Final Report for Period: 09/2009 - 08/2010
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Organization: GA Tech Res Corp - GIT

Submitted By:
Huo, Xiaoming - Principal Investigator

Title:
Fundamentals and Applications of Connect-the-Dots Methods

Project Participants

Senior Personnel
Name: Huo, Xiaoming
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Tovey, Craig
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student
Name: Chen, Jie
Worked for more than 160 Hours: No
Contribution to Project:
GRA for one semester from this project.

Name: Smith, Andrew
Worked for more than 160 Hours: No
Contribution to Project:
GRA for one semester in Spring 2008.

Name: Kim, Heeyoung
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Shepardson, Dylan
Worked for more than 160 Hours: Yes
Contribution to Project:

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates
Research and Education Activities:
We studied the dynamic programming approach for the connect-the-dots (CTD) problems. Numerical experiments were carried out. Some research findings have been written in a research report that is released online. Four graduate students have been involved in various stages of this project. Since the beginning of this project, nine published journal papers and five submitted journal papers are produced. Not all of them are on the CTD problems. However, all involves dynamic programming and optimization. All of these papers are coauthored with PhD students. Research activities also include releasing a software package online.

Findings:
On the CTD problems, we use the multiscale idea to develop some fast algorithms for the CTD problems. Some proposed algorithms have the best order of complexity that we know of. Efficient implementation in computer has been done. The technical report (TR) that was released online includes most of the results we have obtained so far. The URL is provided. We summarize our findings below.
1. We describe the dynamic programming as a generic approach to solve various connect-the-dots problems. These problems may involve functional classes such as increasing functions, unimodal functions, Holder functions, convex functions, and so on. We point out some connections between the CTD problems associated with different functional classes. For example, we found that the unimodal functional class is as hard to process as the increasing functional class, which consequently is as hard to process as the Lipschitz functional class.
2. We further demonstrate that the direct application of the dynamic programming is not very efficient. Instead, one can utilize the multiscale (AKA divide and conquer) approach to reduce the required computational complexity significantly. For example, a direct application of dynamic programming in the increasing function gives an order $O(n^2)$ algorithm. The multiscale strategy can reduce the complexity to $O(n \log n)$.
3. A new dynamic programming algorithm for the Holder-2 graphs is developed: the algorithm is nontrivial, and to our knowledge is in its first appearance. Our computational experiments indicate that the algorithm is very efficient and potentially has low order of average complexity. We have not been able to prove the theoretical complexity for that algorithm. This is a work ongoing.
4. The problem of directional data, which is named the connect-the-darts problem, is explicitly solved for the first time in the aforementioned TR. Several interesting conjectures are drawn, motivated by simulations. This problem has interesting connection with neural science. We discussed the connection in the TR.
5. We also use the above numerical algorithms to study the possible theoretical/analytical distributions on the solution. For
example, we studied the empirical number of the dots linked by an increasing function within a uniformly distributed point cloud. The asymptotic distribution in this case is known. Our simulations confirm these distributional analyses. We made some new conjectures corresponding to our own simulation studies. This project has spawned the following outputs. They are not exactly the aforementioned CTD problems, however the methodology that applied shares many commonalities. We have studied the relation between the computational problem in CTD and the detectability problem. Some findings are reported in a paper published in Statistic Sinica—a top 10 journal in statistics. We have studied how to utilize the multiscale approaches to expedite the dynamic programming algorithms in solving the shortest path problems. In theoretical analysis, we showed that the multiscale strategy can reduce the computational order of complexity. In simulations, we observed that the improvement is even better than prediction based on the theoretical analysis. Two submitted papers are under revision. We have also studied various statistical and computational problems, which either utilized dynamic programming, or optimization. It has resulted in several papers published or under revision.

Training and Development:

Students gain research experience by working with us and writing papers together.

Outreach Activities:

Journal Publications


Huo, XM; Ni, XL, "DETECTABILITY OF CONVEX-SHAPED OBJECTS IN DIGITAL IMAGES, ITS FUNDAMENTAL LIMIT AND MULTISCALE ANALYSIS", STATISTICA SINICA, p. 1439, vol. 19, (2009). Published,


Books or Other One-time Publications

Bibliography: NIPS

Bibliography: Visual Communications and Image Processing (VCIP)

Bibliography: 49th IEEE Conference on Decision and Control

Web/Internet Site

URL(s):
http://www2.isye.gatech.edu/statistics/papers/07-07.pdf

Description:
Technical report online:
Huo, Xiaoming, Tovey, Craig, Donoho, David L. and Arias-Castro, Ery DYNAMIC PROGRAMMING METHODS FOR CONNECT THE DOTS" IN SCATTERED POINT CLOUDS.

This paper reports recent works on the algorithms that are related to CTD.
**Other Specific Products**

**Product Type:**
Software (or netware)

**Product Description:**
We developed a comprehensive software package that is related to the CTD problems. We have released it online.

**Sharing Information:**
A version has been released online at http://www2.isye.gatech.edu/~xiaoming/CTDLab/.

**Contributions**

**Contributions within Discipline:**
Many of those dynamic programming algorithms that are developed in the online technical report are new. The insights in extensive simulations may lead to new discovery in theory. The resulting publications contribute to various problems that involve optimization and dynamic programming.

**Contributions to Other Disciplines:**
The CTD problems have connections with probability theory, geometric discrepancy theory, filament detection, vision research, batched disk scheduling, and airplane boarding, as described in our proposal. Our results have potential impacts there.

**Contributions to Human Resource Development:**
Four PhD students were supported in various stages of their graduate study. They have gained experience via coauthoring papers with the PIs.

**Contributions to Resources for Research and Education:**
The online software will be useful to others who are interested in these problems that we have studied.

**Contributions Beyond Science and Engineering:**

**Conference Proceedings**

**Categories for which nothing is reported:**
Organizational Partners
Activities and Findings: Any Outreach Activities
Contributions: To Any Beyond Science and Engineering
Any Conference