

A tour with Constructive Real Numbers

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Abstract. The aim of this work is to characterize constructive real numbers through a minimal axiomatization. We introduce, discuss and justify 16 constructive axioms. Then we address their expressivity considering the alternative axiomatizations.

1 Overview of the work

Real numbers are classically defined as a complete ordered field, but this is not the case in a constructive logic setting: actually the totality of order is not a constructive property.

This work tries to understand (again) constructive real numbers. Our main contribution is a new system of axioms, synthesized with the aim of being minimal, i.e. of assuming the least number of primitive notions and properties. Such a system is consistent with respect to reference models we have in mind — (equivalence classes of) Cauchy sequences [TvD88] and co-inductive streams of digits [CDG00] — and will be compared to other proposals in the literature [Br99, GPWZ00]. The expressive power of the axioms will be addressed in order to guarantee that a sufficient part of the constructive analysis can be derived from them.

We define constructive real numbers through sixteen axioms organized in four groups: arithmetic operations, ordering, Archimedes' postulate and completeness. Our axiomatization uses only three basic concepts: addition (+), multiplication (\times) and strict order (<).

In most of the constructive approaches to analysis [Br97, Bee85, Wei00] real numbers are defined as a quotient of a set of representations (e.g. equivalence classes of Cauchy sequences, digit expansions, etc.). It follows that also in an axiomatic approach it is necessary to see the reals as a set provided with an equivalence relation. In our proposal, this equivalence relation (\sim) is not a primitive notion, but it is derived together with its fundamental properties through the strict order relation. We define the equivalence by $(x \sim y) \triangleq \neg((x < y) \vee (y < x))$; the fact that the equivalence relation is preserved by the arithmetic operations follows from the following axioms, which reverse the usual perspective:

$$\begin{aligned}(x + z < y + z) &\rightarrow (x < y) \\(x \times z < y \times z) &\rightarrow (x < y) \vee ((y < x) \wedge (z < 0))\end{aligned}$$

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