Parameterized complexity of reconfiguration of atoms

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Our work is motivated by the challenges presented in preparing arrays of atoms for use in quantum simulation. The recently-developed process of loading atoms into traps results in approximately half of the traps being filled. To consolidate the atoms so that they form a dense and regular arrangement, such as all locations in a grid, atoms are rearranged using moving optical tweezers. Time is of the essence, as the longer that the process takes and the more that atoms are moved, the higher the chance that atoms will be lost in the process. Viewed as a problem on graphs, we wish to solve the problem of reconfiguring one arrangement of tokens (representing atoms) to another using as few moves as possible. Because the problem is NP-complete on general graphs as well as on grids, we focus on the parameterized complexity for various parameters, considering both undirected and directed graphs, and tokens with and without labels. For unlabelled tokens, the problem is in FPT when parameterized by the number of tokens, the number of moves, or the number of moves plus the number of vertices without tokens in either the source or target configuration, but intractable when parameterized by the difference between the number of moves and the number of differences in the placement of tokens in the source and target configurations. For labelled tokens, most of the tractability results are replaced by hardness results.