

bas.1 Dense Linear Orders

Definition bas.1. A dense linear ordering without endpoints is a structure \mathfrak{M} for the language containing a single 2-place predicate symbol $<$ satisfying the following sentences:

1. $\forall x x < x$;
2. $\forall x \forall y \forall z (x < y \rightarrow (y < z \rightarrow x < z))$;
3. $\forall x \forall y (x < y \vee x = y \vee y < x)$;
4. $\forall x \exists y x < y$;
5. $\forall x \exists y y < x$;
6. $\forall x \forall y (x < y \rightarrow \exists z (x < z \wedge z < y))$.

mod:bas:dlo: **Theorem bas.2.** Any two enumerable dense linear orderings without endpoints are isomorphic.
thm:cantorQ

Proof. Let \mathfrak{M}_1 and \mathfrak{M}_2 be enumerable dense linear orderings without endpoints, with $<_1 = <^{\mathfrak{M}_1}$ and $<_2 = <^{\mathfrak{M}_2}$, and let \mathcal{I} be the set of all partial isomorphisms between them. \mathcal{I} is not empty since at least $\emptyset \in \mathcal{I}$. We show that \mathcal{I} satisfies the Back-and-Forth property. Then $\mathfrak{M}_1 \simeq_p \mathfrak{M}_2$, and the theorem follows by ??.

To show \mathcal{I} satisfies the Forth property, let $p \in \mathcal{I}$ and let $p(a_i) = b_i$ for $i = 1, \dots, n$, and without loss of generality suppose $a_1 <_1 a_2 <_1 \dots <_1 a_n$. Given $a \in |\mathfrak{M}_1|$, find $b \in |\mathfrak{M}_2|$ as follows:

1. if $a <_2 a_1$ let $b \in |\mathfrak{M}_2|$ be such that $b <_2 b_1$;
2. if $a_n <_1 a$ let $b \in |\mathfrak{M}_2|$ be such that $b_n <_2 b$;
3. if $a_i <_1 a <_1 a_{i+1}$ for some i , then let $b \in |\mathfrak{M}_2|$ be such that $b_i <_2 b <_2 b_{i+1}$.

It is always possible to find a b with the desired property since \mathfrak{M}_2 is a dense linear ordering without endpoints. Define $q = p \cup \{(a, b)\}$ so that $q \in \mathcal{I}$ is the desired extension of p . This establishes the Forth property. The Back property is similar. So $\mathfrak{M}_1 \simeq_p \mathfrak{M}_2$; by ??, $\mathfrak{M}_1 \simeq \mathfrak{M}_2$. \square

Problem bas.1. Complete the proof of Theorem bas.2 by verifying that \mathcal{I} satisfies the Back property.

Remark 1. Let \mathfrak{S} be any enumerable dense linear ordering without endpoints. Then (by Theorem bas.2) $\mathfrak{S} \simeq \mathfrak{Q}$, where $\mathfrak{Q} = (\mathbb{Q}, <)$ is the enumerable dense linear ordering having the set \mathbb{Q} of the rational numbers as its domain. Now consider again the structure $\mathfrak{R} = (\mathbb{R}, <)$ from ??. We saw that there is an enumerable structure \mathfrak{S} such that $\mathfrak{R} \equiv \mathfrak{S}$. But \mathfrak{S} is an enumerable dense linear

ordering without endpoints, and so it is isomorphic (and hence elementarily equivalent) to the **structure** \mathfrak{Q} . By transitivity of elementary equivalence, $\mathfrak{R} \equiv \mathfrak{Q}$. (We could have shown this directly by establishing $\mathfrak{R} \simeq_p \mathfrak{Q}$ by the same back-and-forth argument.)

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Bibliography