Probabilistic damage localization using embedded piezoelectric sensor network

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Outline

- Introduction
- Basic concept of Active sensing techniques
- The proposed damage localization algorithms
- Test results
- Summary and Conclusion

Introduction

1. Motivation

Development of more reliable and effective damage localization techniques on detecting structural damage using PZT sensor networks .

2. Objectives

- Research objective
  - Development of a new methodology for damage localization.
- The uniqueness of this study
  - Probabilistic approaches for damage localization
  - Computation of the uncertainty of damage diagnosis using PZT sensor layout configuration

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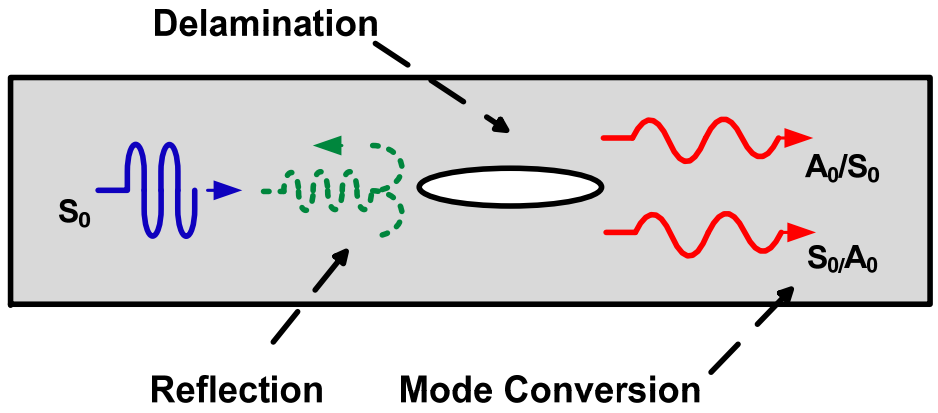
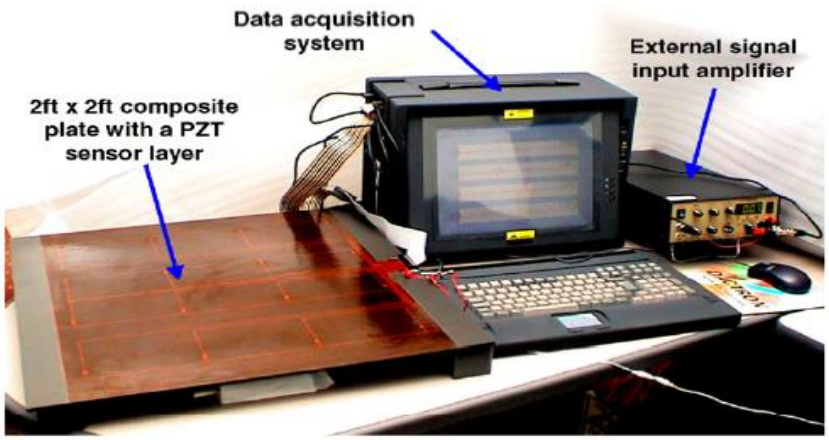
The effect of delamination on Lamb wave propagation

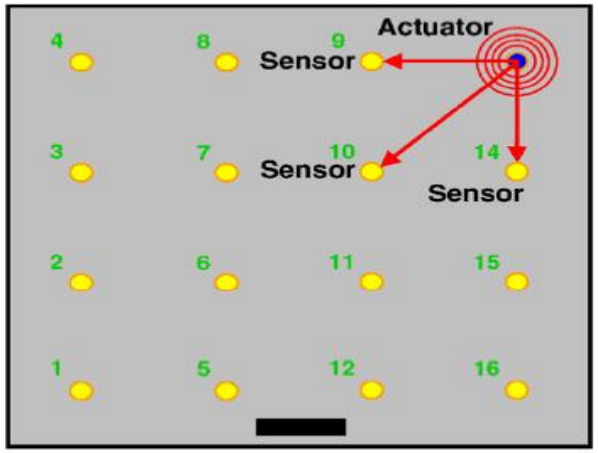
- If Lamb waves propagating along a thin plate encounter a thickness variation point, some portion of the waves are reflected at that point and others are transmitted through it.
- Moreover, a S_0(symmetric) mode is divided into a S_0 and an A_0(anti-symmetric) mode. (an A_0 into a S_0 and an A_0)
- Therefore, the damage can be identified based on this concept.



< Mode conversion due to a delamination >

What is the PZT sensor network?





<Sohn ,2004>

- - The array configuration enables us to receive several signals from different adjacent actuator- sensing pairs

- Why we need the probabilistic approach?
  - We only have information about damage existences along the path so it might be impossible to detect exact damage location without knowing damage size and the number of damage

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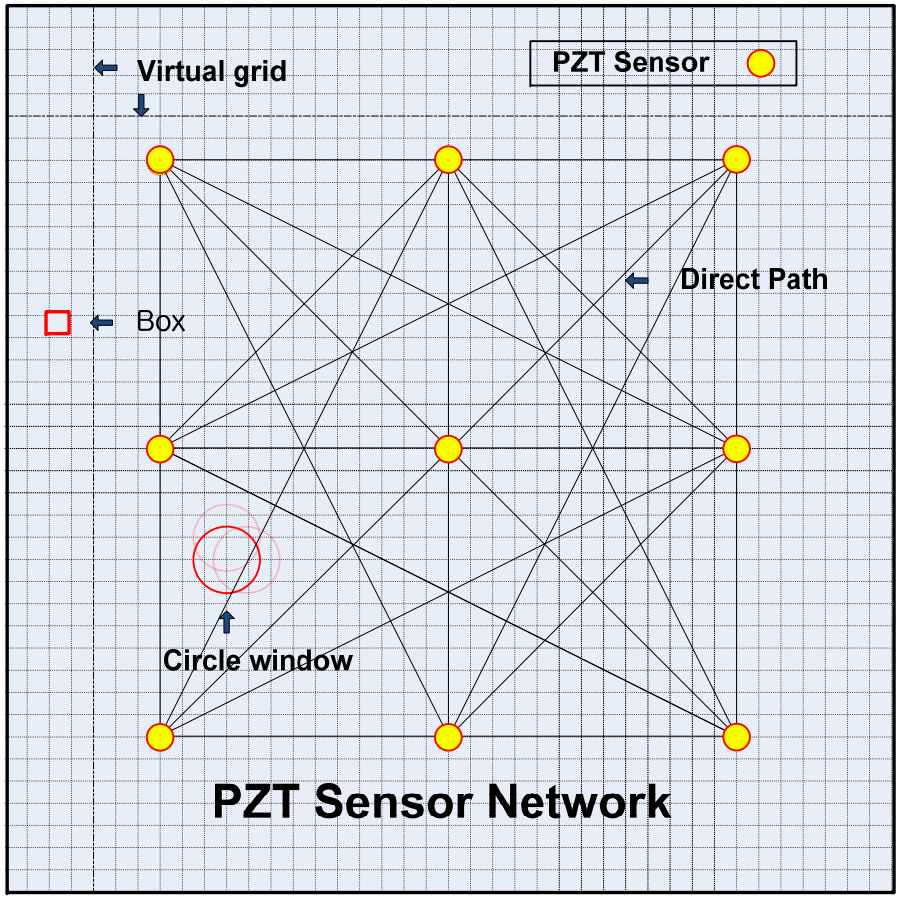
Definition of terminology for proposed localization technique



- **Direct path**

The straight Lamb wave path between the PZT actuator and sensor pair

- **Box**

Box is surround with virtual grids. The value in the box will be used for images of damage location

- **Circle window**

It presents possible damage Locations and damage size

Step1. Overall damage detection probability

- Supposing that if there might be at least one path passing the circle, we can detect damage.

What percentages of damages are detected in the given plate?

$$\textit{Overall damage detection probability} = \frac{\textit{Posssible to Detect damage locations}}{\textit{All possible damage locations}}$$

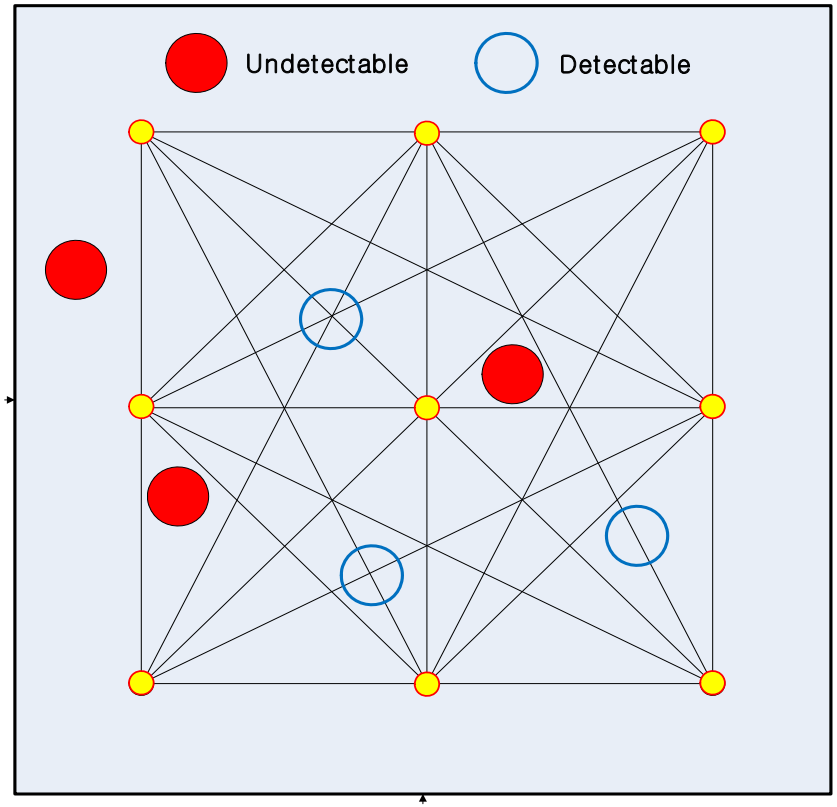
- Possible to detect damage locations ->

  the number of circle passing the direct path(s)

- All possible damage locations ->

  the number of all circles that can be positioned

Step1. Where is the undetectable position and detectable position?



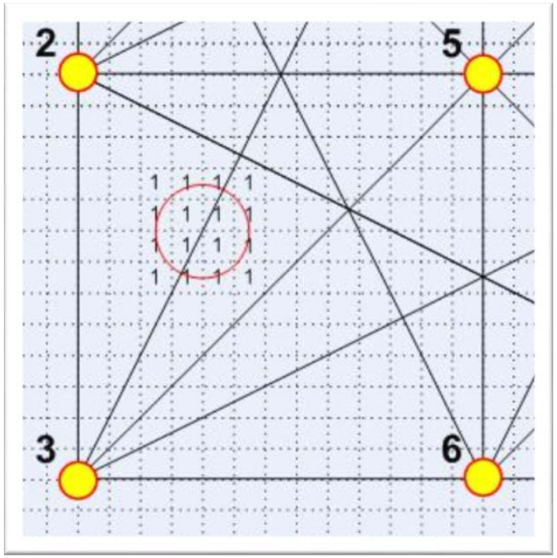
- **A circle which overlaps with path(s) is detectable**
- **A circle which paths is not overlapped is undetectable**

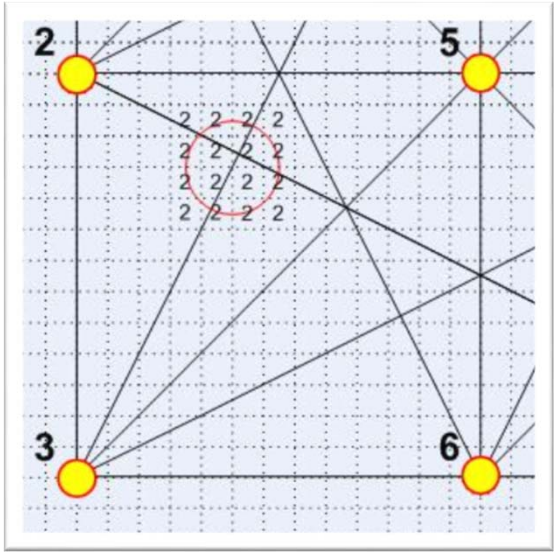
Step2. Reliability test

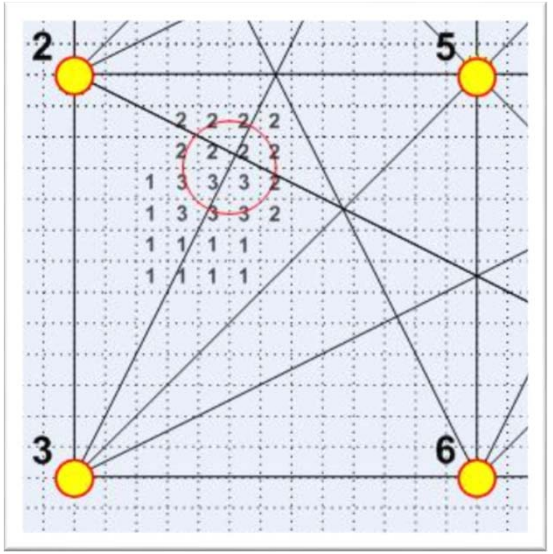
- It is not reasonable dealing with the probability of damage localization to the same between regions with many paths overlapped and others

- Reliability means that if there might be damage at the position with many paths overlapped, those positions are checked with many paths whether they are damage locations or not . Therefore, that position is more reliable than other positions.

Step2. Explanation of the method for reliability test







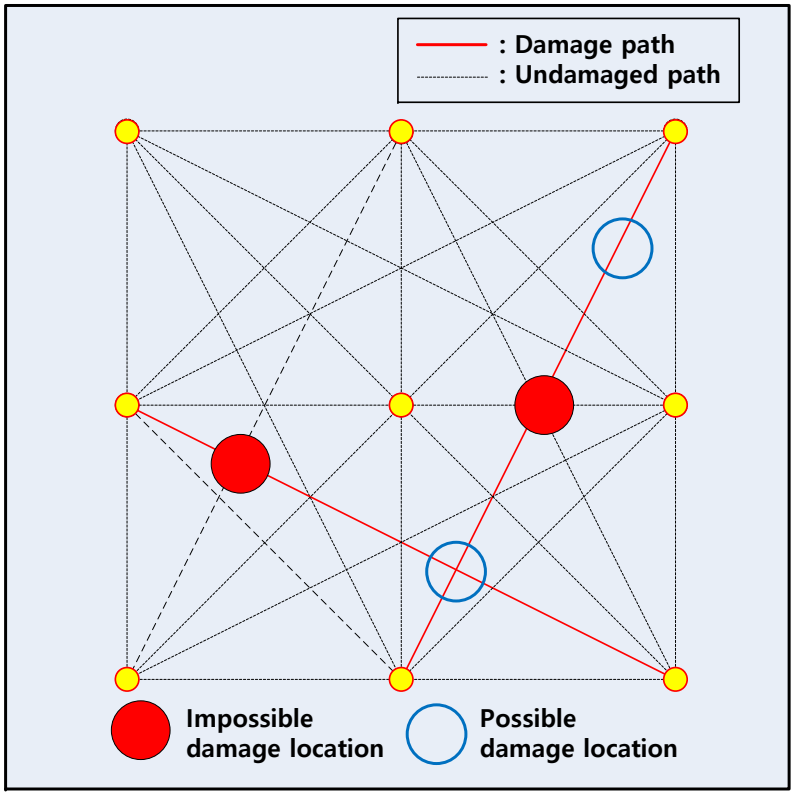
- **When a circle overlaps with N path(s), the counting number 'N' is assigned to all boxes cross with the circle**

Step3. Probabilistic approach for damage localization

- Probabilistic approach for damage localization means the probability of da mage localization under existing damages (the existence of damage path)

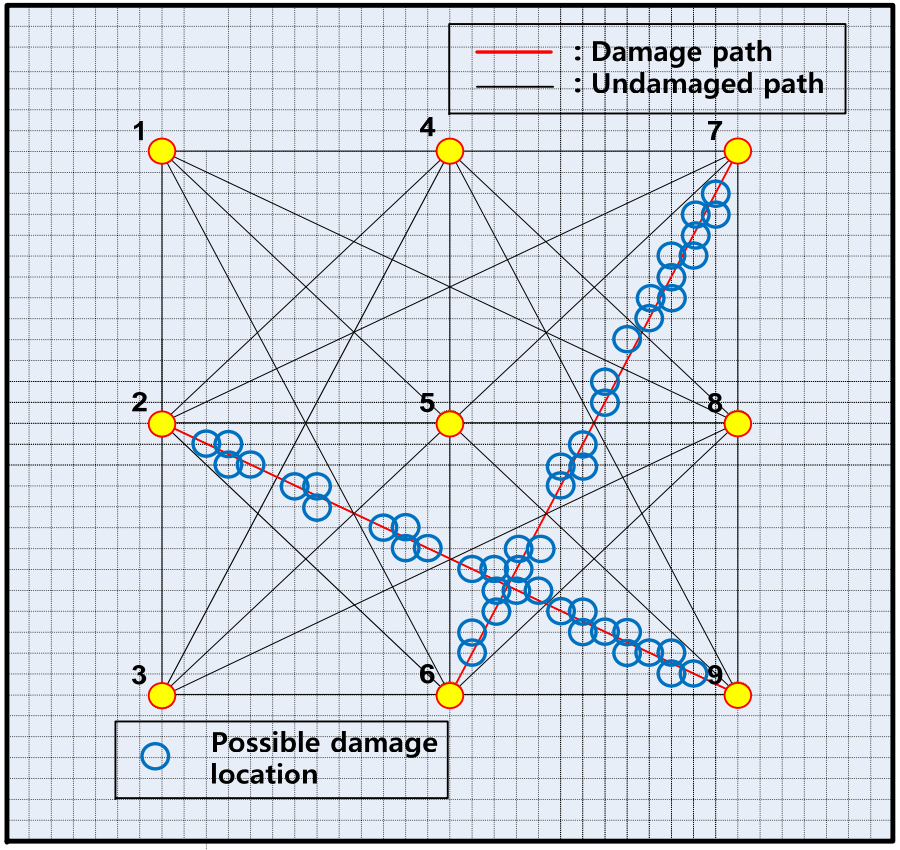
- Based on the identified damage paths, it shows where the damages are m ost likely located in a probabilistic manner

Step3. Where is the possible damage location(s)?



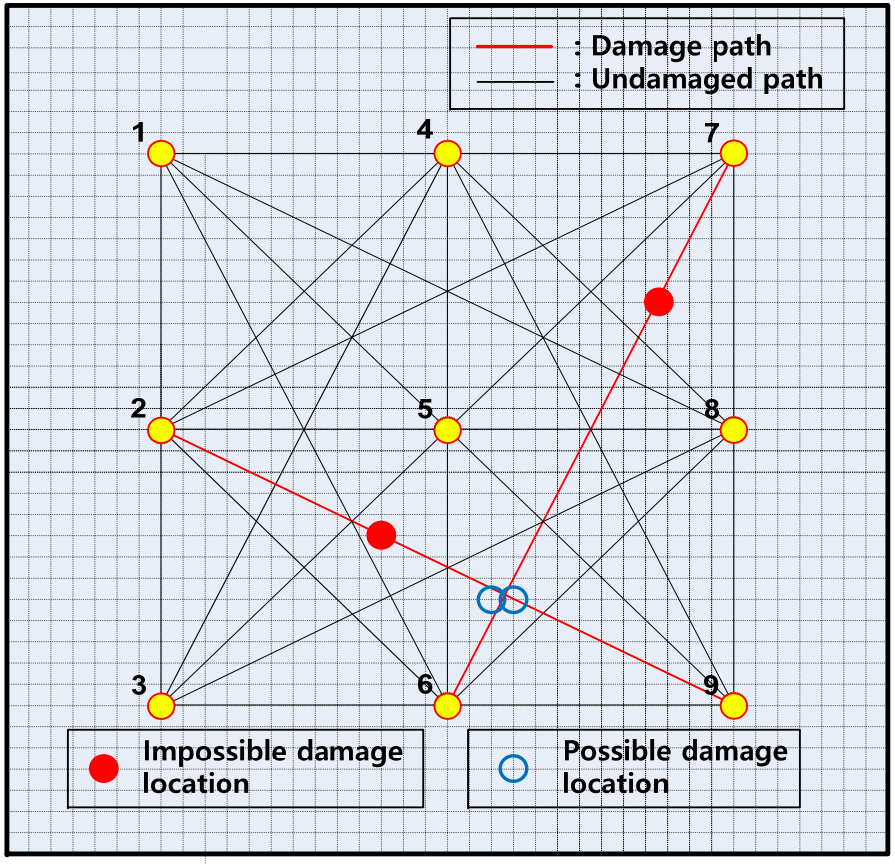
- **The possible damage location(s) can be only overlapped with damage path(s)**

Step3. All possible damage location along the path(s)



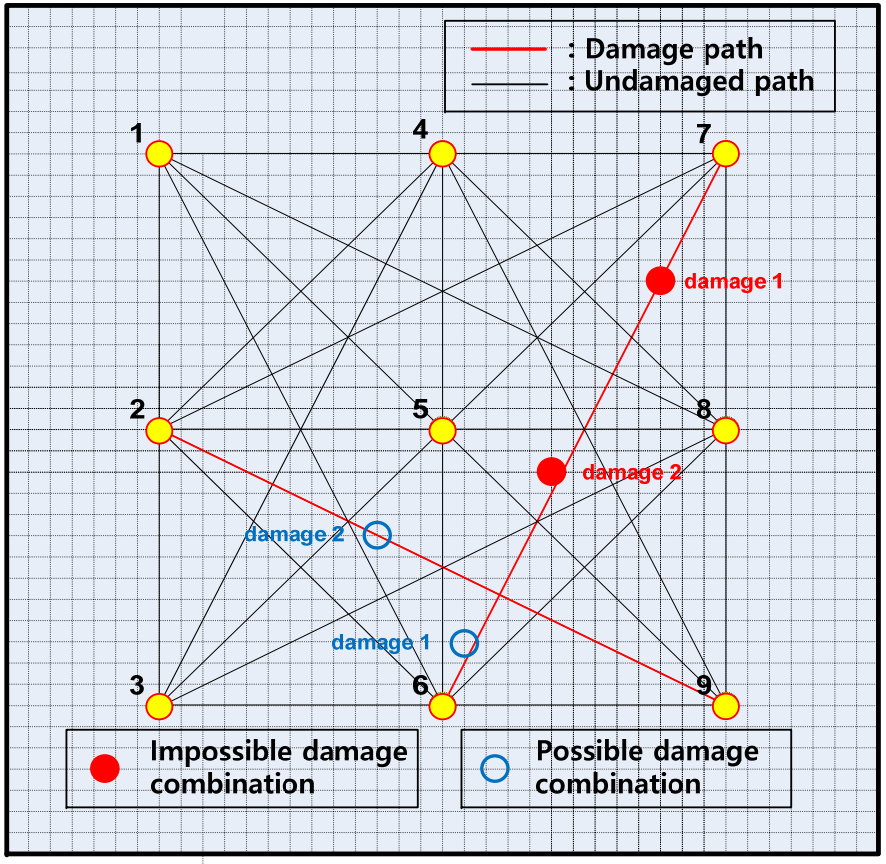
- **The main idea of step 3 is the sum of all possible circle combination.**

Step3 . One damage assumption along the paths



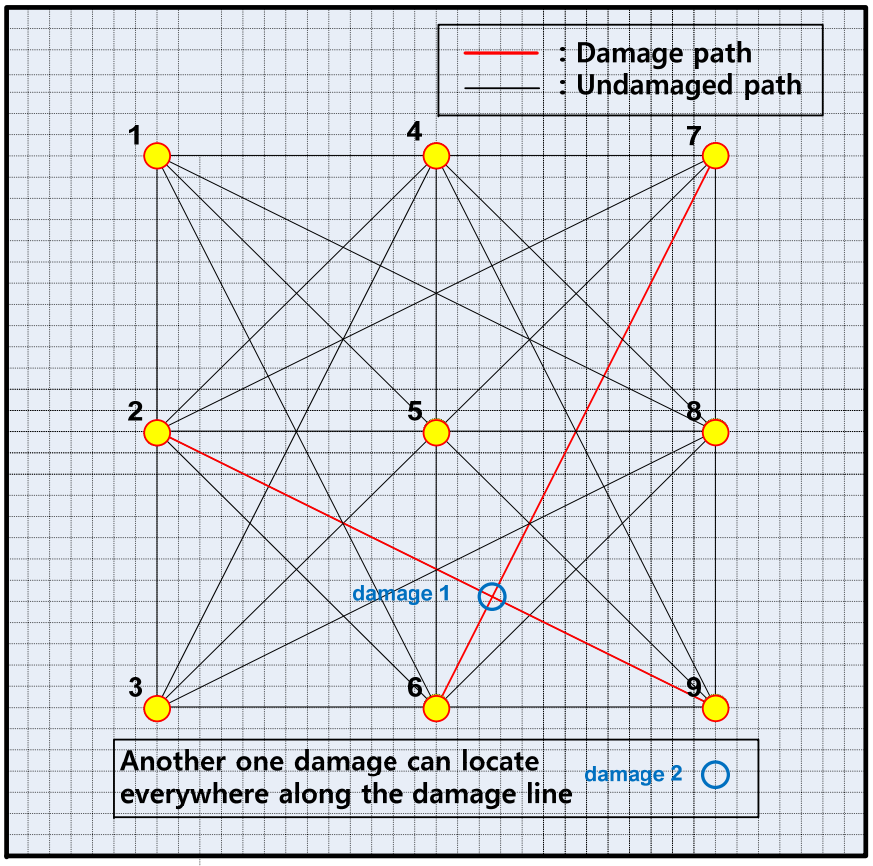
- **In this case, a circle must be overlapped with the crossing point between these two damage paths because damage path(s) must have at least one damage along its path.**

Step3 . Two damage assumption along the paths (case Ⅰ)



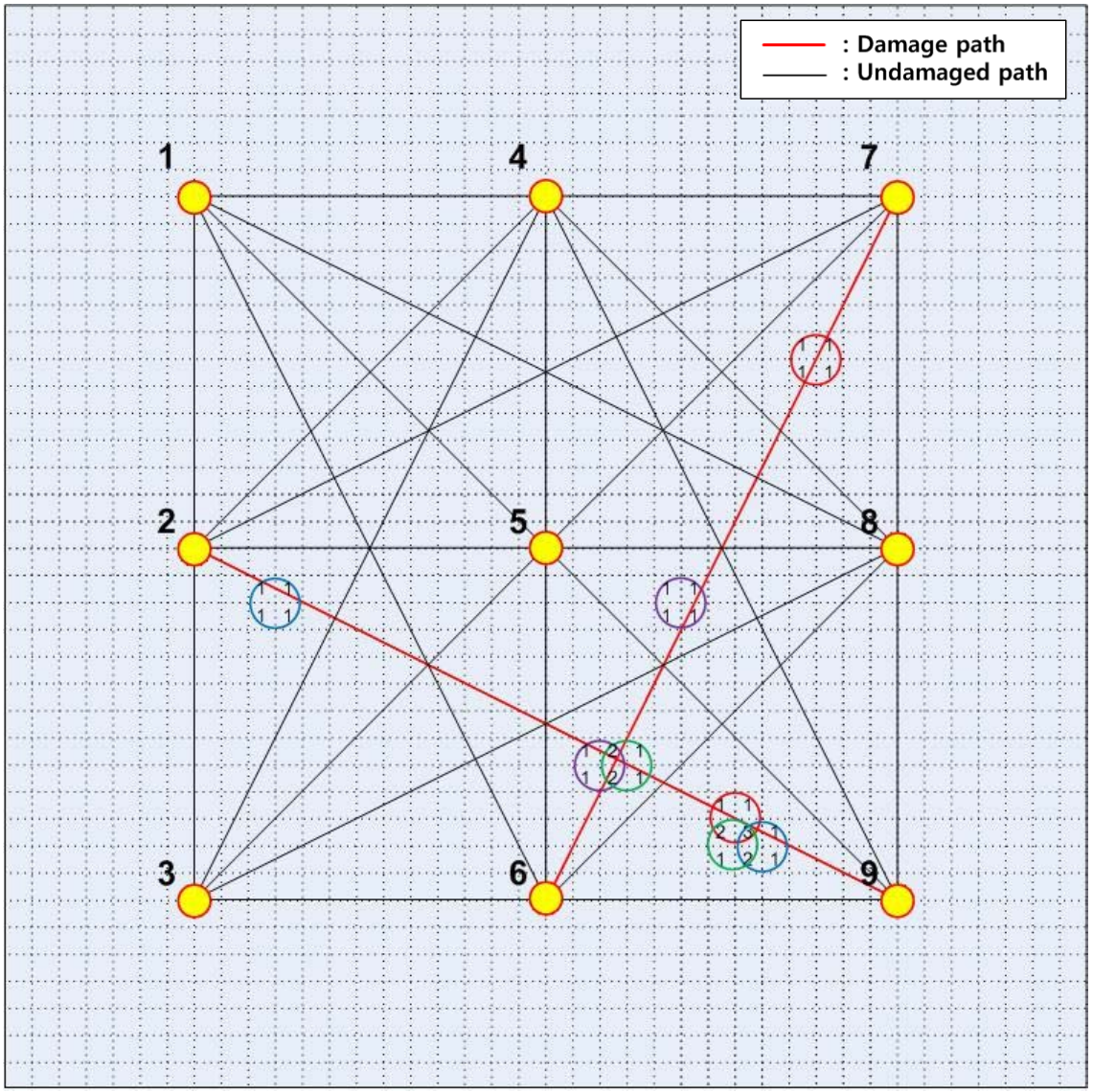
- **All two damage must not be located at the same damage path**

Step3 . Two damage assumption along the paths (case Ⅱ)



- Damage paths have at least one damage along its path

Step3 : How to represent the combination of circles for damage localization



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Test setting

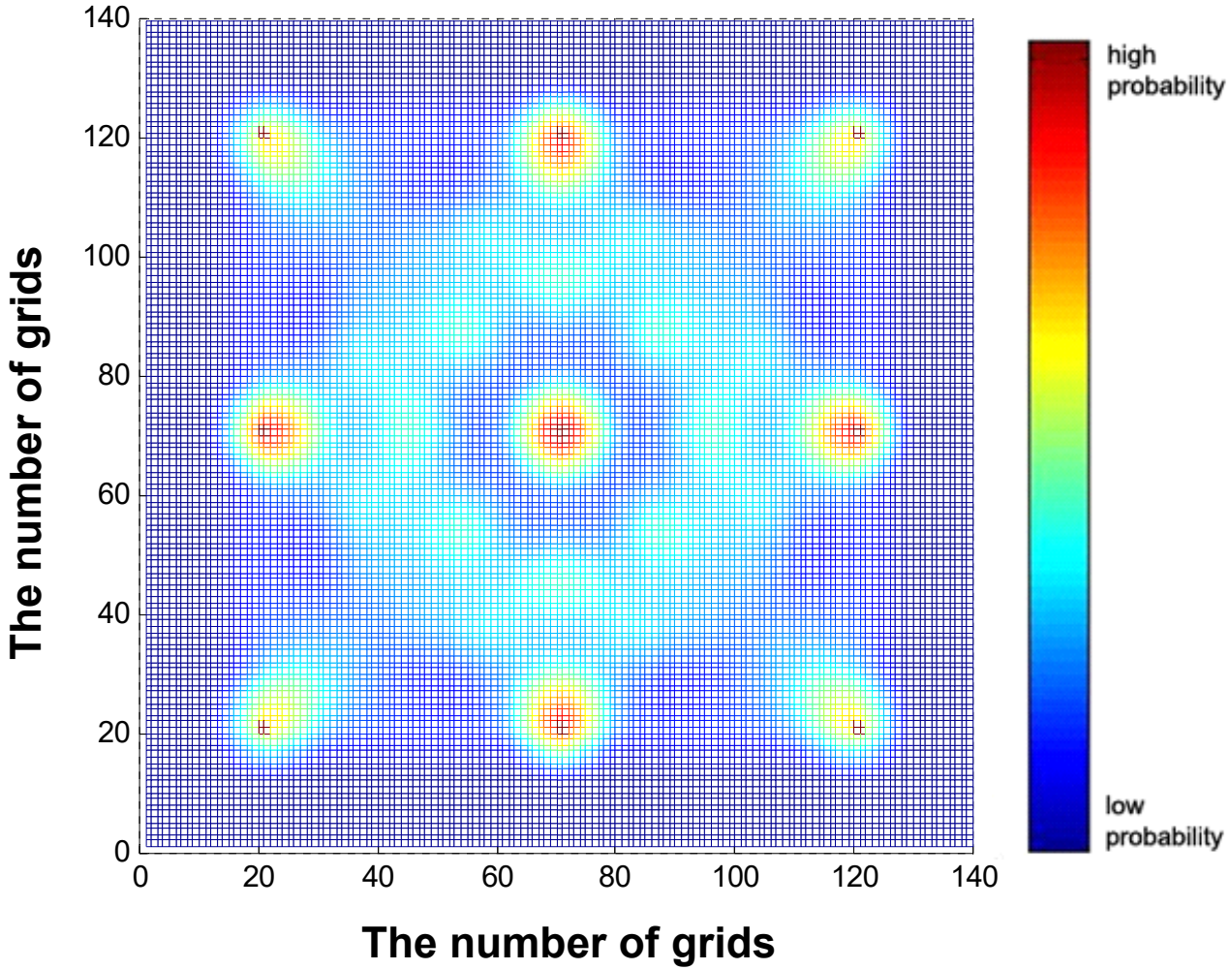
- 3 by 3 PZT wafer transducer network system modeling
- Divided into 140 by 140 virtual grids
- Test case is the two damage paths and one overlapped point,
- The damage size (diameter) is represented with the number of boxes
- Simulation using MATLAB

Result (Step 1. Overall damage detection probability)

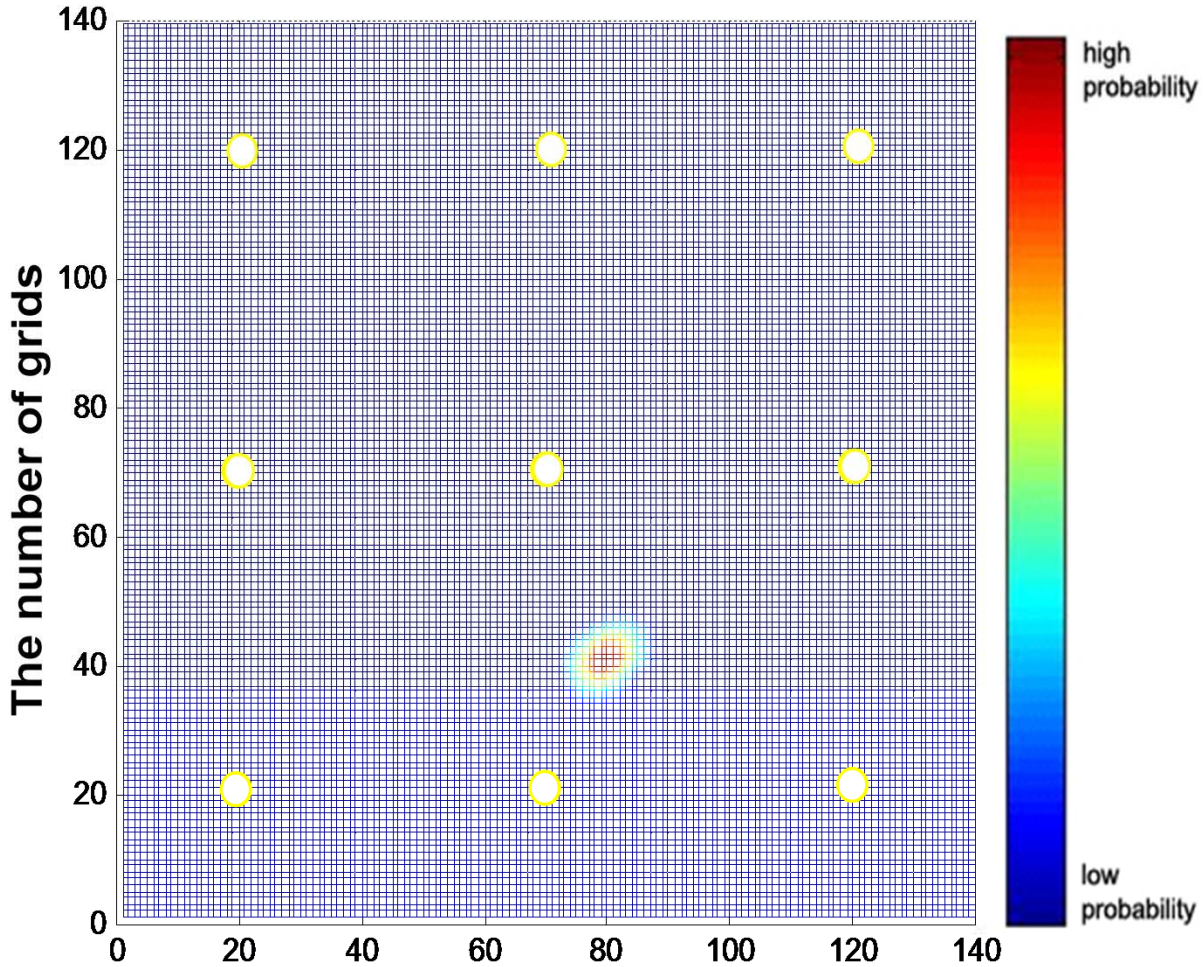
Diameter	Overall damage detection probability
4 box	0.461
6 box	0.578
8 box	0.648
10 box	0.711

$$\textit{Overall damage detection probability} = \frac{\textit{Posssible to Detect damage locations}}{\textit{All possible damage locations}}$$

Result (Step 2. Reliability test)

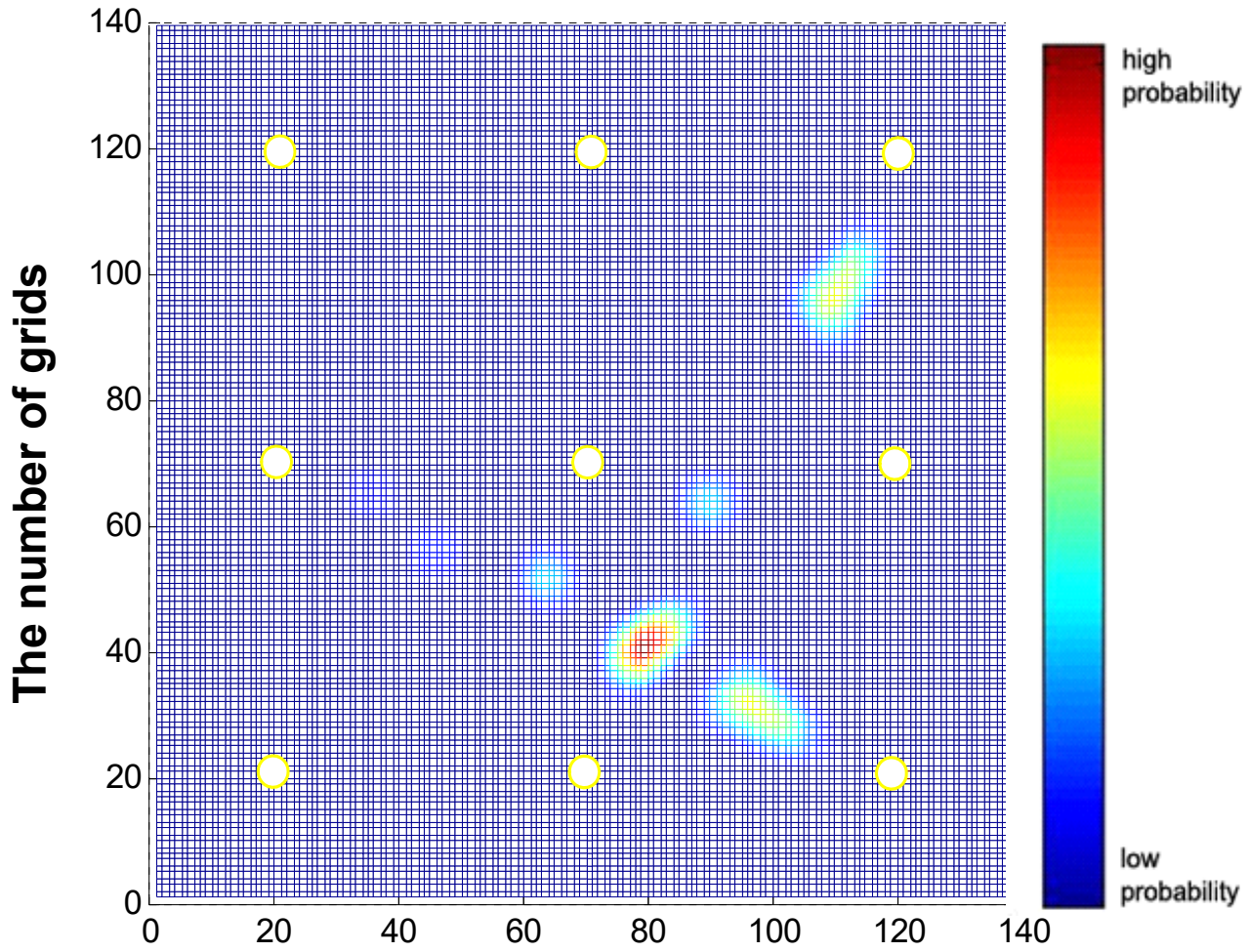


Result (Step 3. Probabilistic for damage localization)



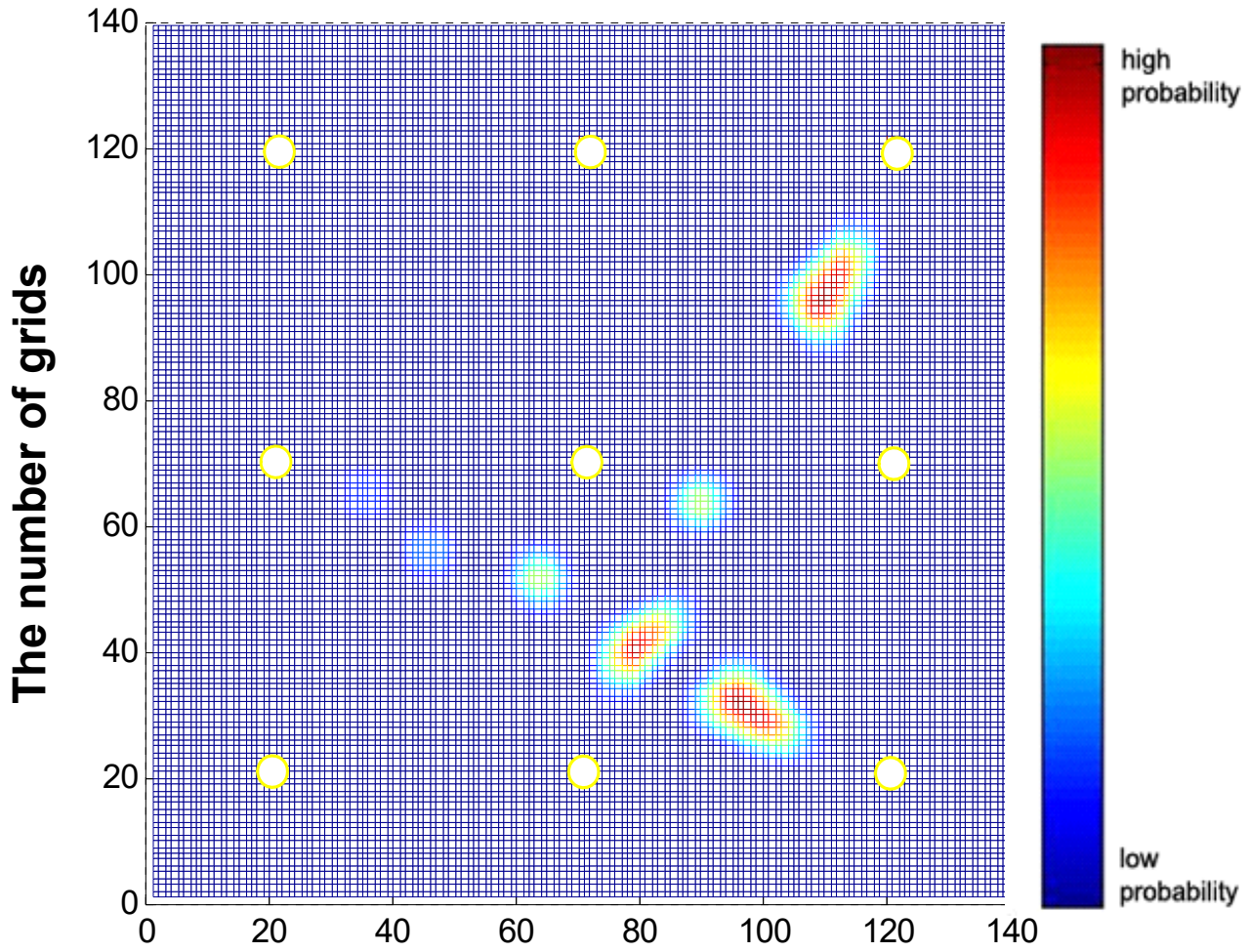
< one damage assumption >

Result (Step 3. Probabilistic for damage localization)



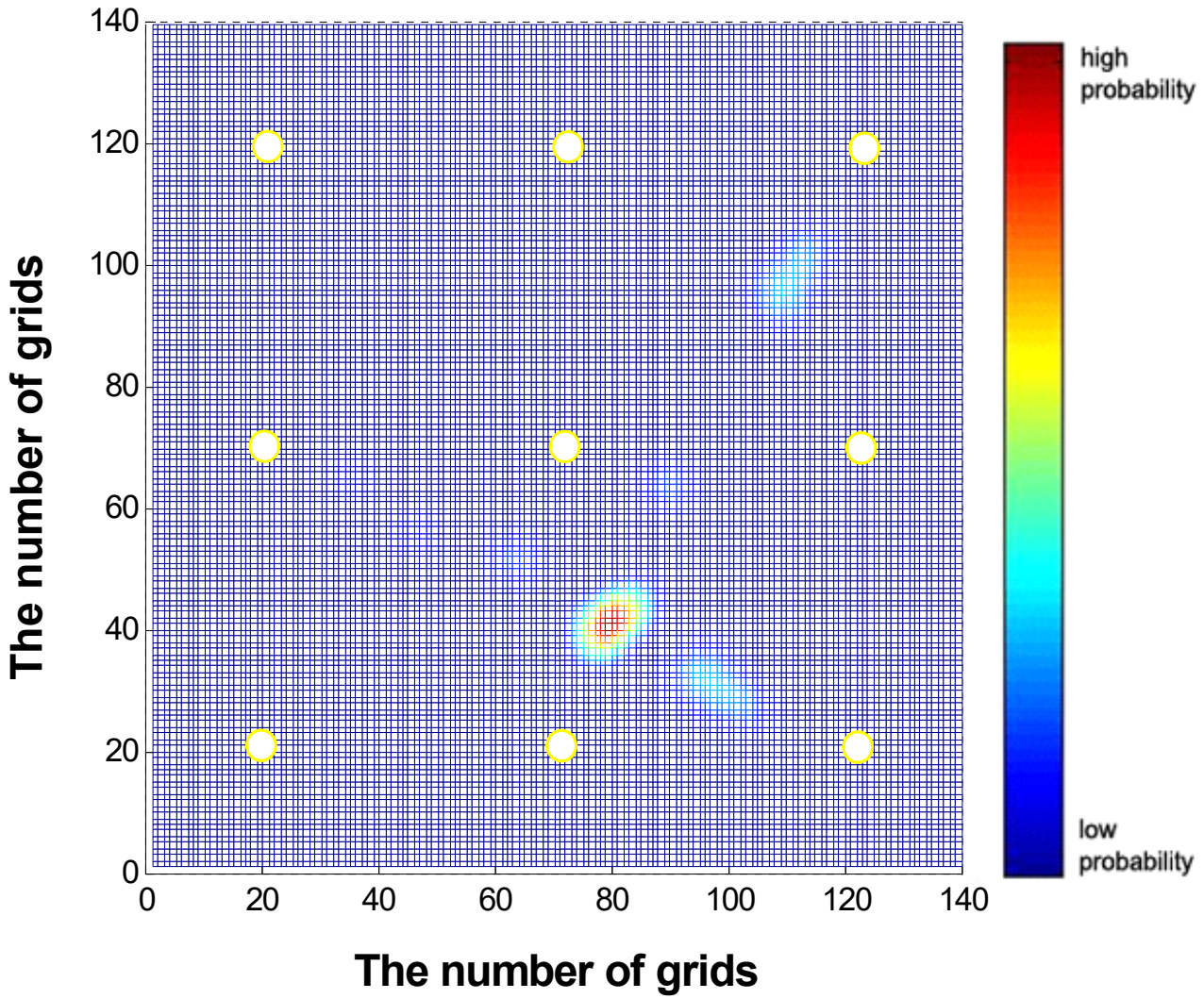
< two damage assumption >

Result (Step 3. Probabilistic for damage localization)



< Three damage assumption >

Result (Step 3. Probabilistic for damage localization)



< Summation of one, two, and three damage case >

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Summary and Conclusion

- A new probabilistic approach-based damage localization technique using piezoelectric sensor network has been proposed.

- The feasibility of the proposed method has been investigated by an example study using MATLAB

- To verify the proposed approach, experimental works will be studied in the near future.

Thank you
terima kasih

THIS WORK IS A PART OF THE URP(UNDERGRADUATE RESEARCH PARTICIPATION) PROGRAM

Make up slide
(basic assumption for proposed localization techniques)

- **The damage size**

- **The number of damage (Step 3)**

p = the probability of one damage's existence in the plate.

The probability of one damage's existence : p
The probability of two damage's existence : P^2
The probability of three damage's existence : P^3

- In the cases of four or more damage existences, their probabilities are too small to be considered.

- If there might be at least one damage in the plate, the probability of d amage existence in the plate should be one. So p+p^2+p^3 = 1