A Machine Learning-Enabled Study of Superconductivity

Raieev At

Introduction

Ittioductioi

Ginzburg-Landau Theor

Superconductivity

Data

Method

Discussion

Conclusion

References

Acknowledgements

A Machine Learning-Enabled Study of Superconductivity

Application of the XGBoost Algorithm

Rajeev Atla

John P. Stevens High School

July 24, 2020

Outline

A Machine Learning-Enabled Study of Superconductivity

Rajeev At

Introduction

XGBoos

nzburg-Landau Theory

Data

Method

Discussion

- Introduction
 - XGBoost
 - Ginzburg-Landau Theory
 - Superconductivity
- 2 Data
- Methods
- Discussion
- Conclusion
- 6 References
- Acknowledgements

XGBoost

A Machine Learning-Enabled Study of Superconductivity

XGBoost

Ginzburg-Landau Theo

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Method

Disamaian

Acknowledgement

eXtreme Gradient Boosting

XGBoost

A Machine Learning-Enabled Study of Superconductivity

Painou Atl

ntroductioi

XGBoost Ginzburg-Landau Theo

Superconductivity

Date

Method

Discussion

Conclusio

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- eXtreme Gradient Boosting
- Package for Python, C++, Java, R, Julia, and Scala

XGBoost

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atl

ntroduction

XGBoost

Ginzburg-Landau Theo

Date

Metho

Discussio

Conclusio

References

eXtreme Gradient Boosting

- Package for Python, C++, Java, R, Julia, and Scala
- Was used to process data from Large Hadron Collider (LHC) [Chen 2015]

XGBoost

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atl

Introduction XGBoost

Ginzburg-Landau Theo

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Method

Discussion

Conclusio

References

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XGBoost

A Machine Learning-Enabled Study of Superconductivity

Rajeev At

XGBoost

Ginzburg-Landau Theo

Data

Method

Discussion

Conclusion

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- Ensemble learning [Elements of Statistical Learning Chapter 16]

XGBoost

A Machine Learning-Enabled Study of Superconductivity

Rajeev At

XGBoost
Ginzburg-Landau The

Ginzburg-Landau Theo uperconductivity

Dat

Method

Discussion

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 - Combination of homogenous weak learners

XGBoost

A Machine Learning-Enabled Study of Superconductivity

Rajeev At

XGBoost

Ginzburg-Landau Theo

Data

Method

Discussion

Doforono

Acknowledgement

eXtreme Gradient Boosting

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 - Won the Higgs Boson Machine Learning Challenge
- Ensemble learning [Elements of Statistical Learning Chapter 16]
 - Combination of homogenous weak learners
 - End result is a weighted sum of weak learners

$$\theta_f = \sum_j w_j \theta_j$$

Ginzburg-Landau Theory

A Machine Learning-Enabled Study of Superconductivity

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Introduction

Ginzburg-Landau Theory

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Data

Methods

Discussion

Conclusio

References

Ginzburg-Landau Theory

A Machine Learning-Enabled Study of Superconductivity

Raieev Atl

Introduction

Ginzburg-Landau Theory

Masha

Discussion

Conclusio

References

Acknowledgement

 For a homogenous superconductor, the Ginzburg-Landau equation is

$$\alpha\phi + \beta|\phi|^2\phi = 0$$

Ginzburg-Landau Theory

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atla

Introduction

Ginzburg-Landau Theory

D-4.

Metho

Discussion

Conclusio

Acknowledgement

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$$\alpha\phi + \beta|\phi|^2\phi = 0$$

• The nontrivial solution for $T < T_c$ is

$$|\phi|^2 = -\frac{\alpha}{\beta} (T - T_c)$$

Ginzburg-Landau Theory

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atla

Introduction XGBoost

Ginzburg-Landau Theory

Date

Metho

Discussion

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Referenc

Acknowledgement

 For a homogenous superconductor, the Ginzburg-Landau equation is

$$\alpha\phi + \beta|\phi|^2\phi = 0$$

• The nontrivial solution for $T < T_c$ is

$$|\phi|^2 = -\frac{\alpha}{\beta} \left(T - T_c \right)$$

• The characteristic length scale ξ is called the Ginzburg-Landau coherence length

$$\xi = \sqrt{\frac{\hbar^2}{2m^*|\alpha|}}$$

Types of Superconductors

A Machine Learning-Enabled Study of Superconductivity

Raisey At

Industrian

YCRoost

Ginzburg-Landau The

Superconductivity

Date

Method

Discussion

Conclusio

References

Acknowledgement

• Two types - Type 1 and Type 2

Types of Superconductors

A Machine Learning-Enabled Study of Superconductivity

Raisey At

Introduction

Cinabura Landau The

Superconductivity

Date

Method

Discussion

Conclusion

References

- Two types Type 1 and Type 2
- Notation

Types of Superconductors

A Machine Learning-Enabled Study of Superconductivity

Rajeev At

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Ginzburg-Landau Theo

Superconductivity

Date

Method

Discussion

Conclusio

References

- Two types Type 1 and Type 2
- Notation
 - $H_c(T)$ is critical field as a function of temperature

Types of Superconductors

A Machine Learning-Enabled Study of Superconductivity

Rajeev At

ittroduction

Ginzburg-Landau Theo

Superconductivity

Dat:

ivietilou

Discussion

Conclusion

References

- Two types Type 1 and Type 2
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 - $H_c(T)$ is critical field as a function of temperature
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Types of Superconductors

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atla

Introduction XGBoost

Ginzburg-Landau Theo

Data

Method

Discussion

Conclusion

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- Two types Type 1 and Type 2
- Notation
 - $H_c(T)$ is critical field as a function of temperature
 - \bullet T_c is critical temperature

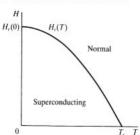


Figure: H - T phase diagram for a Type 1 superconductor [Tinkham]

Type 2 Superconductors

A Machine Learning-Enabled Study of Superconductivity

Introduction

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Method

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Discussion

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Type 2 Superconductors

A Machine Learning-Enabled Study of Superconductivity

Raisey At

Introduction

Cinghurg Landau Tho

Superconductivity

Date

Metho

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Discussio

Acknowledgement

 \bullet Ginzburg-Landau parameter $\kappa>\frac{1}{\sqrt{2}}$

Type 2 Superconductors

A Machine Learning-Enabled Study of Superconductivity

Raieev Atl

Introduction

....

Ginzburg-Landau The

Superconductivity

Dat:

ivietno

Discussio

Conclusio

References

- Ginzburg-Landau parameter $\kappa > \frac{1}{\sqrt{2}}$
 - Definition: $\kappa = \frac{\lambda}{\xi} = \frac{e\hbar}{m_{\rm e}c} \sqrt{\frac{\beta}{2\pi}}$
 - Surface energy is negative

Type 2 Superconductors

- A Machine Learning-Enabled Study of Superconductivity
 - Raieev Atl

Introduction

XGBoost

Ginzburg-Landau Th

Superconductivity

Data

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Discussio

Conclusion

• Ginzburg-Landau parameter
$$\kappa > \frac{1}{\sqrt{2}}$$

• Definition:
$$\kappa = \frac{\lambda}{\xi} = \frac{\mathrm{e}\hbar}{m_{\mathrm{e}}c}\sqrt{\frac{\beta}{2\pi}}$$

- Surface energy is negative
- $\bullet \ H_{c2} = H_{c1} \kappa \sqrt{2}$

Type 2 Superconductors

- A Machine Learning-Enabled Study of Superconductivity
 - Rajeev Atl

Introduction

YCRoost

Ginzburg-Landau The

Superconductivity

Data

ivietno

Discussio

Conclusio

References

- Ginzburg-Landau parameter $\kappa > \frac{1}{\sqrt{2}}$
 - Definition: $\kappa = \frac{\lambda}{\xi} = \frac{e\hbar}{m_e c} \sqrt{\frac{\beta}{2\pi}}$
 - Surface energy is negative
- $\bullet \ H_{c2} = H_{c1} \kappa \sqrt{2}$
- In type 1, $H_{c2} = H_{c1}$

Type 2 Superconductors

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atl

Introduction

XGBoost Ginzburg-Landau The

Superconductivity

Data

Method

Discussio

Conclusio

• Ginzburg-Landau parameter $\kappa > \frac{1}{\sqrt{2}}$

• Definition:
$$\kappa = \frac{\lambda}{\xi} = \frac{e\hbar}{m_e c} \sqrt{\frac{\beta}{2\pi}}$$

Surface energy is negative

$$\bullet \ H_{c2} = H_{c1} \kappa \sqrt{2}$$

• In type 1, $H_{c2} = H_{c1}$

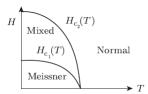


Figure: H - T phase diagram for a Type 2 superconductor [Girvin and Yang 2019]

Type 2 Superconductors: Abrikosov Lattice Vortices

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atla

Introduction

Ciashina Landan The

Superconductivity

Date

Metho

Discussion

Conclusio

References

Acknowledgement

• For $H_{c1} < H < H_{c2}$ in a Type 2 Superconductor, Abrikosov vortices appear in the material

Type 2 Superconductors: Abrikosov Lattice Vortices

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atl

ntroduction

Ginzburg-Landau Theo

Superconductivity

Data

Method

Discussio

Conclusio

References

- For $H_{c1} < H < H_{c2}$ in a Type 2 Superconductor, Abrikosov vortices appear in the material
- These are flux vortices that are quantized, with

$$\Phi = \frac{nhc}{2e}, \quad n \in \mathbb{Z}$$

Type 2 Superconductors: Abrikosov Lattice Vortices

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atl

Introduction

Ginzburg-Landau Theo

Data

Method

Discussio

Conclusio

Reference

Acknowledgement

- For $H_{c1} < H < H_{c2}$ in a Type 2 Superconductor, Abrikosov vortices appear in the material
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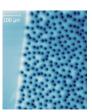


Figure: Abrikosov vortices in YBCO - created by Wells et al. 2015 using scanning SQUID microscopy

A Machine Learning-Enabled Study of Superconductivity

Raieev Atl

ntroductio

Ginzburg-Landau Theor

Data

ivietnoc

Discussion

Conclusion

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 Machine Learning Repository

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atla

ntroduction

Ginzburg-Landau Theor

Superconductivity

Data

Discussior

Conclusion

- Taken from UCI (University of California, Irvine)
 Machine Learning Repository
- 21,263 examples with 81 features

A Machine Learning-Enabled Study of Superconductivity

Data

- Taken from UCI (University of California, Irvine) Machine Learning Repository
- 21,263 examples with 81 features
- Model was only trained with 11 features to prevent overfitting

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atla

Introduction

XGBoost

Ginzburg-Landau Theor

Superconductivity

Data

ivictilou

Discussio

Conclusion

Acknowledgement

- Taken from UCI (University of California, Irvine)
 Machine Learning Repository
- 21,263 examples with 81 features
- Model was only trained with 11 features to prevent overfitting



Figure: UCI Machine Learning Repository

Methods

A Machine Learning-Enabled Study of Superconductivity

Raieev Atla

Introduction

XGBoost Ginzburg-Landau Theory

Data

Methods

Discussion

Conclusio

D (

Methods

A Machine Learning-Enabled Study of Superconductivity

Painou Atla

Introduction

GBoost Ginzburg-Landau Theory

Superconductivity

Data

Methods

Discussion

. . .

Acknowledgements

XGBoost library

Methods

A Machine Learning-Enabled Study of Superconductivity

D 1 A.I

Introduction

VCD----

Ginzburg-Landau Theory

D. . .

Methods

Discussion

Conclusion

References

- XGBoost library
 - XGBClassifier class

Discussion

A Machine Learning-Enabled Study of Superconductivity

Painou Atla

Introduction

VCD----

Ginzburg-Landau Theory

Data

Method

Discussion

.

. .

Discussion

A Machine Learning-Enabled Study of Superconductivity

Delan Ad

ntroductioi

Ginzburg-Landau Theo

Data

 Method

Discussion

Conclusion

References

Acknowledgements

Confusion matrix made using matplotlib library

Discussion

A Machine Learning-Enabled Study of Superconductivity

Raieev Atla

Introduction

XGBoost

Sinzburg-Landau Theor

Data

Method

Discussion

Conclusion

References

Acknowledgement

• Confusion matrix made using matplotlib library

Positive (1) Negative (0) Positive (1) TP FP Negative (0) FN TN

Actual Values

Figure: Example Confusion Matrix

Conclusion

A Machine Learning-Enabled Study of Superconductivity

Raieev Atla

Introduction

VCD----

Ginzburg-Landau Theory

Data

Method

Discussion

Conclusion

. .

References

A Machine Learning-Enabled Study of Superconductivity

Painou Atla

Introduction

KGBoost

Ginzburg-Landau Theory

Data

Method

Diaguagian

References

Acknowledgements

A Machine Learning-Enabled Study of Superconductivity

Rajeev Atla

Introduction

Ginzburg-Landau Theo

Data

Method

Discussion

Conclusion

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