Table of Contents

1. Introduction

The 'Yarnball' scripts in this GitHub repository were developed by Rob Stobbe at the University of Alberta. Please cite the 2020 MRM paper, 'Three-dimensional Yarnball k-space acquisition for accelerated MRI' if using this work. Report any errors or problems to rstobbe@ualberta.ca**.**

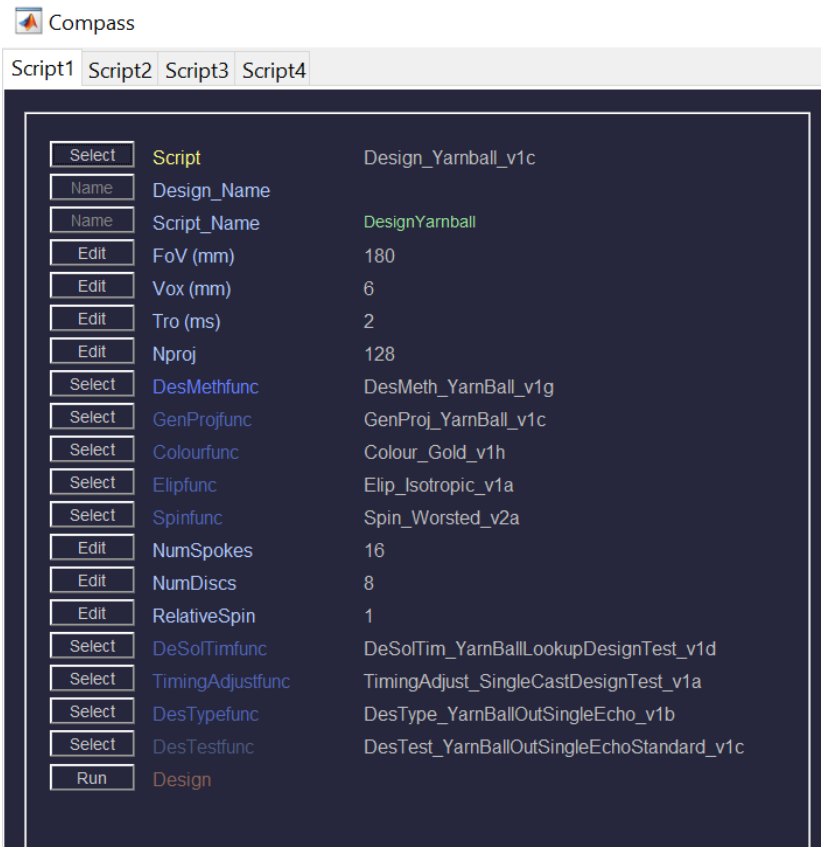
The Yarnball scripts provided are designed to be run within the 'Compass' software tool. This tool is also available for download at (https://github.com/rstobbe/Compass).

The 'CompassScriptsManual' document in the Compass repository describes how to use Compass. Examples for running Yarnball scripts are given in that document.

This document describes the **DesignYarnball** script in the 'Scripts' folder.

2. The DesignYarnball Script

The **DesignYarnball** script is the starting point for creating Yarnball trajectories. The following information will appear in the associated column when the default (on GitHub) **DesignYarnball** script is selected.



3. The Overarching Function

The DesignYarnball script currently calls the overarching function 'Design_Yarnball_v1c'. This function is effectively a container function. It accepts the general input parameters described below and passes them to DesMethfunc (or the design method function). The purpose of this overarching function is simply to facilitate alternative DesMethfunc selection.

- **FoV** – the diameter of the supported spherical FoV.
    - Note, that as described in the paper the supported FoV is actually greater than specified along the Yarnball z-axis.
- **Vox** – the value of $1/(2k_{max})$
- **Tro** – the readout duration
- **Nproj** – the number of projections (or trajectories) to be used in the design

4. The Design Method Function (DesMethfunc)

The design method function (or DesMethfunc) is also primarily a container function. The only function currently available for selection on GitHub ('DesMeth_YarnBall_v1g') calls 7 underlying design functions. Alternative design method functions may call greater or fewer functions or different types of functions.

4.1. DesMeth_YarnBall_v1g

The 'DesMeth_YarnBall_v1g' function is used for basic Yarnball design and the functions it calls are described below.

5. Underlying Functions

The function underlying Yarnball design are described below. The design method function (DesMethfunc) may call any number of these functions.

5.1. The Generate Projections Function (GenProjfunc)

The generate projections function (or GenProjfunc) solves the ordinary differential equations of Yarnball.

5.1.1. GenProj_YarnBall_v1c

'GenProj_YarnBall_v1c' is currently the only function available for selection on GitHub. Any future update will be given a different version number (major change affecting output) or letter (minor change with negligible effect on output).

5.2. The Colour Function (Colourfunc)

The colour function (or Colourfunc) describes the differential equations solved to generate Yarnball trajectories.

5.2.1. Colour_Gold_v1h

'Colour_Gold_v1h' is currently the only function available for selection on GitHub. Alternative differential equations will be assigned a different colour.

5.3. The Voxel Shape Function (Elipfunc)

The voxel shape function (or Elipfunc) describes the extent to which k-space is sampled in 3-dimensions.

5.3.1. Elip_Isotropic_v1a

'Elip_Isotropic_v1a' samples k-space to a spherical extent.

5.3.2. Elip_Selection_v1c

'Elip_Selection_v1c' allows k-space to be sampled to a oblate spheroidal extent, generating voxels which are stretched in one dimension. Its input parameters are described below.

- **VoxelStretch** – the extent to which a voxel is stretched in one dimension (this value must be greater than 1).
- **YbAxisElip** – the Yarnball axis along which the trajectory is 'squished' (or along which the voxel is stretched. Note that the Yarnball axes define the Yarnball winding. During future implementation Yarnball can be rotated within k-space.

5.4. The Spin Function (Spinfunc)

The spin function (or Spinfunc) describes the "spin parameter" included in the solution of the differential equations as well as the distribution of trajectories.

5.4.1. Spin_Worsted_v2a

'Spin_Worsted_v2a' is currently the only function available for selection on GitHub. Its input parameters are described below.

- **NumSpokes / NumDiscs** – these two parameters describe the number of spokes that are implemented on a disc and the number of discs rotated to fill k-space. For the most efficient sampling, **NumSpokes** should be 2x **NumDiscs**. Note that the values given here will overwrite the **Nproj** parameter of the overarching function.
- **RelativeSpin** – is the "spin parameter" described in the Yarnball paper. Reducing **RelativeSpin** below 1 will result in undersampling.

5.5. The Differential Equation Solution Timing Function (DeSolTimfunc)

The differential equation solution timing function (or DeSolTimfunc) describes how finely/coarsely (in time) the differential equations are solved. Only functions that include the term 'DesignTest' can be selected within the context of Yarnball design.

5.5.1. DeSolTim_YarnBallLookupDesignTest_v1d

'DeSolTim_YarnBallLookupDesignTest_v1d' is the standard function for creating a Yarnball design. However, if the length of the trajectory becomes too long (i.e. too many winds) this function will give an error that says: "Try alternative 'DeSolTim' function". In this case select the function described below.

5.5.2. DeSolTim_YarnBallLookupDesignTestLongTraj_v1d

'DeSolTim_YarnBallLookupDesignTestLongTraj_v1d' will take longer to solve than the function above. However, if a Yarnball trajectory contains many winds this function may be necessary. There is no adverse consequence if this function is used to design Yarnball trajectories with only a few winds (only an increase in processing time).

5.6. The Timing Adjust Function (TimingAdjustfunc)

The timing adjust function (or TimingAdjustfunc) describes how the Yarnball trajectory solution time segments will be modified to achieve a desired gradient slew rate (or level of peripheral nerve stimulation). Only functions that include the term 'DesignTest' can be selected within the context of Yarnball design.

5.6.1. TimingAdjust_DesignTest_v1a

'TimingAdjust_DesignTest' is currently the only function available for Yarnball design selection on GitHub. This function will constrain the Yarnball waveform to a constant gradient slew rate and provide a value for the output parameter **BestCaseMaxSlew** (in mT/m). If this value is above the maximum slew rate of the scanner, this trajectory cannot be implemented. This value may need to be considerably smaller than the maximum slew rate of the scanner to facilitate scanning under PNS stimulation constraint.

5.7. The Design Type Function (DesTypefunc)

The design type function (or DesTypefunc) facilitates different types of Yarnball sampling. In the future, multi-echo spin-in/out functions will be added here as these papers are published.

5.7.1. DesType_YarnBallOutSingleEcho_v1b

'DesType_YarnBallOutSingleEcho_v1b' is currently the only function available for Yarnball design selection on GitHub. This function facilitates standard Yarnball implementation from the centre of k-

space outward and ends at the edge of k-space. This function calls the design test function (DesTestfunc) below.

5.7.1.1. DesTest_YarnBallOutSingleEchoStandard_v1c

‘DesTest_YarnBallOutSingleEchoStandard_v1c’ generates an output figure and information for the Info panel.