for each frame, giving the chance to the coach to analyze thoroughly a great number of game aspect that previously would require programming knowledge skills or exhaustive man work. The tool allows to send alerts to a mobile device during a game if some particular event happens or not, making real time adjustments to the team possible, in order to accomplish the pretended performance.

For being used with other sports, it would be only necessary make some minor adjust, like icons and the background pitch, since de functionalities implemented are not specific for soccer.

It is also important to refer that this tool can be used to study the opposite team procedures after or during a game. This gives the coaches an opportunity to be better prepared when playing against other teams, or once more, if used during a game, to be notified in the bench and adjust how the team is performing. This tool can become a game changer for the ones who use it, bringing soccer to a whole new level.

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