Yarra Framework – Open-Source Toolkit for Clinical-Translational MRI Research

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Introduction: Over the last decade, many promising reconstruction-based techniques for accelerating or enhancing MRI scans have been proposed, including Compressed Sensing, MR Fingerprinting, or Deep Learning-type methods. However, due to the high algorithmic complexity and significant computational demand, implementing such algorithms on existing clinical MRI hardware is very challenging and oftentimes infeasible for researchers. As consequence, only a few of these approaches have found their way into clinical practice.

The Yarra Framework is an open-source toolbox intended to bridge this gap and facilitate rapid clinical translation of advanced MRI reconstruction techniques. It comprises a set of tools that can be used either together or independently if only certain functionality is needed. Currently, support is limited to Siemens MRI systems.

Raw Data Collection and Management: *Yarra Raw Data Service* (RDS) offers automatic collection of raw k-space data. It runs as background process on the host computers of the MRI scanners and performs a nightly export of raw data from the desired scan protocols into separate project folders on a network share or USB drive. This enables creating extensive libraries of raw data from routine exams without need to access the scanners during clinical work hours. *Yarra Archive Search* (YAS) can be used to index large amounts of collected cases. It provides a convenient web interface that allows searching for cases by project, sequence, or patient information and shows the storage location of the corresponding raw data files.

Clinical Workflow Analysis: The Yarra RDS software also facilitates collecting workflow information from the scanners. When used in combination with *Yarra LogServer*, RDS transfers data on all executed sequences and adjustments hourly to an intranet server where the information is aggregated and stored in a relational database. Existing business intelligence tools can be used to analyze the workflow and create customized dashboards and visualizations. This enables easy calculation of performance indicators, such as scanner utilization, exam durations and efficiencies, patient turnaround times, and sequence repetitions. It also simplifies monitoring research scans across the enterprise. Moreover, LogServer can be connected to additional data sources such as scheduling, dictation, or EMR systems.

Offline Reconstruction Pipeline: *YarraServer* automates offline reconstructions on external Linux servers and enables integration of reconstruction prototypes into the clinical workflow with minimal effort. Cases can be submitted with two mouse-clicks from MRI scanners with the *Yarra Offline Reconstruction Task* (ORT) client, or from workstations with the *Yarra Stand-Alone Client* (SAC). The reconstruction prototypes can be implemented using any programming language running under Linux, ranging from Matlab over Python to C++, or using existing frameworks like BART, Gadgetron, and TensorFlow. Yarra servers can be monitored and controlled using the web-based *Yarra WebGUI*, which includes an interface for configuring reconstruction settings and a packaging system for simple installation of additional processing modules. Moreover, Yarra features a load-balancing and routing mechanism for distributing jobs across multiple servers, as well as an email notification system.

Cloud-Based Reconstruction Service: *YarraCloud* is a cloud-based service that allows performing offline reconstructions without need to install and operate local servers. Built on the YarraServer software and seamlessly integrated into the Yarra ORT and SAC clients, it enables researchers to offer prototypes to collaboration sites that don't have the required technical knowledge or funds available to setup on-premise Linux servers. YarraCloud runs on Amazon Web Services (AWS) and meters utilized compute resources for every user. Patient health information (PHI) is removed prior to upload and reinserted before storing results in PACS. User information, storage locations, and reconstruction settings are configured through an admin interface.

Summary: Yarra is a collection of open-source software tools developed to simplify the process of evaluating and translating novel MRI reconstruction techniques into clinical practice. It can be downloaded free-of-charge from http://yarraframework.com. Information on YarraCloud can be found at http://yarracloud.com.