

クラスタリングと深層学習による クロスカットされた文書画像の再構成

工学研究科 情報システム工学分野

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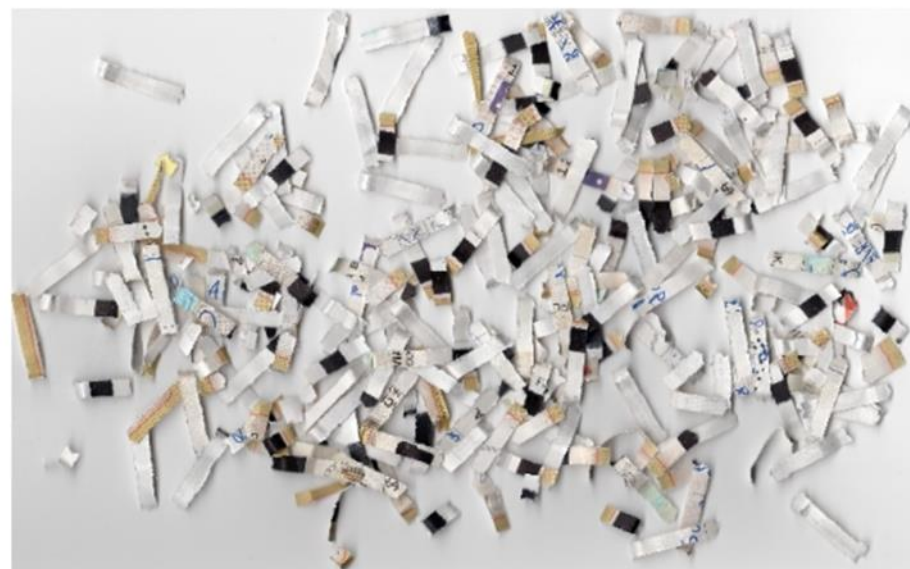
細断された文書の再構成問題

- 近年、文書分析の分野で細断された文書の再構成問題への研究の関心が高まっている

手動では手間と時間がかかる



細断された文書を自動で再構成する手法



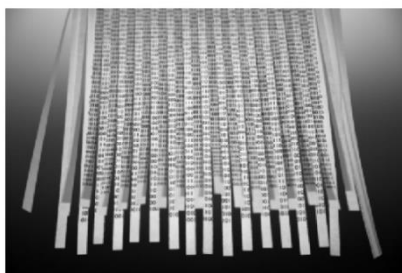
細断された文書の再構成問題

- 3種類の文書の細断法[1]

<手作業>



<スプリットカット>

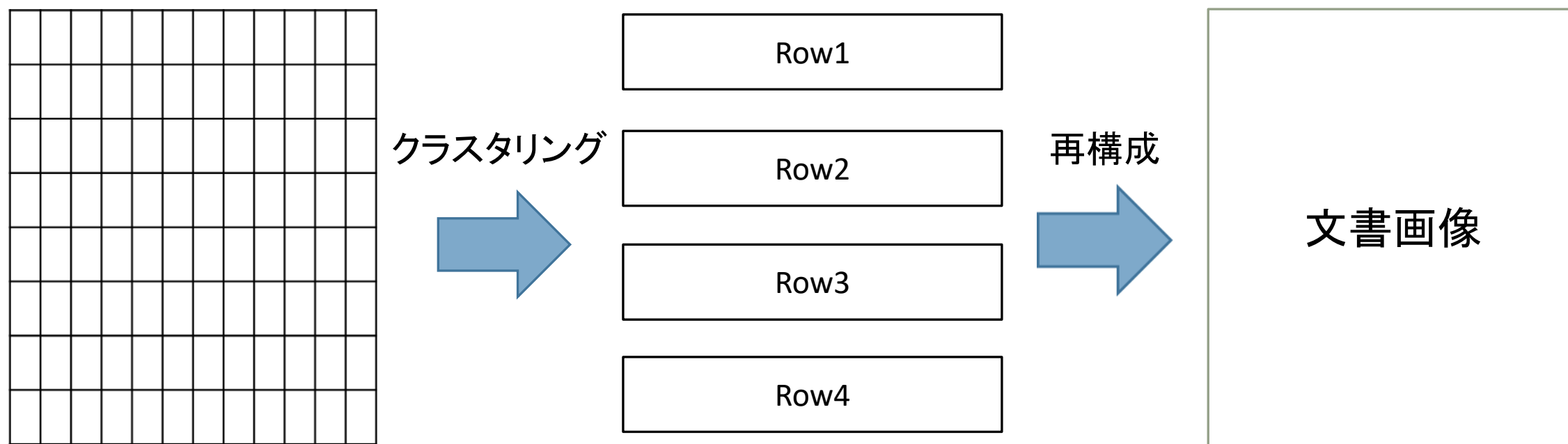


<クロスカット>

[1] H. Xu, J. Zheng, Z. Zhuang, S. Fan "A solution to reconstruct cross-cut shredded text documents based on character recognition and genetic algorithm," Abstract and applied analysis, 2014.

クロスカットされた文書画像の再構成

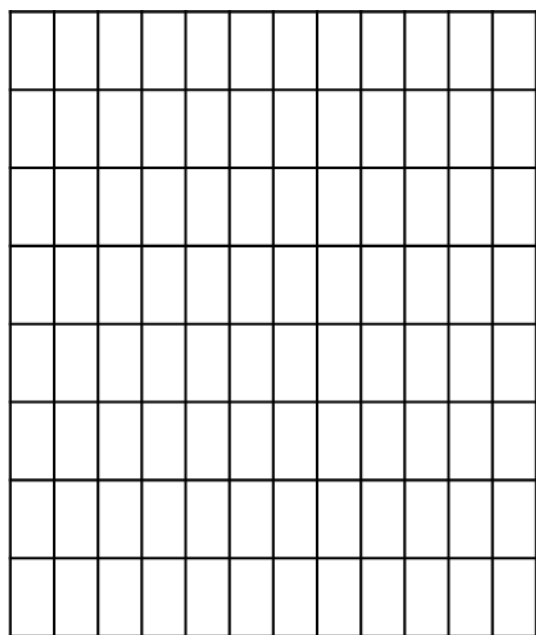
- クラスタリングを用いた再構成手法[2]



<細断された文書の断片(※フラグメント)> [2]H. Xu, J. Zheng, Z. Zhuang, S. Fan "A solution to reconstruct cross-cut shredded text documents based on character recognition and genetic algorithm," Abstract and applied analysis, 2014.

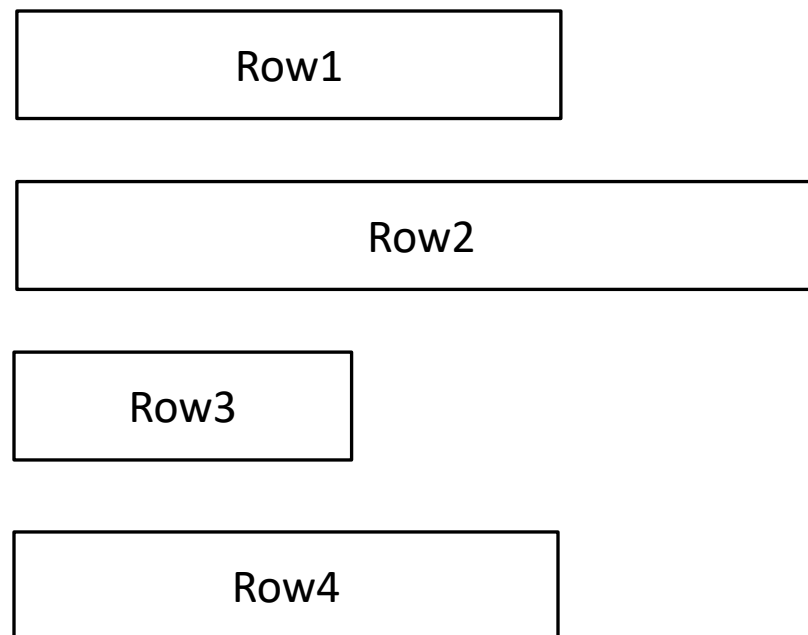
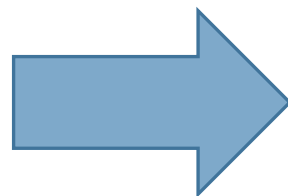
クロスカットされた文書画像の再構成

- クラスタリングを用いた再構成手法の問題点



<フラグメント>

クラスタリング



研究目的

クロスカットされた文書画像の再構成に対して

- クラスタリング
- 行内の再構成

従来手法からの精度向上を目指す

提案手法

- クラスタリングでは

- Same-Size-K-means法

- ⇒ クラスタの数を指定するK-means法のバリエーション

- ⇒ クラスタに含まれるデータ数を指定する

- 行内の再構成では

- 深層学習による再構成手法

- ⇒ スプリットカットされた文書画像の再構成で高い精度を示していた手法

文書画像再構成の流れ

- クラスタリングによるクロスカットされた文書画像再構成

単一のクロスカット文書再構成問題



複数のスプリットカット文書再構成問題

- 3段階の処理手順

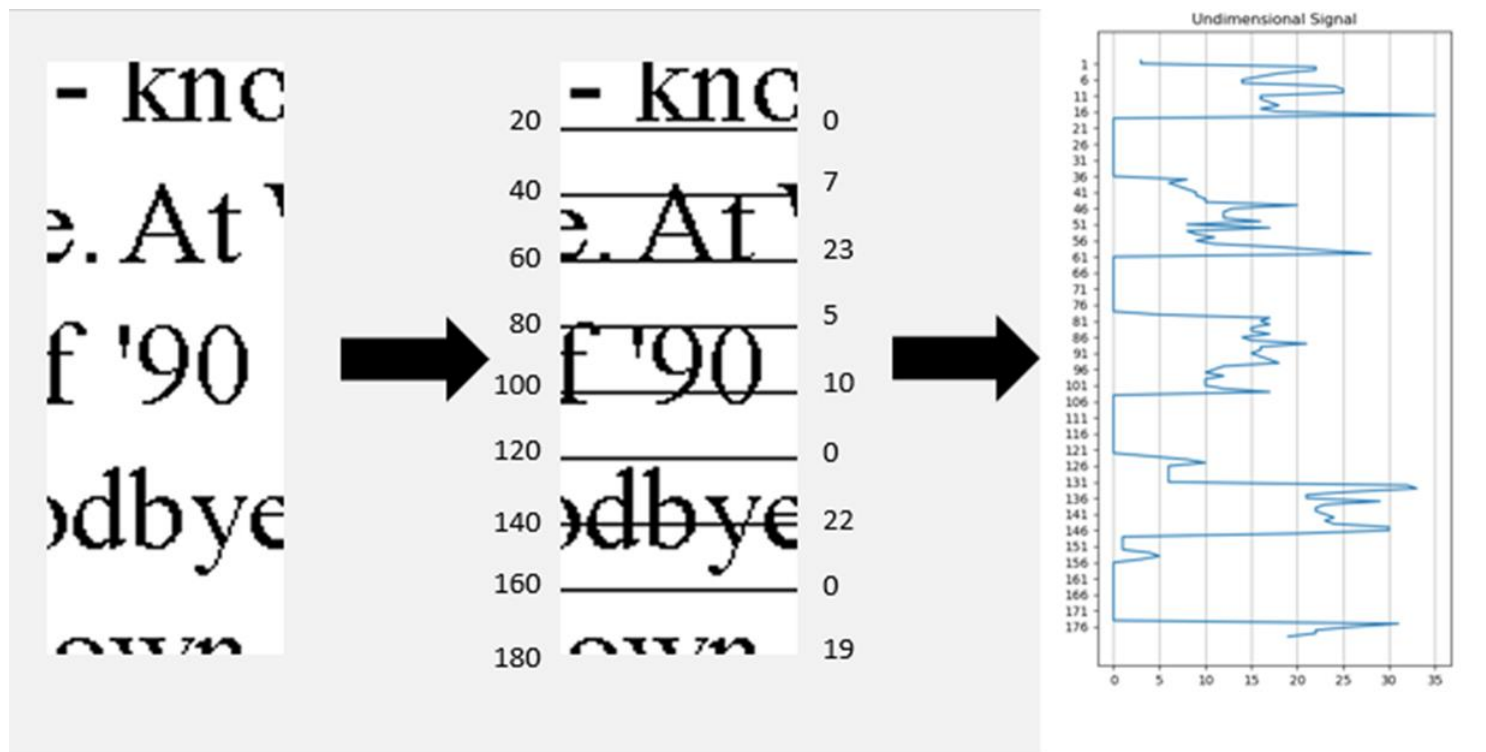
- ① クラスタリング

- ② 行内の再構成

- ③ 行間の再構成

① クラスタリング

1) フラグメントからの特徴抽出



① クラスタリング

2) クラスタ中心の指定

- クラスタの重心
- 本来の初期値はランダム

Th
fa
ne
1

- ・フラグメントの左側に空白がある
- ・識別が容易である

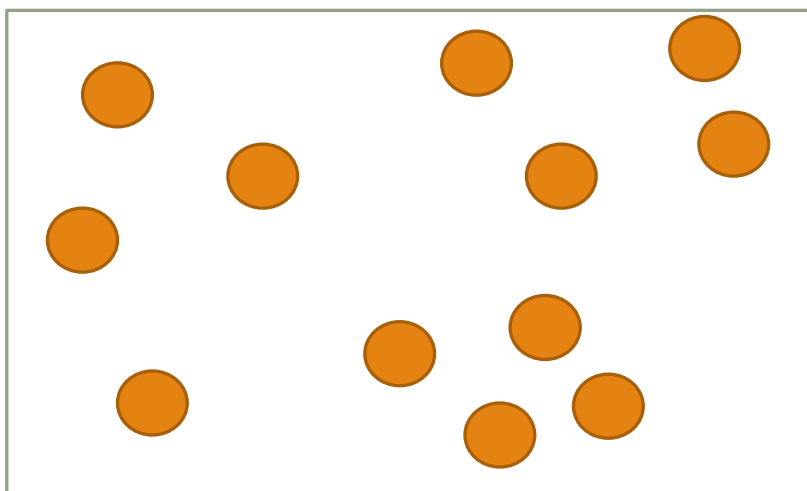


クラスタ中心として使用可能

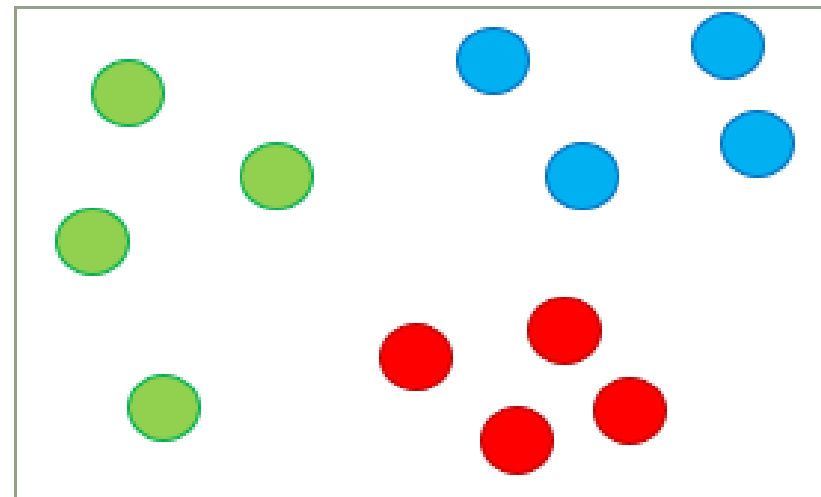
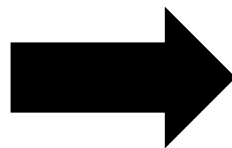
① クラスタリング

3) Same-Size-K-means法によるクラスタリング

- クラスタ内のデータ数を同じ大きさに揃えるクラスタリング
- 最適なクラスタが埋まっていたら、2番目に良いクラスタに割り当てる



<データ>



<クラスタリング後>

②行内の再構成

1) 前処理

- 2つのフラグメント(i, j)の距離を求める $d(i, j) = \|x_i - x_j\|_2 = \sqrt{\sum_{u=1}^l |x_{iu} - x_{ju}|^2}$
- 閾値以下なら接続する

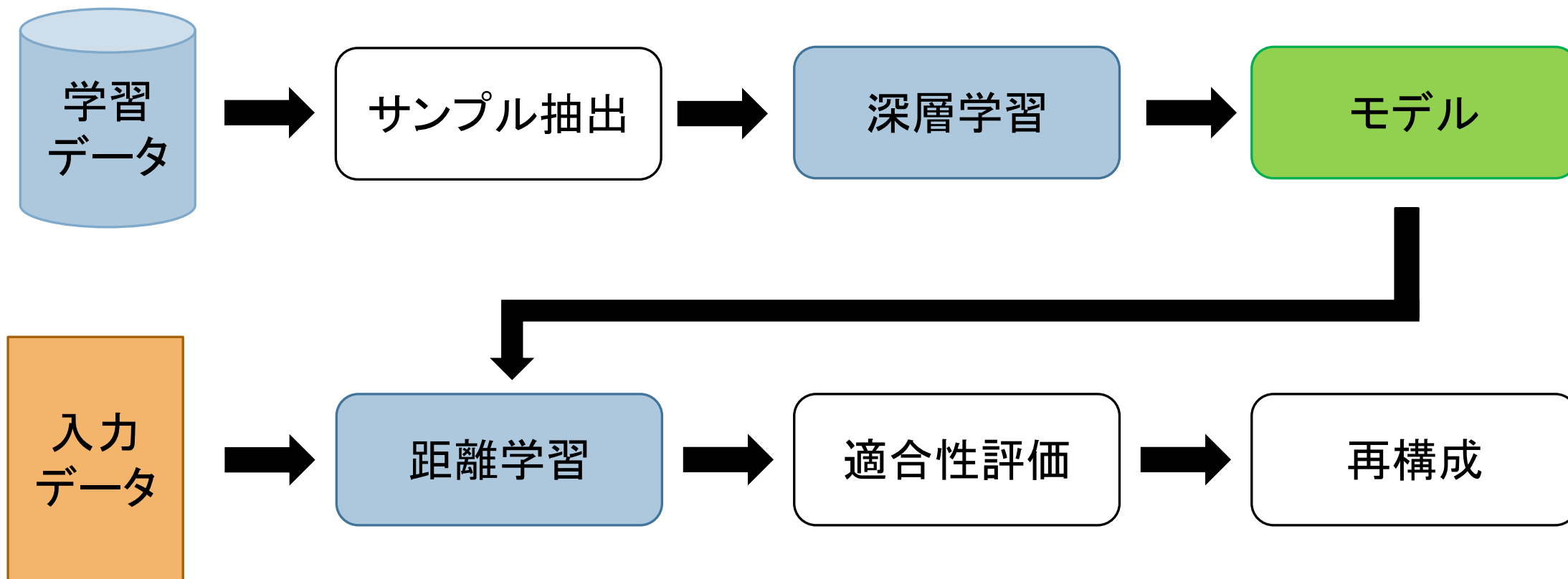
<前処理の例>

フラグメントの数を減らし
再構成の精度を向上

to be here to be here
she could she could
are excited = are excited
forward to forward to
it should be it should be

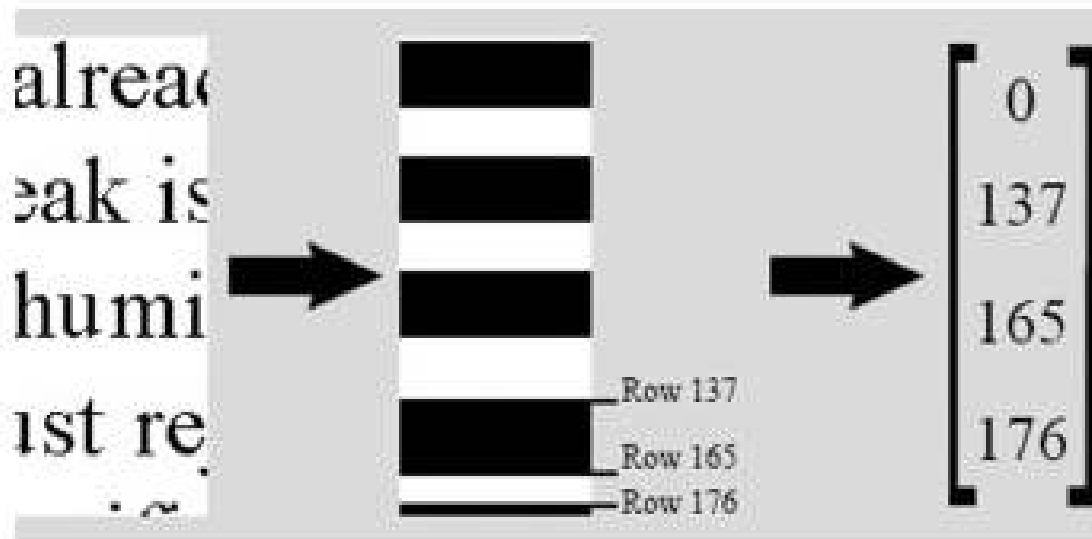
②行内の再構成

2) 深層学習による再構成



③行間の再構成

1) クラスタリングベクトルの抽出[2]



$$\cdot CV = (a_1, a_2, a_3, a_4)$$

a_1 = フラグメント上部の行の下辺

a_2 = フラグメント内の行の上辺

a_3 = フラグメント内の行の下辺

a_4 = フラグメント下部の行の上辺

③行間の再構成

2) 再構成

$$CV = (a_1, a_2, a_3, a_4)$$

$$CV' = (a'_1, a'_2, a'_3, a'_4)$$

$$\cdot l - \delta < a_4 + a'_1 < l + \delta$$

$$\cdot nl + l' - \delta < a_3 + a'_2 < nl + l' + \delta$$

➤ l : 文字列の高さ

➤ l' : 行間の高さ

➤ n : 文字列の数以下の整数

➤ δ : 誤差範囲 (= 3)

実験

実験概要

- ① クラスタリングの精度の比較実験
- ② 行内の再構成の精度の比較実験
- ③ 全体の再構成結果の考察

テストデータ

- 解像度1980 × 1224の7枚の英文文書画像T1～T7
- 11 × 17個のフラグメントに細断
- フラグメントのサイズは180 × 70画素

	行間	サイズ	フォント
T1	13	10	Times New Roman
T2			
T3			
T4			Bold Times New Roman
T5			
T6			
T7			

文書画像の例

T1

Thank you very, very much, President Keohane. Mrs. Gorbachev, Trustees, faculty, parents, and I should say, Julia Porter, class president, and certainly my new best friend, Christine Bicknell - and, of course, the Class of 1990. I am really thrilled to be here today, and very excited, as I know all of you must be, that Mrs. Gorbachev could join us.

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You should all be very proud that this is the Wellesley spirit. Now I know your first choice today was Alice Walker - guess how I know! - known for The Color Purple. Instead you got me - known for the color of my hair. Alice Walker's book has a special resonance here. At Wellesley, each class is known by a special color. For four years the Class of '90 has worn the color purple. Today you meet on Severance Green to say goodbye to all of that, to begin a new and a very personal journey, to search for your own true colors.

In the world that awaits you, beyond the shores of Waban - Lake Waban, no one can say what your true colors will be. But this I do know: You have a first class education from a first class school. And so you need not, probably cannot, live a "paint-by-numbers" life. Decisions are not irrevocable. Choices do come back. And as you set off from Wellesley, I hope that many of you will consider making three very special choices.

The first is to believe in something larger than yourself, to get involved in some

T6

for moment to upset the peace of the world. It is this happy fact, now clear to the view of every public man whose thoughts do not still linger in an age that is dead and gone, which makes it possible for every nation whose purposes are consistent with justice and the peace of the world to avow now or at any other time the objects it has in view.

We entered this war because violations of right had occurred which touched us to the quick and made the life of our own people impossible unless they were corrected and the world secure once for all against their recurrence. What we demand in this war, therefore, is nothing peculiar to ourselves. It is that the world be made fit and safe to live in; and particularly that it be made safe for every peace-loving nation which, like our own, wishes to live its own life, determine its own institutions, be assured of justice and fair dealing by the other peoples of the world as against force and selfish aggression. All the peoples of the world are in effect partners in this interest, and for our own part we see very clearly that unless justice be done to others it will not be done to us. The program of the world's peace, therefore, is our program; and that program, the only possible program, as we see it, is this: I. Open covenants of peace, openly arrived at, after which there shall be no private international understandings of any kind but diplomacy shall proceed always frankly and in the public view.

II. Absolute freedom of navigation upon the seas, outside territorial waters, alike in peace and in war, except as the seas may be closed in whole or in part by international action for the enforcement of international covenants.

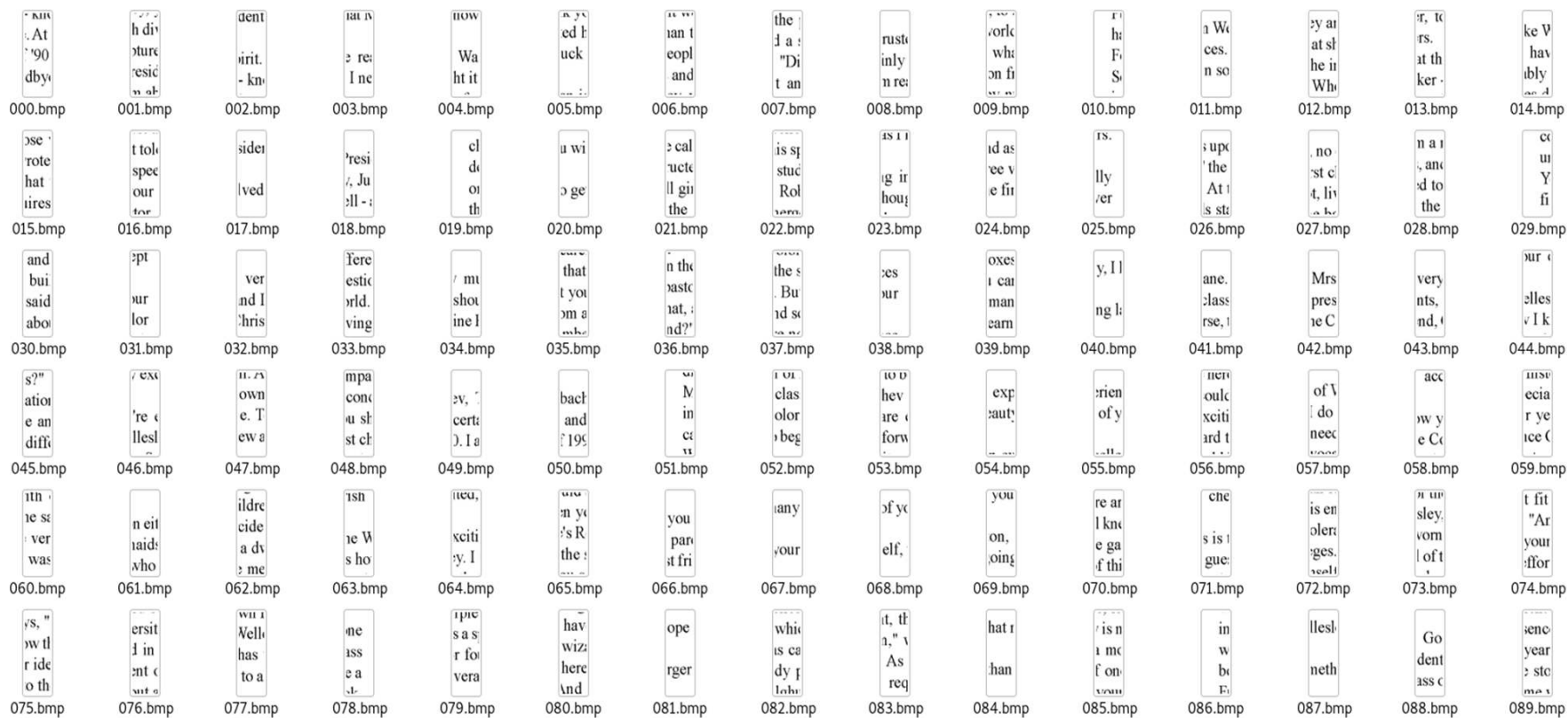
III. The removal, so far as possible, of all economic barriers and the establishment of an equality of trade conditions among all the nations consenting to the peace and associating themselves for its maintenance.

IV. Adequate guarantees given and taken that national armaments will be reduced to the lowest point consistent with domestic safety.

V. A free, open-minded, and absolutely impartial adjustment of all colonial claims, based upon a strict observance of the principle that in determining all such questions of sovereignty the interests of the populations concerned must have equal weight with the equitable claims of the government whose title is to be determined.

VI. The evacuation of all Russian territory and such a settlement of all

細断された文書画像のフラグメントの例



実験1: クラスタリングの精度比較

➤ 実験目的

提案手法 (same-Size-K-means法) が文書画像で有効であるか検証

➤ 実験方法

従来手法 (※制約付きK-means法) と文書画像T1~T7におけるクラスタリングの精度を比較

※制約付きK-means法・・・クラスタ中心の初期値として与えている

実験結果

	制約付きK-means法		Same-Size-K-means法	
	エラー数	精度	エラー数	精度
T1	1	99%	0	100%
T2	0	100%	0	100%
T3	0	100%	0	100%
T4	0	100%	0	100%
T5	18	90%	0	100%
T6	12	93%	0	100%
T7	24	87%	3	98%

実験2：行内の再構成の精度比較

➤ 実験目的

フラグメントの前処理が再構成へ有効であるか検証

深層学習による再構成がクロスカット文書画像で有効であるか検証

➤ 実験方法

前処理の有無による再構成のエラーペア数を文書画像T1で行ごとに比較

従来手法[3]と深層学習による行内の再構成の精度を比較

[3]Chen, Junhua, et al. "A solution to reconstruct cross-cut shredded text documents based on constrained seed K-means algorithm and ant colony algorithm," Expert Systems with Applications 127: 35-46,2019.

実験結果

	Row1	Row2	Row3	Row4	Row5	Row6	Row7	Row8	Row9	Row10	Row11	合計
深層学習	5	5	7	6	3	5	8	6	8	10	11	74
深層学習 +前処理	5	3	8	5	3	0	5	0	5	6	3	43

- 行ごとのエラーペア数の比較
- 1行(Row3)だけエラーペア数が増えた⇒前処理で誤った接続が原因

実験結果

● Row7の再構成の比較

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unconditionally the same in others.

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実験結果

- 従来手法と深層学習の行内の再構成の精度の比較
- 従来手法は行内の再構成をTSP問題と見なして解く

	従来手法[3]	深層学習
精度(%)	94.7	77.0

クロスカットされた文書画像の再構成が困難である

実験3 : クロスカットされた文書画像の再構成の結果

正解

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実験3: クロスカットされた文書画像の再構成の結果

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再構成

クラスタリングと行間の再構成は成功

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Now this little girl knew what she was, and she was not about to give up on either her identity, or the game. She intended to take her place wherever mermaids fit into the scheme of things. "Where do the mermaids stand? All of those who are different, those who do not fit the boxes and the pigeonholes?" "Answer that question," wrote Fulghum, "And you can build a school, a nation, or a whole world." As that very wise young woman said, "Diversity, like anything worth having, requires effort - effort to learn about and respect difference, to be compassionate with one another, to cherish our own identity, and to accept unconditionally the same in others.

You should all be very proud that this is the Wellesley spirit. Now I know your first choice today was Alice Walker - guess how I know! - known for The Color Purple. Instead you got me - known for the color of my hair. Alice Walker's book has a special resonance here. At Wellesley, each class is known by a special color. For four years the Class of '90 has worn the color purple. Today you meet on Severance Green to say goodbye to all of that, to begin a new and a very personal journey, to search for your own true colors.

In the world that awaits you, beyond the shores of Waban - Lake Waban, no one can say what your true colors will be. But this I do know: You have a first class education from a first class school. And so you need not, probably cannot, live a "paint-by-numbers" life. Decisions are not irrevocable. Choices do come back. And as you set off from Wellesley, I hope that many of you will consider making three very special choices.

The first is to believe in something larger than yourself, to get involved in some

実験3: クロスカットされた文書画像の再構成の結果

正解

Thank you very, very much, President Keohane, Mrs. Gorbachev, Trustees, faculty, parents, and I should say, Julia Porter, class president, and certainly my new best friend, Christine Bicknell - and, of course, the Class of 1990. I am really thrilled to be here today, and very excited, as I know all of you must be, that Mrs. Gorbachev could join us.

These are exciting times. They're exciting in Washington, and I have really looked forward to coming to Wellesley. I thought it was going to be fun. I never dreamt it would be this much fun. So, thank you for that.

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再構成

行内の再構成
精度が課題

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まとめ

クロスカットされた文書画像の再構成問題にて精度の向上を目指した

- Same-Size-K-means法によるクラスタリング
 - ⇒クラスタリングの精度を改善
- 深層学習による行内の再構成
 - ⇒従来手法よりも劣る結果
 - ⇒クロスカットされた文書画像再構成が困難であること

今後の課題

- 行内の再構成で有効な手法を見つけること
- 難しい文書画像を対象とした再構成