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Dividing local Gaussian processes for particle physics applications

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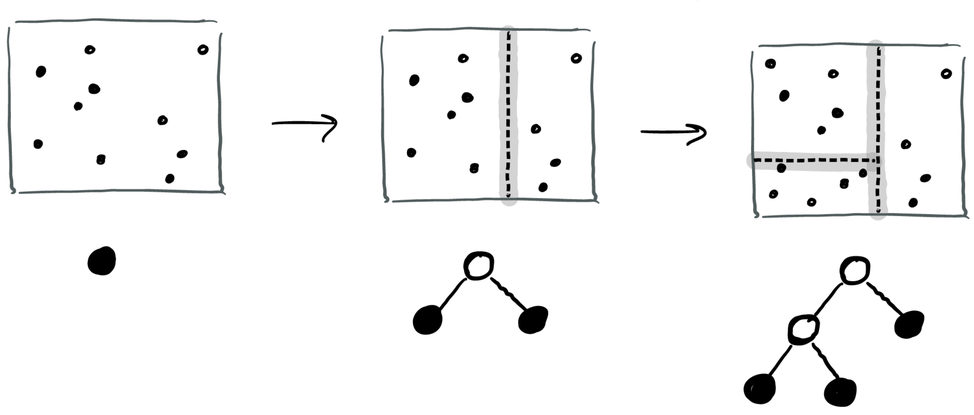
Introduction

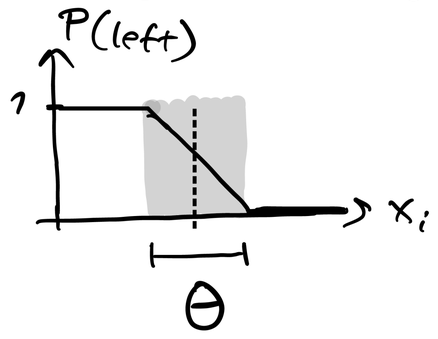
- Theoretical particle physicist develop models to explain particle interactions on a fundamental level
- Verifying models requires time-consuming simulations of large $\mathcal{O}(10)$ GB data sets
  $\rightarrow$ need way of speeding computation of likelihood L up
- Long data stream makes single Gaussian Process (GP) infeasible due to inversion of large covariance matrix
- **Goal**: modify dividing local Gaussian processes (DLGP) to replace costly physics calculations & create an R package

Method

- General idea of DLGP: grow a tree of many small GPs
- Start by adding one point at a time to a GP until size cap $\bar{N}$ is reached
- Next, split it into two GPs with approx. $\bar{N}/2$ points each:



- Input space becomes gradually partitioned
- Perform probabilistic assignment of points near adjacent GPs:

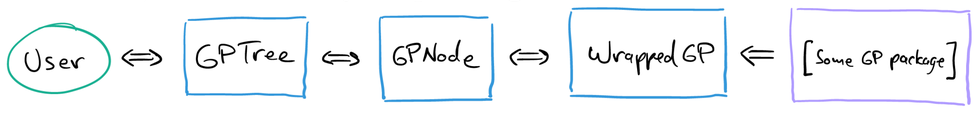


References

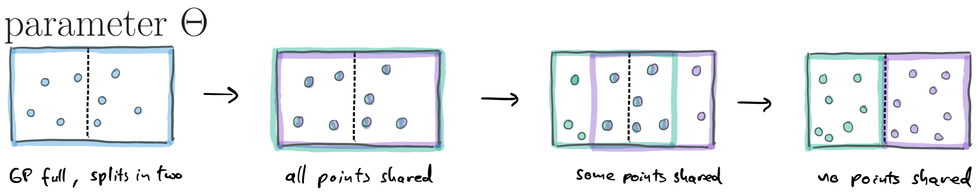
- Lederer, A., Conejo, A. J. O., Maier, K., Xiao, W., Umlauft, J., & Hirche, S. (2020). Real-time regression with dividing local Gaussian processes. *arXiv preprint arXiv:2006.09446*.
- GAMBIT Collaboration: Ananyev, V., Balázs, C. et al (2023). Collider constraints on electroweakinos in the presence of a light gravitino. *arXiv preprint arXiv:2303.09082*.

Improvements / changes from DLGP

- Modular, user-friendly R package



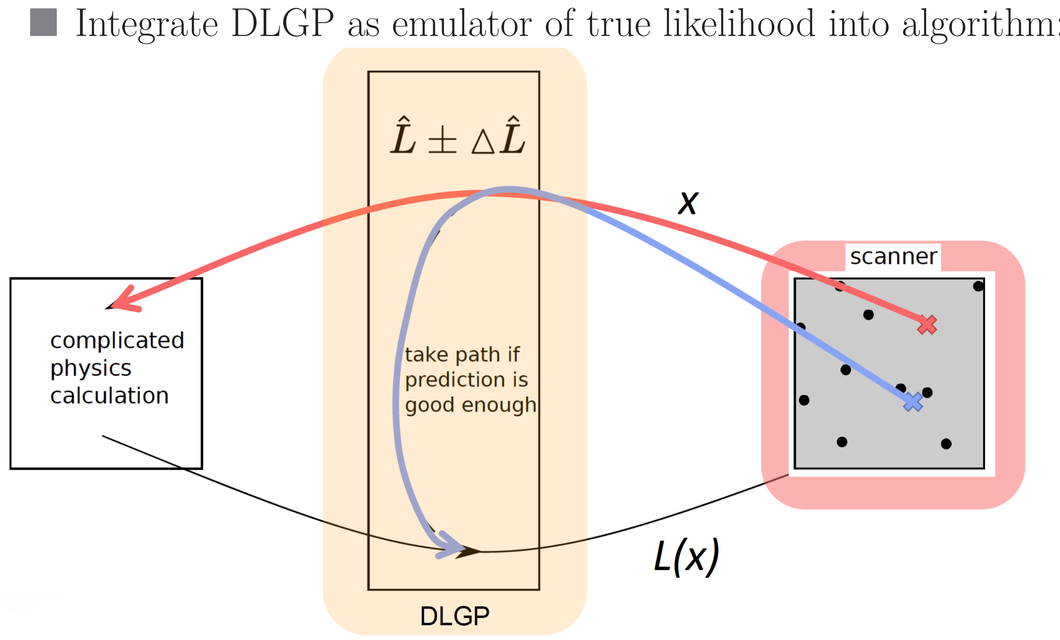
- User can choose number of hyper-parameters updates
- Numerous and more sophisticated ways to determine the "split direction"
- Introducing "gradual split" allows for removal of overlap parameter Θ



Application & Example

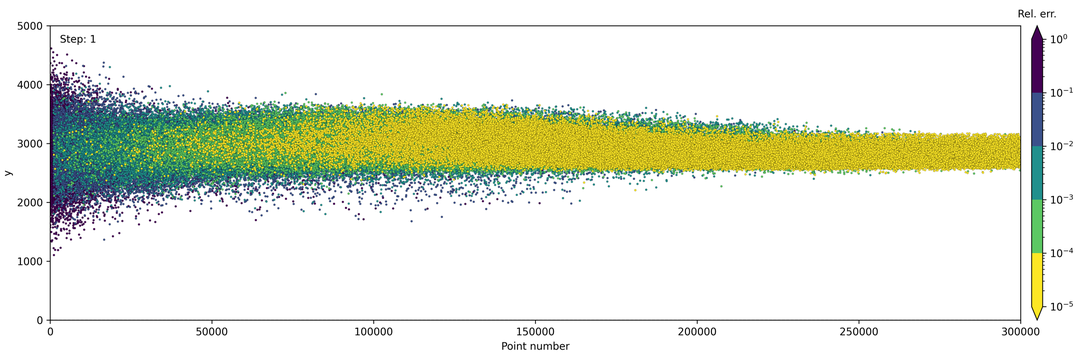
Application:

- Integrate DLGP as emulator of true likelihood into algorithm:



Example:

- Apply diff. evolution sampler to explore 4D Rosenbrock function (simulating the "likelihood")
- Evaluate 4D Eggholder function for each point (simulating the "expensive physics computation")
- GPTreeO configuration: $\bar{N} = 1000$, Matérn kernel ($\nu = 3/2$)



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References:
[1] Lederer, A., Conejo, A. J. O., Maier, K., Xiao, W., Umlauft, J., & Hirche, S. (2020). Real-time regression with dividing local Gaussian processes. *arXiv preprint arXiv:2006.09446*
[2] GAMBIT Collaboration: Ananyev, V., Balázs, C. et al (2023). Collider constraints on electroweakinos in the presence of a light gravitino. *arXiv preprint arXiv:2303.09082*