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# Rigorous bounds on irrelevant operators in the 3d Ising model CFT

The central problem in the numerical conformal bootstrap is finding isolated allowed regions in some subspace of the potential CFT data and to determine the boundaries of these regions. These bounds on the allowed CFT data can be translated into rigorous bounds on physically observable quantities such as the critical exponents controlling the behavior of second order phase transitions.

Until recently the numerical conformal bootstrap mainly used feasibility tests which only tell whether a certain assumption on the CFT data can be excluded or not. However, if a point is excluded this test gives no information on where a feasible point might be found. Or in the case where an allowed point is found it says nothing about where the boundary separating this allowed region from the disallowed region is located. Therefore, using such a feasibility test, a sufficiently dense grid needs to be tested in order to find an allowed point and triangulations or bisections are subsequently required to determine the shape of the connected allowed region. The number of tests required for these tasks grows exponentially with the dimensionality of the search space. Using these techniques the numerical conformal bootstrap is thus restricted to problems involving only very few parameters.

Recently a new navigator method was introduced for the numerical conformal bootstrap (M. Reehorst, S. Rychkov, D. Simmons-Duffin, B. Sirois, N. Su, and B. van Rees, 2021). In this navigator method the binary 'feasible'/'infeasible' test is replaced with a navigator function that gives a continuous measure of success; negative values correspond to an allowed point and positive values correspond to a disallowed point. It was also shown that the gradient of this navigator function can cheaply be computed once the function itself has been computed. By minimizing the navigator an allowed point can efficiently be found. Similarly constrained optimization algorithms allow for efficient determinations of the boundaries of the allowed region.

We applied this method to the 3d Ising CFT in order to obtain rigorous bounds on heretofore unknown OPE data. For example, assuming that there are only two Z2-even scalar operators $\epsilon$ and $\epsilon'$ with a dimension below 6 we find a narrow allowed interval for $\Delta\epsilon'$, $\lambda\sigma\sigma\epsilon'$ and $\lambda\epsilon\epsilon\epsilon'$. With similar assumptions in the Z2-even spin-2 and the Z2-odd scalar sectors we are also able to constrain: the central charge cT; the OPE data $\Delta T'$, $\lambda\epsilon\epsilon T'$ and $\lambda\sigma\sigma T'$ of the second spin-2 operator; and the OPE data $\Delta\sigma'$ and $\lambda\sigma\epsilon\sigma'$ of the second Z2-odd scalar. We compare the rigorous bounds we find with estimates that have been previously obtained using the extremal functional method (EFM) and find a good match. This is an important test because it validates the EFM and it shows the navigator-search method to be a feasible and more rigorous alternative for estimating a large part of the low-dimensional operator spectrum. We also investigate the effect of imposing sparseness conditions on all sectors at once. We find that the island does not greatly reduce in size under these assumptions. We efficiently find islands and determine their size in high-dimensional parameter spaces (up to 13 parameters). This shows that using the navigator method the numerical conformal bootstrap is no longer constrained to the exploration of small parameter spaces.

## Type of contribution

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