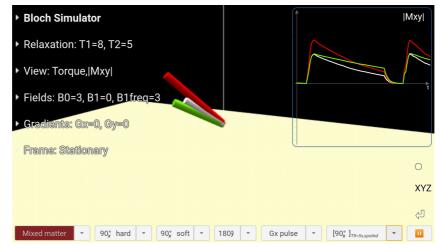# Interactive MR simulation in a browser: Flexible reimplementation of the educational *Bloch Simulator*

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Introduction: The free, open-source *Bloch Simulator* [1,2] for 3D visualization of spin physics and MRI methods is widely used (~9000 annual page loads). With the discontinued support of Flash/ActionScript web technologies, a complete rewrite became imperative. A new version based on the web standard HTML5/JavaScript[3] was made. In addition to using widely supported modern web technologies, it offers ease of use and much improved flexibility, even on small devices like smartphones. This is of importance for student use during lectures, for example.

Methods: Unlike most MR simulators, the *Bloch Simulator* is focused on interactive 3D visualization of the evolution of spin isochromates [4] directly in standard web browsers. To meet the needs in early technical MR education, simplicity is chosen over flexibility, though it is also suited for discussion of advanced concepts. The web standard HTML5 [3] is widely supported and offers the ingredients needed to address the wide variety of use cases, including the many physical displays employed by the target users (e.g. smartphones, laptops) providing different computational capabilities also. There are important differences between browsers, however, and the primary development challenge was to make simulation and visualization flexible and appealing in most relevant environments. The new implementation is conceptually close to that of the original Bloch Simulator [1]. The aptness of some of the employed web technologies were tested in related, but smaller software projects, e.g., http://drcmr.dk/CompassMR/. The library *dat.gui* was used for UI implementation (http://github.com/dataarts/dat.gui/). *Three.js* is the main 3D graphics engine, offering hardware acceleration when available (http://threejs.org/). These libraries can be bundled with the simulator to ease offline use. The reimplementation [5, Figure 1] offered an option to extent the functionality, even with a simplified user interface. The new software options include multidimensional samples, adjustable gradients, configurable viewing, 3D navigation, and more.

Figure 1. The Bloch Simulator, http://drcmr.dk/BlochSimulator, can be used to explore relaxation time weigting interactively, for example. Three isochromates with different T1 and T2s are excited.

Discussion: The new implementation [5] solved the problem of vanishing browser support of dated web technologies, but introduced limited browser dependencies. The simulator is open-source. In the primary tested setup, it works as intended, with many improvements over the prior version.

References: [1] Hanson LG, A Graphical Simulator for Teaching Basic and Advanced MR Imaging Techniques, RadioGraphics 27, *https://pubs.rsna.org/doi/10.1148/radiographics.27.6.e27, 2007.* [2] Hanson LG, The Bloch Simulator: Interactive MR physics directly in a browser, Proceedings of the ESMRMB annual meeting, 2011. [3] HTML5, W3C Recommendation, 2014. ECMAScript Language Specification, ECMA International, 1997-2019 [4] Bloch F, Nuclear induction, Phys Rev 70:460-73, 1946. [5] http://www.drcmr.dk/bloch, Tutorials, videos, downloads.