

# <sup>1</sup> stl2sdf: Parallel scalable signed-distance-field generator for arbitrary cartesian grids

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## Software

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## <sup>8</sup> Summary

<sup>9</sup> In this paper, we present a message-passing interface (MPI) based signed distance field (SDF)  
<sup>10</sup> utility for fluid flow simulations over arbitrary Cartesian grids. Computing non-degenerate  
<sup>11</sup> SDF for large grids (order 10 Million or greater grid count) can take anywhere from 10 minutes  
<sup>12</sup> to hours in serial. To solve this issue, we developed a scalable Python-based code that can  
<sup>13</sup> accurately and efficiently compute the SDF over cartesian grids as large as 2 Billion grid points.

## <sup>14</sup> Statement of need

<sup>15</sup> Urban fluid flow simulations have become increasingly appealing and viable due to the  
<sup>16</sup> accelerated growth and accessibility in Graphics Processing Units (GPU)-based computing  
<sup>17</sup> platforms as demonstrated by the development of GPU-based Computational Fluid Dynamics  
<sup>18</sup> (CFD) codes such as Muñoz-Esparza et al. (2020) and Costa (2018). These CFD codes use  
<sup>19</sup> an Immersed Boundary Method (IBM) to introduce a solid interface within the Cartesian  
<sup>20</sup> computational domain. One flavour of the IBM method that was originally introduced by Yang  
<sup>21</sup> & Balaras (2006) can be easily implemented using SDF. For urban flow simulations and other  
<sup>22</sup> high-Reynolds number simulations, the grid requirements can easily reach large numbers e.g.,  
<sup>23</sup> order Billion grid points, as a result, these simulations require SDF computations over such a  
<sup>24</sup> Cartesian grid that prove to be unfeasible when done in serial.

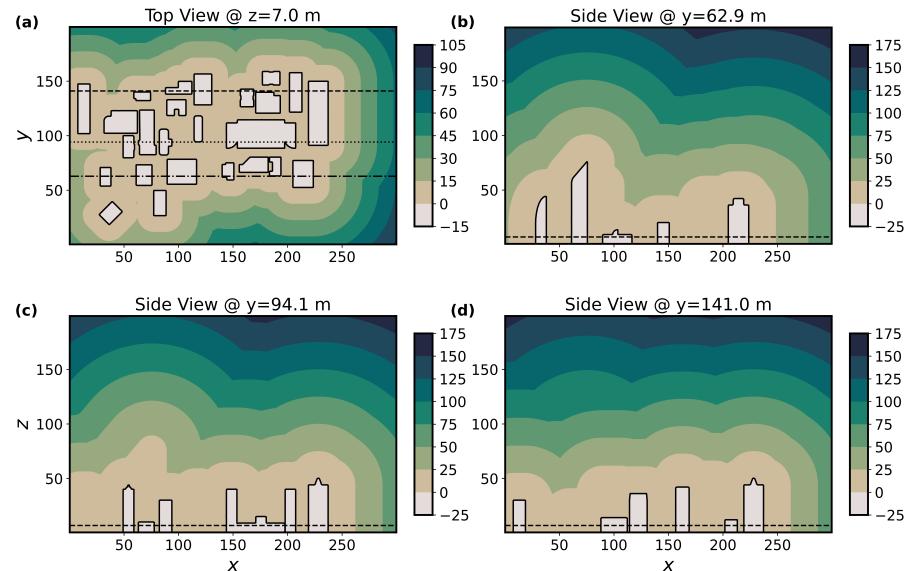
<sup>25</sup> stl2sdf was designed with the CFD users in mind that generally have access to high-  
<sup>26</sup> performance computing (HPC) computing clusters and can leverage the use of MPI-based  
<sup>27</sup> speed up. We have thoroughly tested stl2sdf on various different geometries, such as urban  
<sup>28</sup> landscapes and coral beds, to demonstrate the versatile application of this utility. The code  
<sup>29</sup> is based on mpi4py, mesh\_to\_sdf, and trimesh libraries that are freely available for Python  
<sup>30</sup> users from standard repositories. Our code has been extensively tested on various geometries  
<sup>31</sup> such as urban landscape as shown in [Figure 1](#) and coral beds as shown in [Figure 2](#).

## <sup>32</sup> Methodology

<sup>33</sup> The central idea of the SDF computation in this code is to utilise the existing mesh\_to\_sdf  
<sup>34</sup> Python library and port it to an MPI-based framework. This code uses the sampling method  
<sup>35</sup> to compute the SDF where the numerical grid over which the SDF is computed is decomposed  
<sup>36</sup> using a 1D slab decomposition (i.e., the x coordinate is split into chunks). As for the  
<sup>37</sup> geometry (stl/obj file), each processor holds a copy, thus leading to a relatively larger memory  
<sup>38</sup> requirement. Consequently, this ends up being the most memory-intensive part of the program.  
<sup>39</sup> It is important to realise that decomposing the geometry file can lead to other bottlenecks

in the algorithm. Since most CFD users will have access to larger computing facilities, the memory requirements are not demanding. The input for the code can be provided through the supported file formats within the trimesh library. However, we recommend the stl and obj file formats. For applications where the SDF computation is required to be computed only close to the geometry, such as urban fluid dynamics simulations and heterogenous roughness of fixed height, the clipSDF user flag can expedite the SDF computation by not computing the SDF far away from the bottom wall thus further accelerating the usability of stl2sdf. Our MPI-version of the SDF generator would be the first of its kind utilising a well-known SDF computation library mesh\_to\_sdf, and porting it to a parallel version, thereby making it operational for more CFD users and codebases that rely on computing accurate SDF's.

## Figures



**Figure 1:** SDF field generated using stl2sdf for an urban landscape. Horizontal lines in panel (a) correspond to the locations of panels (b), (c), and (d).

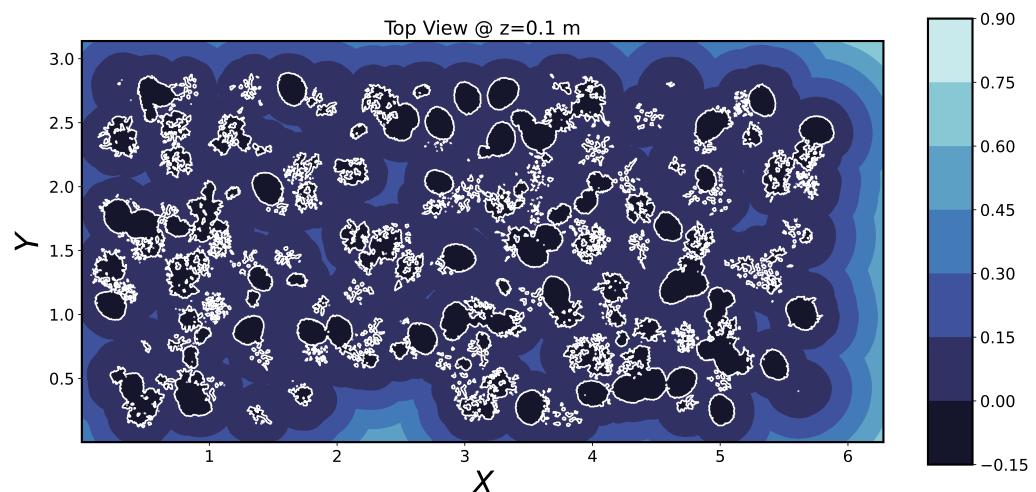


Figure 2: SDF field generated using `stl2sdf` for stochastically generated coral bed.

## 51 Acknowledgments

52 AP would like to thank the support and computing resources within the 3D-Geoinformation  
53 research group that enabled the development and testing of `stl2sdf`.

## 54 References

- 55 Costa, P. (2018). A FFT-based finite-difference solver for massively-parallel direct numerical  
56 simulations of turbulent flows. *Computers & Mathematics with Applications*, 76(8),  
57 1853–1862.
- 58 Muñoz-Esparza, D., Sauer, J. A., Shin, H. H., Sharman, R., Kosović, B., Meech, S., García-  
59 Sánchez, C., Steiner, M., Knievel, J., Pinto, J., & Swerdlin, S. (2020). Inclusion of  
60 building-resolving capabilities into the FastEddy® GPU-LES model using an immersed body  
61 force method. *Journal of Advances in Modeling Earth Systems*, 12(11), e2020MS002141.
- 62 Yang, J., & Balaras, E. (2006). An embedded-boundary formulation for large-eddy simulation  
63 of turbulent flows interacting with moving boundaries. *Journal of Computational Physics*,  
64 215(1), 12–40.