D3Box Task for BCI2000

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Abstract

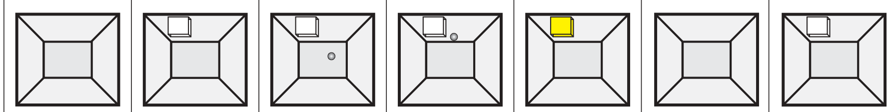
The purpose of the D3Box task is to provide a BCI2000 User Application module that can realize 1D, 2D, or 3D cursor movement tasks. It is intended to provide a superset of the functionality provided in the RJB and D2Box task. This task is implemented using a generic 3D API based on OpenGL that may be used to create other 3D user applications.

1 Introduction

The D3Box task implements a cursor movement task based on a 3-dimensional control signal communicated to it by an appropriate BCI2000 Signal Processing module. This task is characterized by a sequence of five subsequent stages that are illustrated in Figure 1. In stage 1, the screen shows an empty workspace. This period is called *Inter-Trial Interval*. Subsequently, a target (that is represented as a cuboid) appears in one out of n possible locations. This period is called *Pre-Trial Pause*. After the pre-trial pause, the cursor appears in stage 3. It immediately starts to move as determined by the 3-dimensional control signal. During stage 3 and 4, the user's task is to move the cursor towards and into the target. This period of cursor movement is called the *Feedback Period* or *Trial Period*. Period 4 can end in one of three ways: Either the cursor hits the correct target, it misses by hitting any other of the defined targets, or the feedback period takes too long and times out. Stage 5, the *Reward Period*, follows stage 4. The cursor disappears and the target changes its color to indicate completion of the trial period. After a defined duration, the target disappears and the next trial starts with an Inter-Trial Interval.

2 Visual Representation

The visual representation of the D3Box task is represented in Figure 2. It consists of a 3-dimensional workspace that can (if selected) be indicated by five bounding rectangles. These rectangles can have a user-selectable texture, which is the same for each rectangle. Targets are represented by cuboids, whose edges can also have a particular texture. Finally, the cursor is represented by a sphere. It also may have a user-defined texture. To facilitate depth perception, the cursor's color provides an additional cue about the



State							
TargetCode	0	2	2	2	2	0	3
Feedback	0	0	1	1	0	0	0
IntertrialInterval	1	0	0	0	0	1	0
ResultCode	0	0	0	0	1	0	0
Stage	1	2	3	4	5	6	7

Figure 1: The time line of the D3Box task. The BCI2000 state variables that encode the trial sequence are *TargetCode* (i.e., which of the defined targets is currently present on the screen), *Feedback* (i.e., whether or not user feedback is provided by the cursor), *IntertrialInterval* (i.e., whether or not we are presently in this period), and *ResultCode* (i.e., which of the defined targets has been selected).

cursor's Z position as follows. The operator specifies two colors that indicate the cursor's color at Z position +32767 and -32767. In other words, a cursor at position +32767 or -32767 will have the corresponding color. For any color between these extremes, the cursor's color will be linearly interpolated between the two colors. (Specifically, each of the three color components (i.e., red, green, and blue) will be interpolated to result in the cursor's color for a given Z position.)

3 Control of the D3Box Task

The cursor in the D3Box task can be controlled in two different ways. The first option is to control the cursor using the control signals communicated to it from an appropriate BCI2000 Signal Processing module. The second option is to control the cursor using a standard joystick that is attached to the computer. In this case, joystick movements left/right and up/down control the cursor's x and y position, respectively. If the user presses the joystick button, the cursor slowly moves towards the front of the workspace (i.e., towards the screen). If the user does not press the joystick button, the

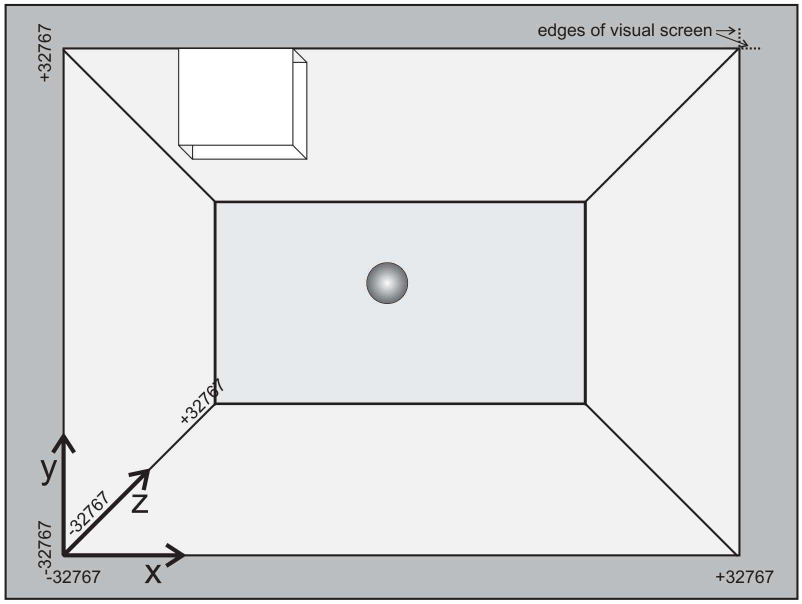


Figure 2: The screen layout of the D3Box task.

cursor slowly moves towards the back of the workspace (i.e., away from the screen). Whether the cursor is controlled by the joystick or by the control signals coming from the signal processing module is defined by a parameter.

4 Parameters

This section describes the parameters that configure the D3Box task. The parameters are grouped by the section they belong to, i.e., the tab in the Operator's config menu they appear in.

Section *Joystick*:

- `JoyXGain` After subtracting XOffset, the joystick signal in X is multiplied with JoyXGain. Thus, if JoyXGain is higher, horizontal cursor movement will be more reactive to joystick movement.
- `JoyYGain` Same as JoyXGain, but for Y dimension.
- `JoyZGain` Same as JoyXGain, but for Z dimension.

- `UseJoyStick` If this parameter is 0, the cursor is controlled by the three control signals communicated to the D3Box task by Signal Processing. If it's set to 1, the cursor is controlled by the joystick.
- `XOffset` This value is subtracted from the current joystick X direction. This can be used to either compensate for or to create a bias in the joystick movement.
- `YOffset` Same as XOffset, but for Y dimension.
- `ZOffset` Same as XOffset, but for Z dimension.

Section *Targets*:

- `IncludeAllTargets` If 1, the trial will end if the cursor hits any of the specified targets, even though only one target is on the screen at a given time. If 0, the trial will end only if the cursor hits the visible target or if the trial times out.
- `NumberTargets` Specifies the number of targets. This has to correspond to the number of columns in the TargetPos matrix.
- `StartCursorX` Starting X coordinate of the cursor (in percent of screen width).
- `StartCursorY` Starting Y coordinate of the cursor (in percent of screen height).
- `StartCursorZ` Starting Z coordinate of the cursor (in percent of screen depth).
- `TargetPos` This is a matrix that defines the targets and their positions on the screen. Each target occupies one column and 10 rows. In ascending order starting with one, the rows correspond to: X coordinate of midpoint of target, Y coordinate of midpoint of target, Z coordinate of midpoint of target, width of target, height of target, depth of target, X adaptation coordinate, Y adaptation coordinate, Z adaptation coordinate, adaptation code. The first six rows define the position and spatial extent of each target in screen coordinates, i.e., they are defined in percent of screen width, height, or depth. For rows 7-10, the adaptation coordinates and adaptation code, the values in

these rows are assigned to states XAdapt, YAdapt, ZAdapt, AdaptCode, respectively for the target that is currently visible on the screen.

Section *UsrTask*:

- `BorderTexture` If defined, this defines the full path to the texture that is applied to the rectangles that enclose the workspace. The texture has to be in BMP format. If this parameter is not defined (i.e., the screen is empty), no texture is applied. The D3Box task sends a BCI2000 warning message if the texture is not found.
- `CursorSize` Defines the size of the cursor in percent of screen width.
- `CursorTexture` Defines the full path to the texture that is applied to the cursor. See `BorderTexture`.
- `CursorColorFront` Color of cursor if cursor is at the very front of the workspace (i.e., Z of -32767) in RGB[1]
- `CursorColorBack` Color of cursor if cursor is at the very back of the workspace (i.e., Z of +32767) in RGB. Cursor color between these extremes is linearly interpolated.
- `FeedbackDuration` This parameter defines the maximum trial duration in feedback updates[2].
- `ItiDuration` The duration of the *Inter Trial Interval*, i.e., the time that the empty workspace is shown without a target or a cursor. This time is defined in feedback updates.
- `PreTrialPause` The duration of the *Pre-Trial Pause*, i.e., the time the target is visible but the cursor is not. This time is defined in feedback updates.

[1] For convenience, RGB values may be entered in hexadecimal notation, e.g. `0xff0000` for red.

[2] A feedback update is defined as the ratio of $\frac{SampleBlockSize}{Samplingrate}$ in seconds. Thus, for a blocksize of 16 and a sampling rate of 160 Hz, this comes out to 0.1 seconds=100 ms. In this example, if `FeedbackDuration` were specified as 80, the trial would time out after 8 seconds.

- `RewardDuration` The duration of the *Reward Period*, i.e., the time the target flashes after it is hit by the cursor.
- `TargetTexture` Defines the full path to the texture that is applied to each target.
- `TimeLimit` Defines the maximum time of the session in seconds. The D3Box task will automatically suspend if a trial completes and the session has been running for the defined period.
- `WinHeight` Width of the D3Box task's window in pixels.
- `WinWidth` Height of the D3Box task's window in pixels.
- `WinXpos` Top Edge of the D3Box task's window in pixels.
- `WinYPos` Left Edge of the D3Box task's window in pixels.

5 States

The time line of stimulus delivery is encoded in state variables as defined in Table 1.

State Name	**Bits**	**Description**
TargetCode	8	target ID of the currently active target, or 0 if no target is on the screen
ResultCode	8	target ID of the currently selected target, or 0 if no target selected
IntertrialInterval	1	1 if we are in the Inter-Trial Interval or 0 otherwise
Feedback	1	1 if the cursor is visible on the screen or 0 otherwise
CursorPosX	16	X position of the cursor if cursor present, or 0 is the cursor is not visible
CursorPosY	16	Same as CursorPosX but for Y coordinate
CursorPosZ	16	Same as CursorPosX but for Z coordinate
XAdapt	16	XAdapt value of target as defined by TargetPos matrix, or 0 if target is not visible
YAdapt	16	Same as XAdapt, except for Y dimension
ZAdapt	16	Same as XAdapt, except for Z dimension
AdaptCode	16	AdaptCode value of target as defined by TargetPos matrix, or 0 if target is not visible
StimulusTime	16	Time of feedback (i.e., cursor movement) update in ms

Table 1: Encoding scheme for this task.

6 The 3D API

6.1 Introduction

The D3Box task is based on the 3D API created by Shidong Zheng. The API is located in the Application/shared/3DAPI directory. Figure 3 and the following sections describe its capabilities.

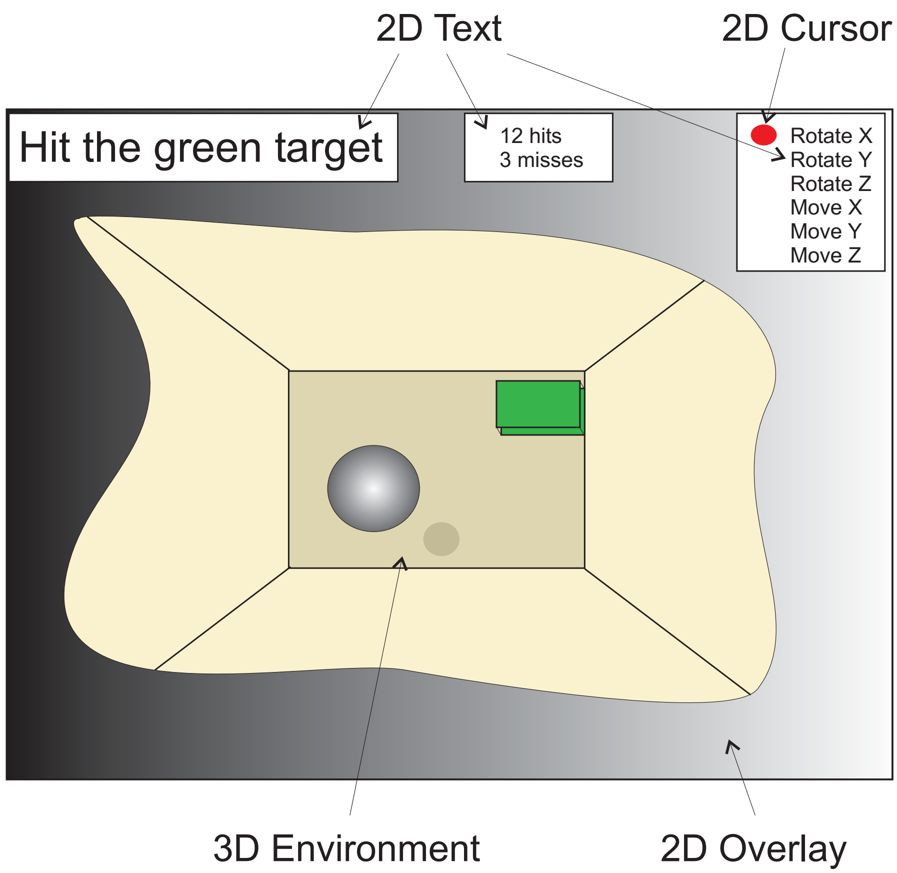


Figure 3: Graphical Environment.

6.2 Rendering

6.3 The 3D Environment

6.3.1 Predefined Graphic Primitives

The 3D environment supports any number of predefined graphic primitives. Each graphic primitive can be assigned a number of different properties. These are:

- Element ID
- Primitive ID
- Primitive-specific properties
- Generic properties
  - Brightness (0-255)
  - Transparency (0-255)
  - Color (RGB)
  - Texture

Supported primitives are spheres (i.e., primitive ID 1), cuboids (i.e., primitive ID 2), and infinite planes (i.e., primitive ID 3). The position of a sphere is defined by midpoint (XYZ) and radius. Textures are mapped using circular mapping using arbitrary alignment. The position of a cuboid is defined by a midpoint (XYZ) and a width, height, and depth (to define the extend in X, Y, and Z, respectively). Texture mapping is defined by the orientation and size of a texture. The only supported mapping type is parallel mapping. Infinite planes are defined by three points in XYZ coordinates. The only supported texture mapping type is parallel mapping with the texture being parallel to the plane.
Once created, there are certain functions that can be applied to any element.

- Change properties
- Turn on/off
- Move midpoint to XYZ

- Test for collision with another element
- Rotate element with rotation defined by
  - Angles in X, Y, Z
  - Reference point in X, Y, Z

6.3.2 Custom Graphic Primitives

In addition to built-in primitives, the system also supports custom graphic primitives. These primitives can be defined by loading their 3D structure from a file and they support the same methods as the predefined primitives except collision detection.

6.3.3 3D Text

The system supports any number of 3D text elements. Each text element is defined by

- Font
- Font size
- Caption
- Brightness (0-255)
- Transparency (0-255)
- Color (RGB)
- Origin (XYZ)
- Direction (XYZ)

The text elements support methods to modify their properties and to turn them on or off.

6.3.4 Camera

The 3D environment supports one camera with the following properties:

- Camera View Point (XYZ)
- Aim Point (XYZ)
- Focal Length
- Camera Orientation (what is ”up” for the camera) (angle)

6.3.5 Light Source

The 3D environment supports one omni-directional light source. The features that describe this light source are:

- Position (XYZ)
- Brightness (0-255)
- Color (RGB)

In addition, the brightness of white ambient background lighting can be defined.

6.4 The 2D Overlay

The 3D display can be overlayed by a 2D display (see Figure 3. This overlay supports a picture with alpha channel (i.e., transparency map), 2D text and a 2D cursor.

6.4.1 Overlay Picture

An overlay picture can be defined by loading it from disc. This picture is stretched to match the window size. Optionally, a transparency map can be defined (i.e., in essence, another picture) whose brightness level defines the s transparency of the overlay. This can create an effect as shown in Figure 3. Once defined, an overlay image can be turned on or off.

6.4.2 2D Text

The system supports any number of 2D text elements. Text elements are always displayed on top of the overlay picture. The texts' background is transparent and the text itself does not destroy the overlay picture. For each 2D text element, the following properties can be defined:

- Position (XY)
- Font
- Size
- Color (RGB)

6.4.3 2D Cursor

The system supports one 2D cursor that is always presented as a circle that is filled with a particular color. Specifically, a 2D cursor has the following properties:

- Position (XY)
- Size
- Color (RGB)