希尔伯特空间浅述 –
兼谈从工程的角度看数学

An Introduction to L^2 Space
- An Engineering's View of Mathematics

唐远炎

Yuan Yan Tang

IEEE Fellow

IAPR Fellow

数学是自然现象和社会现象包括工程技术的高度概括和抽象描述。本学术报告以泛函分析中的一个比较难理解的数学概念，希尔伯特空间为例，从工程的角度给出了形象的，比较好理解的描述。将抽象的数学还原为实际的工程问题。此报告还介绍了有关希尔伯特空间理论在模式识别中的应用实例。

此报告通俗易懂，通过形象的比喻加深听众对数学理论的理解，为工程技术人员更好地应用数学理论以及数学家如何将数学理论和实际应用相结合提供帮助。

此为作者在国家基金委信息科学部所作报告的讲稿整理修改而成，和大家分享。

"Access to wavelet theory has been limited because much of the wavelet literature requires that the reader understand the mathematics of functional analysis 泛函分析 Hilbert space theory 希尔伯特空间

1 An Overview

"Wavelets" has been a very popular topic of conversations in many scientific and engineering gatherings these days. Some view wavelets as a new basis for representing functions, some consider it as a technique for time-frequency analysis, and others think of it as a new mathematical subject. Of course, all of them are right, since "wavelets" is a versatile tool with very rich mathematical content and great potential for applications. However, as this subject is still in the midst of rapid development, it is definitely too early to give a unified presentation. The objective of this book is very modest: it is intended to be used as a textbook for an introductory one-semester course on "wavelet analysis" for upper-division undergraduate or beginning graduate mathematics and engineering students, and is also written for both mathematicians and engineers who wish to learn about the subject. For the specialists, this volume is suitable as complementary reading to the more advanced monographs, such as the two volumes of *Ondelettes et Opérateurs* by Yves Meyer, the edited volume of *Wavelets–A Tutorial in Theory and Applications* in this series, and ...ing CBMS volume by Ingrid Daubechies.

$L^2(0,2\pi)$

...velet analysis is a relatively new subject and the approach and ...n this book are somewhat different from that in the others, the ...apter is to convey a general idea of what wavelet analysis is about ...e what this book aims to cover.

1.1. From Fourier analysis to wavelet analysis

Let $L^2(0,2\pi)$ denote the collection of all measurable functions f defined on the interval $(0,2\pi)$ with

$$\int_0^{2\pi} |f(x)|^2 dx < \infty.$$

For the reader who is not familiar with the basic Lebesgue theory, the sacrifice is very minimal by assuming that f is a piecewise continuous function. It will always be assumed that functions in $L^2(0,2\pi)$ are extended periodically to the real line

$$\mathbb{R} := (-\infty,\infty),$$

namely: $f(x) = f(x-2\pi)$ for all x. Hence, the collection $L^2(0,2\pi)$ is often called the space of 2π-periodic square-integrable functions. That $L^2(0,2\pi)$ is

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2 *1. An Overview*

a vector space can be verified very easily. Any f in $L^2(0,2\pi)$ has a Fourier series representation:

$$f(x) = \sum_{n=-\infty}^{\infty} c_n e^{inx}, \tag{1.1.1}$$

where the constants c_n, called the Fourier coefficients of f, are defined by

$$c_n = \frac{1}{2\pi}\int_0^{2\pi} f(x)e^{-inx}dx. \tag{1.1.2}$$

The convergence of the series in (1.1.1) is in $L^2(0,2\pi)$, meaning that

$$\lim_{M,N\to\infty}\int_0^{2\pi}\left|f(x)-\sum_{n=-M}^{N} c_n e^{inx}\right|^2 dx = 0.$$

There are two distinct features in the Fourier series representation (1.1.1). First, we mention that f is decomposed into a sum of infinitely many mutually orthogonal components $g_n(x) := c_n e^{inx}$, where orthogonality means that

$$\langle g_m, g_n\rangle^* = 0, \quad \text{for all} \quad m \neq n, \tag{1.1.3}$$

with the "***inner product***" in (1.1.3) being defined by

$$\langle g_m, g_n\rangle^* := \frac{1}{2\pi}\int_0^{2\pi} g_m(x)\overline{g_n(x)}dx. \tag{1.1.4}$$

That (1.1.3) holds is a consequence of the important, yet simple fact that

$$w_n(x) := e^{inx}, \qquad n = \cdots,-1,0,1,\ldots, \tag{1.1.5}$$

is an orthonormal (o.n.) basis of $L^2(0,2\pi)$. The second distinct feature of the Fourier series representation (1.1.1) is that the o.n. basis $\{w_n\}$ is generated by "***dilation***" of a single function

$$w(x) := e^{ix}; \tag{1.1.6}$$

that is, $w_n(x) = w(nx)$ for all integers n. This will be called ***integral dilation***.

Let us summarize this remarkable fact by saying that *every 2π-periodic square-integrable function is generated by a "superposition" of integral dilations of the basic function $w(x) = e^{ix}$.*

We also remark that from the o.n. property of $\{w_n\}$, the Fourier series representation (1.1.1) also satisfies the so-called *Parseval Identity*:

$$\frac{1}{2\pi}\int_0^{2\pi} |f(x)|^2 dx = \sum_{n=-\infty}^{\infty} |c_n|^2. \tag{1.1.7}$$

崔景泰 Charles K. Chui, *An Introduction to Waves*, Academic Press, 1992

Functional Analysis
泛函分析

Linear Space 线性空间

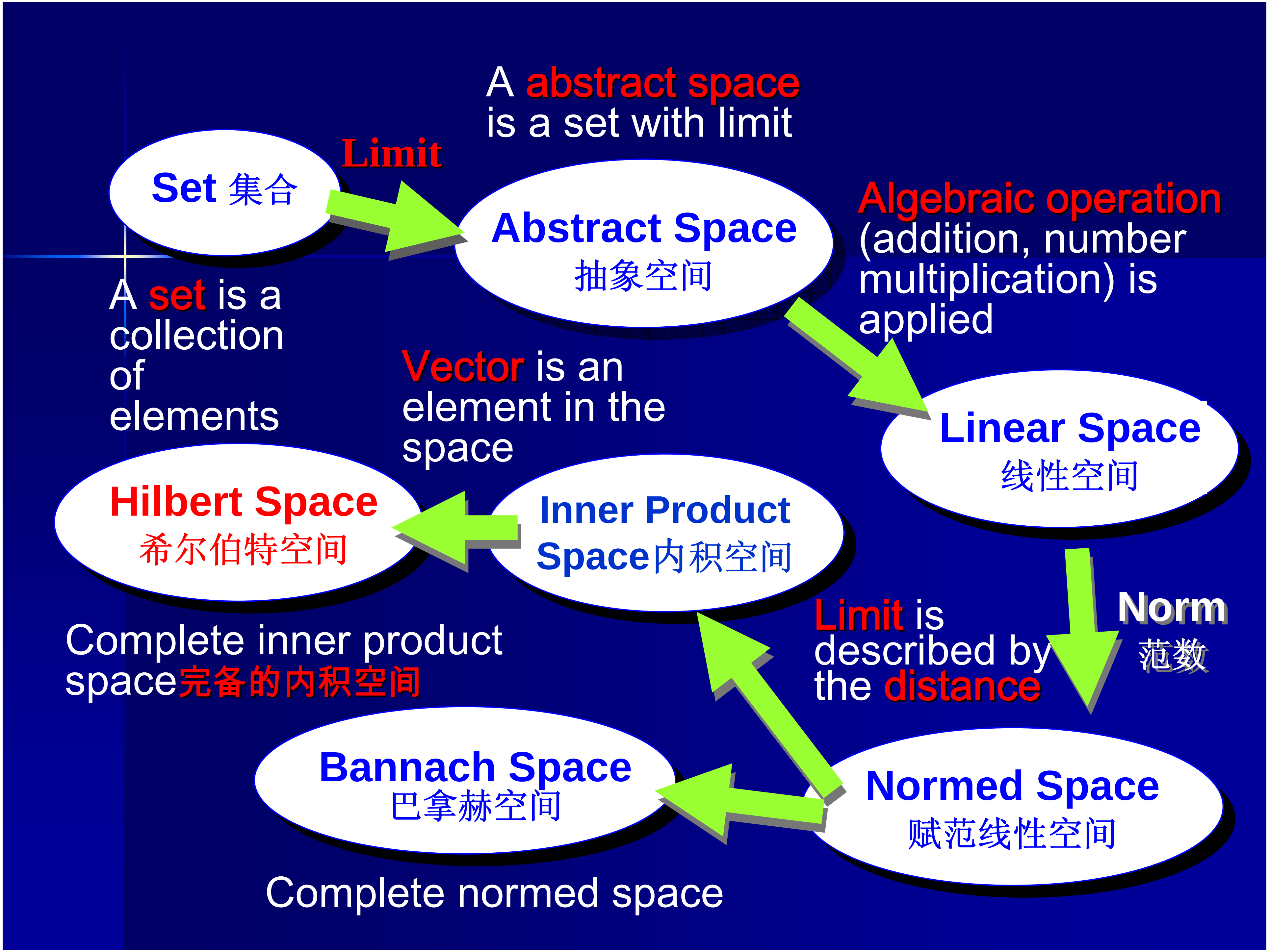
Abstract Space 抽象空间

Bannach Space

Norm 范数

Hilbert Space

Normed Space 赋范空间


A abstract space
is a set with limit
Limit
Set 集合
Abstract Space
抽象空间
Algebraic operation
(addition, number multiplication) is applied
A set is a collection of elements
Vector is an element in the space
Linear Space
线性空间
Hilbert Space
希尔伯特空间
Inner Product Space内积空间
Norm
范数
Limit is described by the distance
Complete inner product space完备的内积空间
Bannach Space
巴拿赫空间
Normed Space
赋范线性空间
Complete normed space

$L^2(R^2)$空间的基本性质：（泛函分析）

└ 定义在R^2上的完备的内积空间.

$\boxed{\text{内积：}}$ $\forall f, g \in L^2(R^2)$，对应一个实数 $\langle f, g\rangle$

（或复数）

$\langle f, g\rangle$
- 非负性 $\langle \boldsymbol{f}, \boldsymbol{f} \rangle \geq 0$
- 对称性 $\langle f, g\rangle = \langle g, f\rangle$
- 线性性 $\langle \alpha f + \beta g, h\rangle = \alpha\langle f, h\rangle + \beta\langle g, h\rangle$

完备：（对极限运算的封闭性）

- 自然数：对"+"封闭，对"−"不封闭
- 整　数：+，−，× 封闭，÷ 〃 〃 〃
- 有理数：（凡可表示为 $\frac{m}{n}$ 的数：整数.分数.有限或无限循环小数）

  +，−，×，÷ 封闭，对极限不封闭

例：$\pi = 3.1415926535932354\,626\cdots$ 是无理数

（山顶一寺一壶酒，尔乐吾煞吾，酒杀尔，杀不死，乐而乐）

完备：（对极限运算的封闭性）

例：$\pi = 3.14159265358932354626 \cdots$ 是无理数

（山顶一寺一壶酒，尔乐吾煞吾，酒杀尔，杀不死，乐而乐）

改紧一有理数的数列 $\{a_n\}$

$a_1 = 3, \quad a_2 = 3.1, \quad a_3 = 3.14, \cdots$

$\lim\limits_{n\to\infty} a_n = \pi$ 此极限不包括在有理数内

- 实数：（有理、无理统称）

$+$，$-$，$\times$，$\div$，极限均封闭

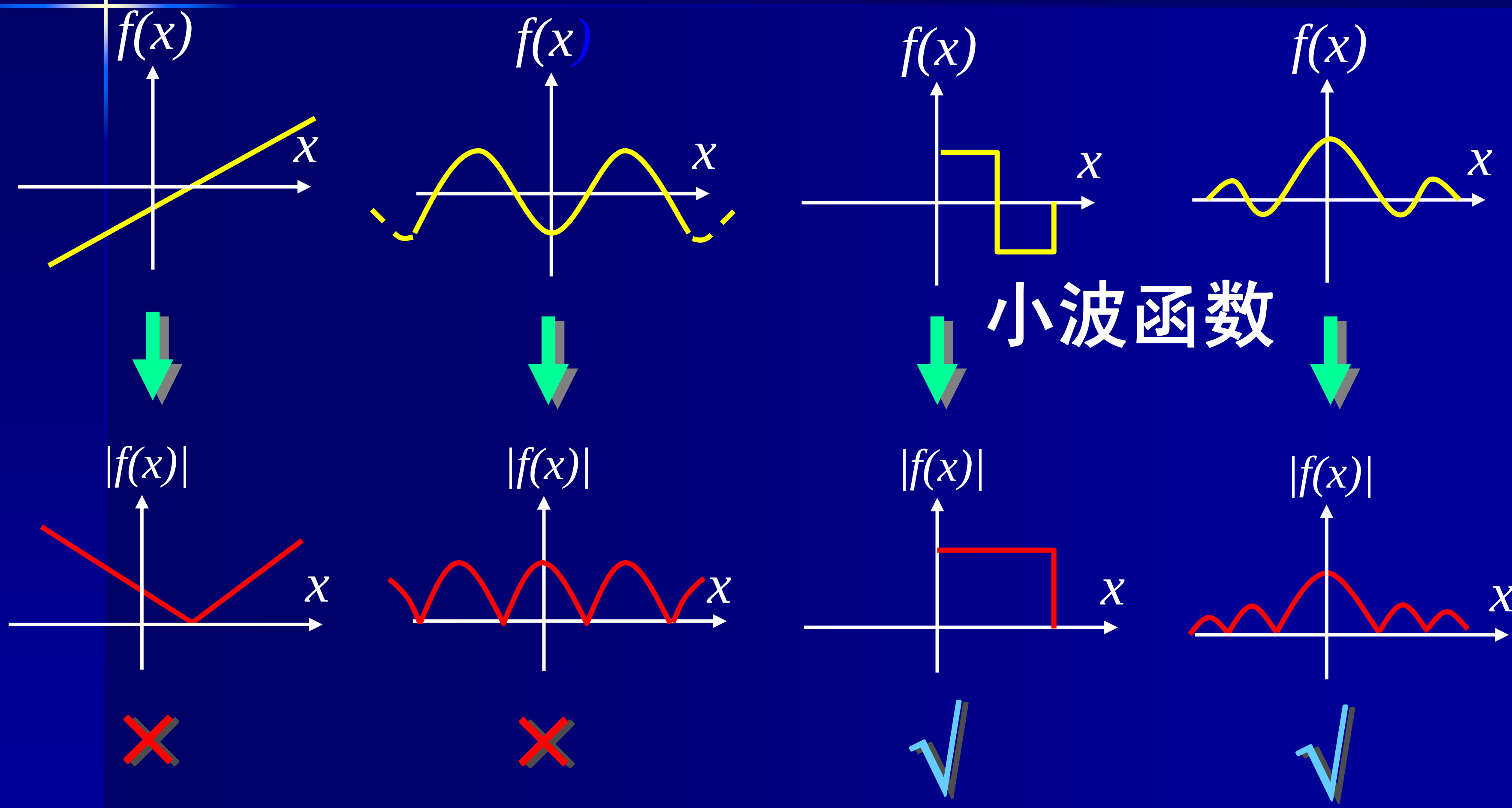
L2(R^2) 空间的函数的重要性质

如果 $f(x,y)$ 是L2(R^2) 空间的函数，即 $f(x,y) \in L^2(R^2)$，则 $f(x,y)$ 是平方可积函数，即函数的能量有限

$$\underbrace{\iint_{R^2} | f(x,y) |^2 \, dxdy}_{\text{函数的能量}} < \infty$$

$f(x) \in L^2(R)$ $\longleftrightarrow$ $\int_{-\infty}^{\infty} |f(x)|^2 dt < \infty$

$f(x)$ 是平方可积函数

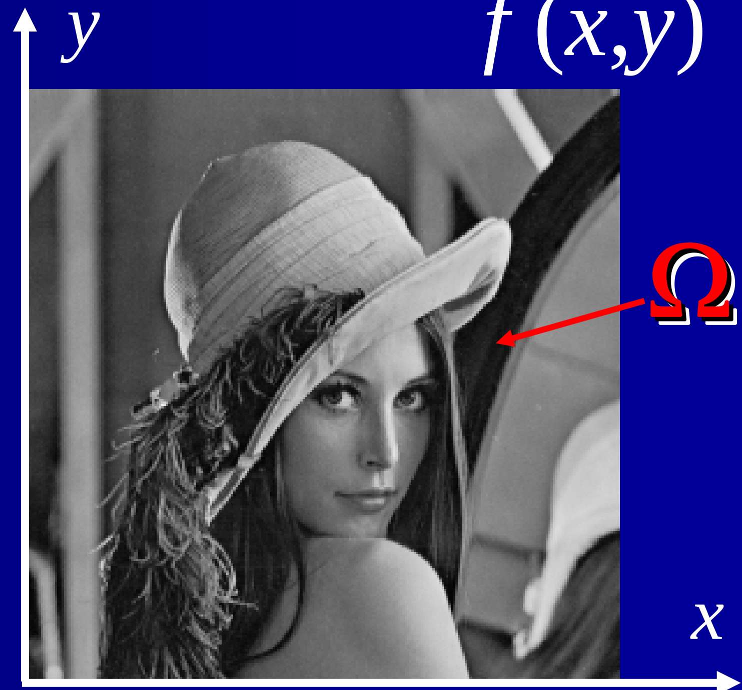


$\boxed{f(x,y) \in \mathrm{L}^2(\mathrm{R}^2)}$ $\longleftrightarrow$ $\iint\limits_{R^2} |f(x,y)|^2 \, dxdy < \infty$

f 是平方可积函数

图像是L2(R^2)空间的函数

- 图像的面积是有限的：Ω
- 图像的像素灰度级是有限的：$0 \le f(x,y) \le 255$
- 所以



$$0 = \iint\limits_{\Omega} 0 \, dxdy \le \iint\limits_{\Omega} |f(x,y)|^2 \, dxdy \le \iint\limits_{\Omega} 255^2 \, dxdy = 255^2 \Omega < \infty$$

图像是L2(R^2)空间的函数

$$0 = \iint_{\Omega} 0\,dxdy \le \iint_{\Omega} |f(x,y)|^2\,dxdy \le \iint_{\Omega} 255^2\,dxdy = 255^2\Omega < \infty$$

- 这个公式仅仅考虑在图像面积 Ω 内的积分.
- 从数学的角度应该考虑在整个 空间R^2内的积分

- 我们在整个 空间R^2内制造一个新的图像

$$f(x,y) = \begin{cases} f(x,y) & (x,y) \in \Omega \\ 0 & (x,y) \notin \Omega \end{cases}$$

- 因此

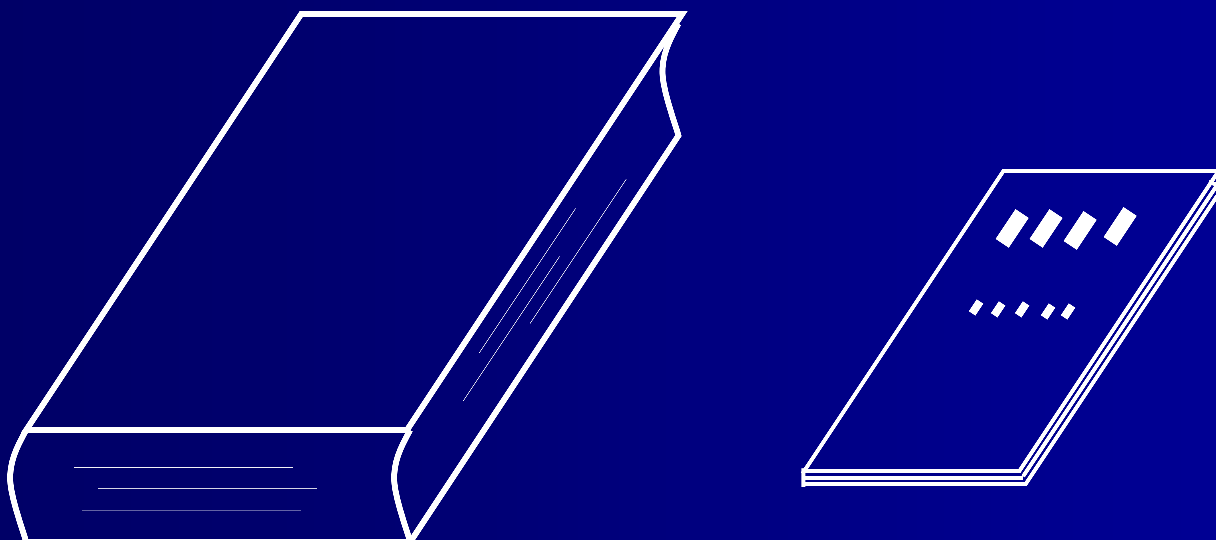
$$0 \le \iint_{R^2} |f(x,y)|^2\,dxdy \le 255^2\Omega < \infty$$

$L2(R^n)$ 空间的一类重要函数 — 小波函数（Wavelets）

Waves, Wavelets, and Transforms 波、小波和变换

Waves & Wavelets 波和小波

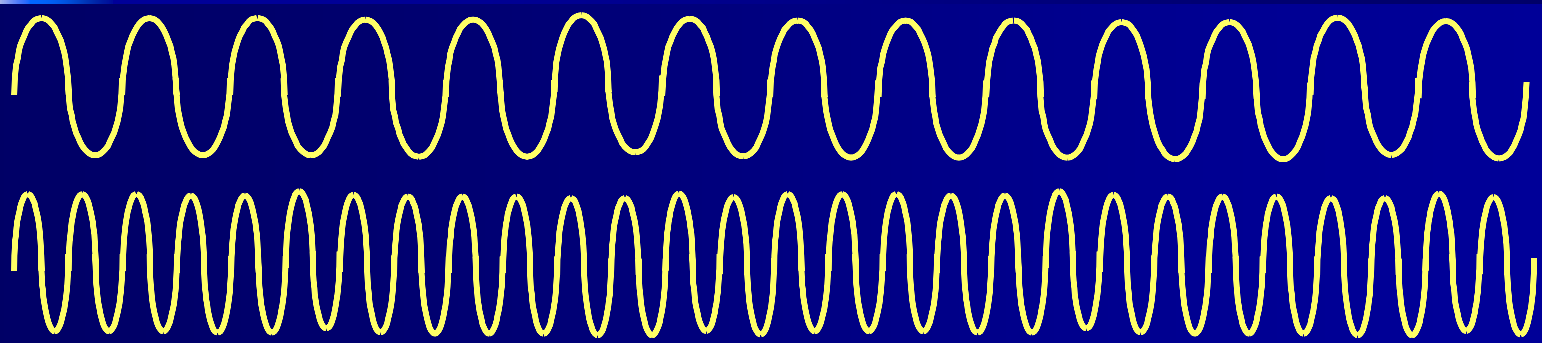
A new word in English - Wavelets



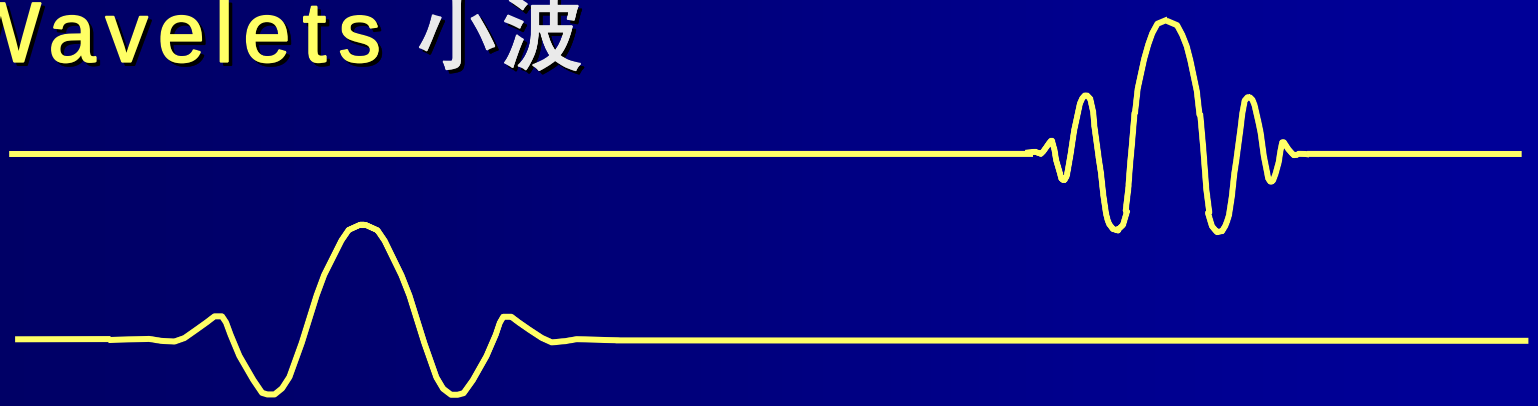
Book and booklet 书和小册子

Waves & Wavelets 波和小波

Waves 波



Wavelets 小波



Transform 变换

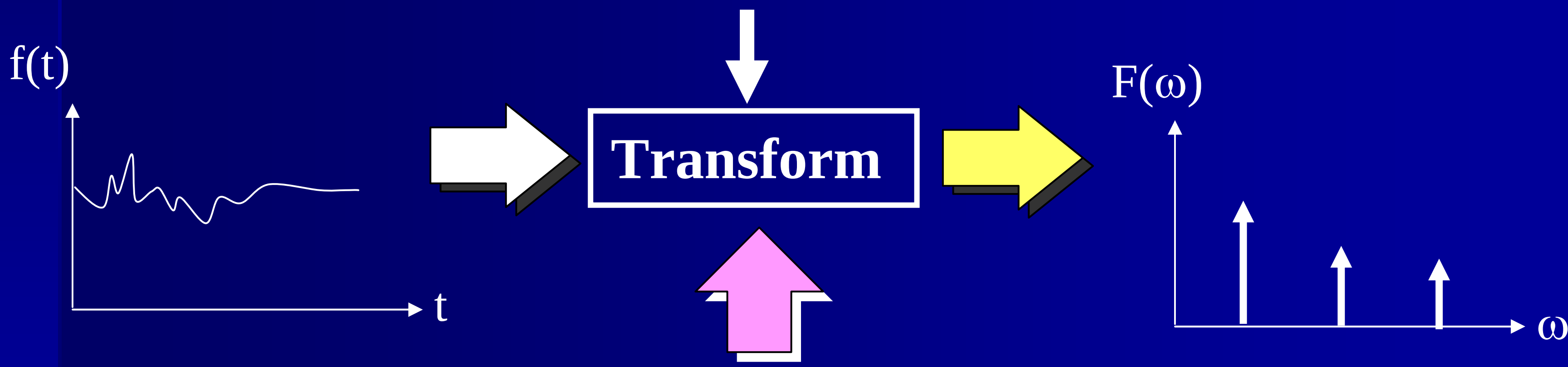
Input function 被处理的信号

$$F(w)=\int_{-\infty}^{\infty} f(t)g(t,w)\,dt=\langle f(t),g(t,w)\rangle$$

Basis function 基本函数

Operation:

Inner Product 内积

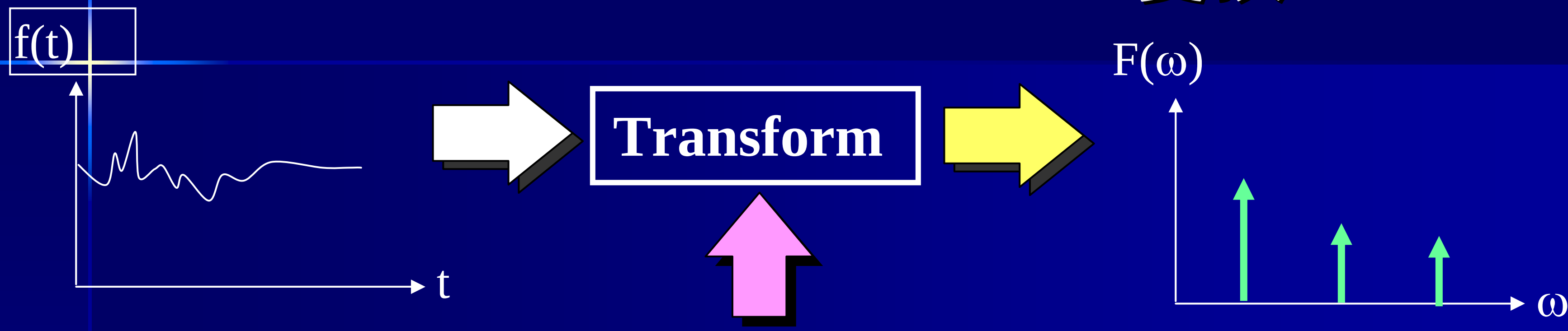


Basis function g(t,w)

基本函数

Wavelet Transform

小波 变换



Basis function g(t)

基本函数

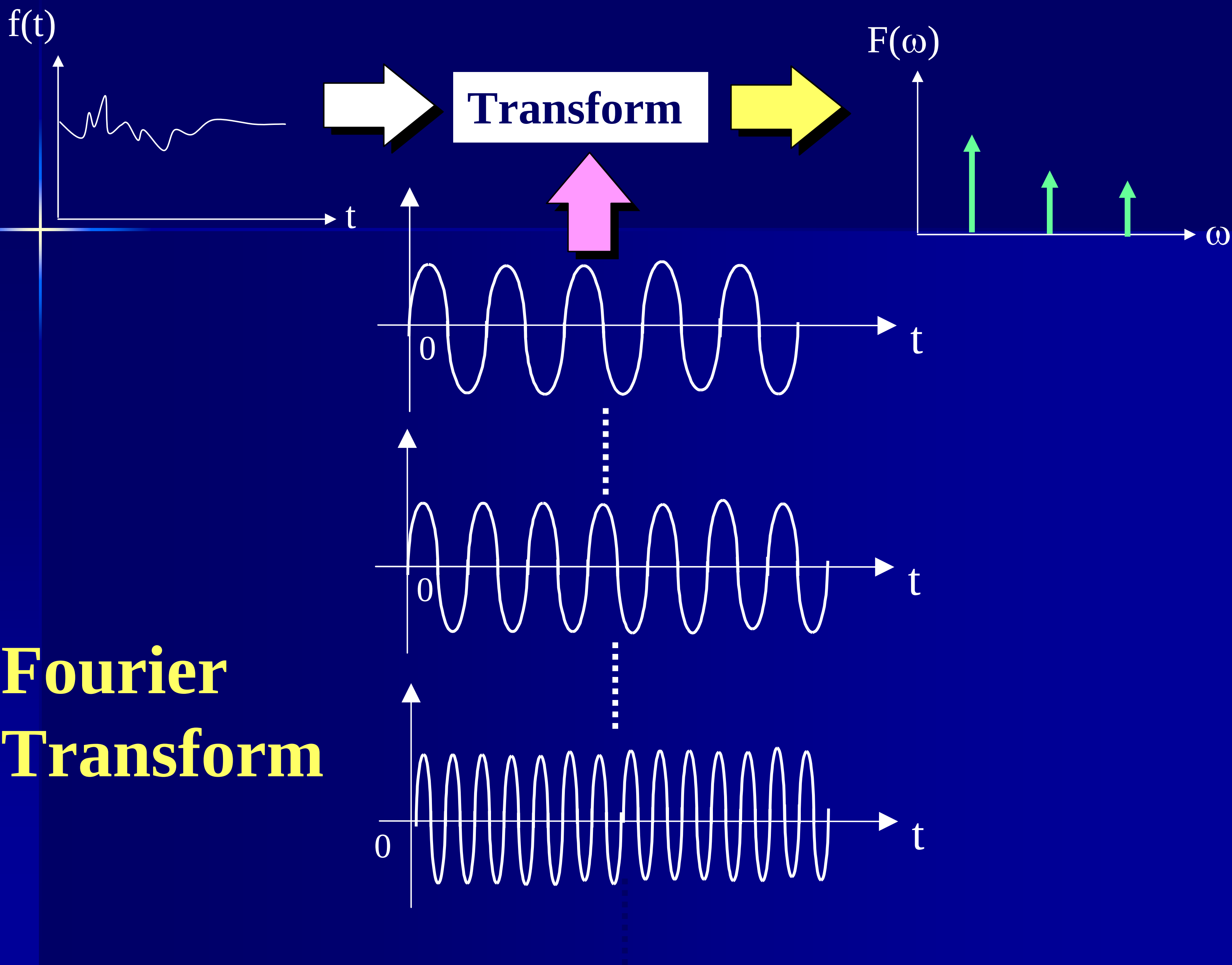
Wave Function

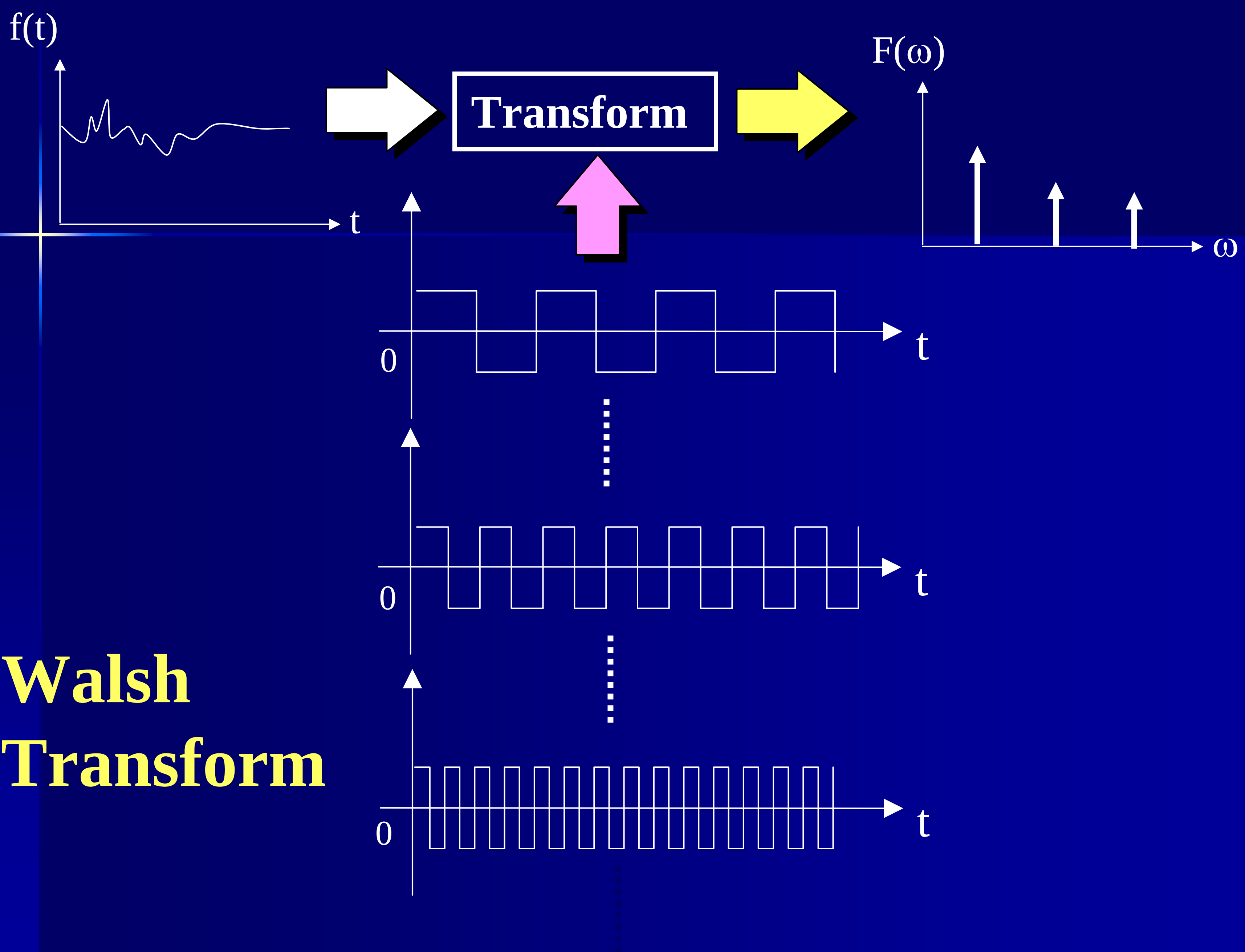
波函数

Wavelet Function

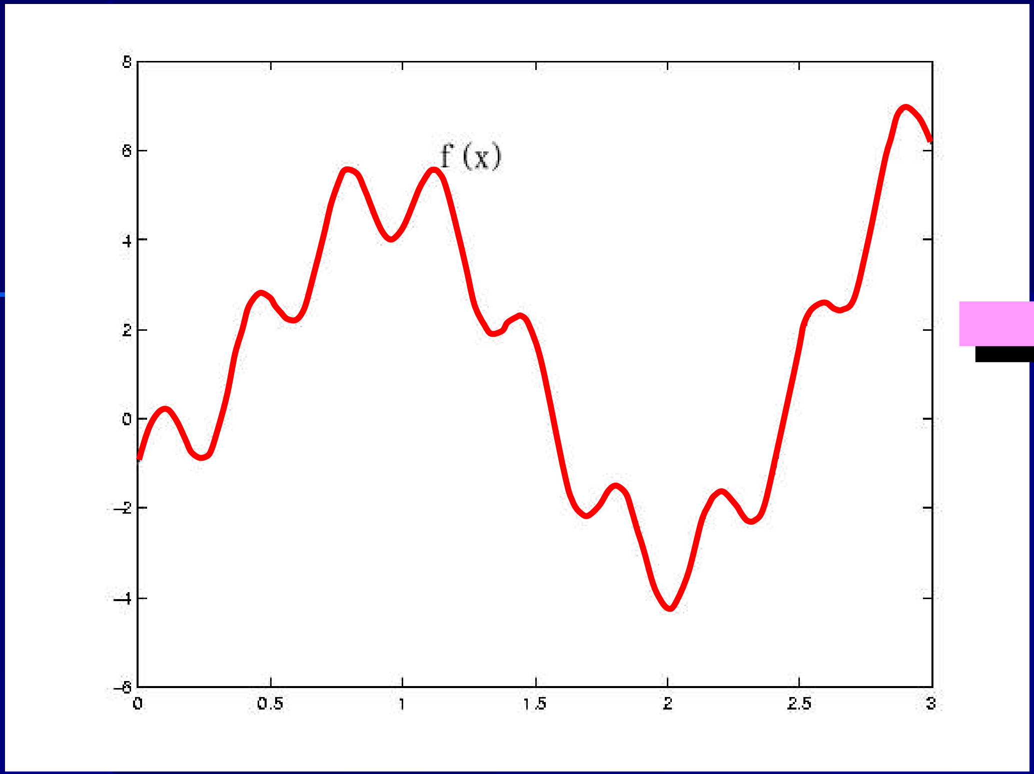
小波函数

Fourier Transform





Walsh Transform



$$f(x) = f0(x) + f1(x) + 2\times f2(x) - 4\times f3(x) + f4(x)$$

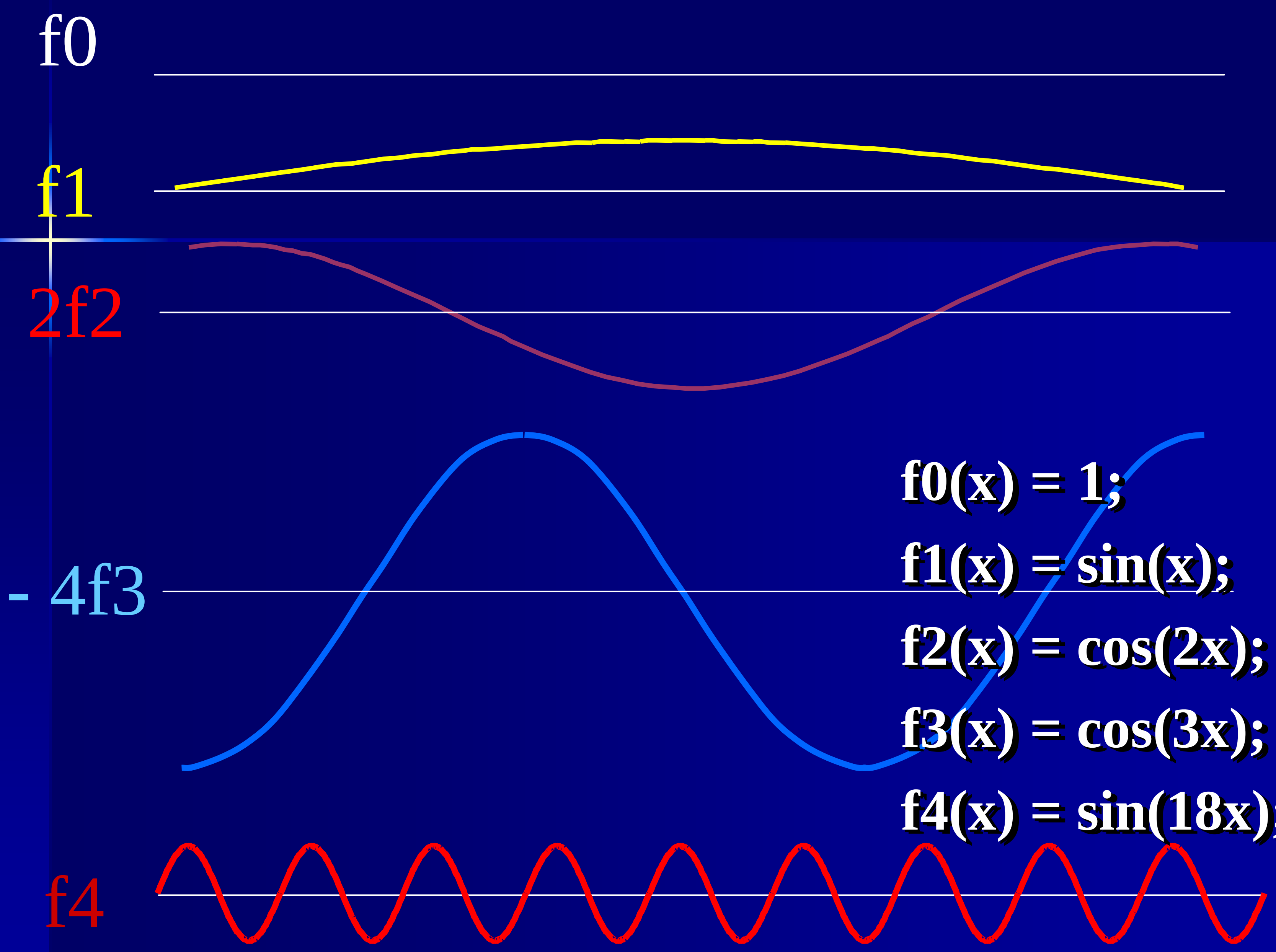
$f0(x) = 1;$

$f1(x) = \sin(x);$

$f2(x) = \cos(2x);$

$f3(x) = \cos(3x);$

$f4(x) = \sin(18x);$



$f0(x) = 1;$

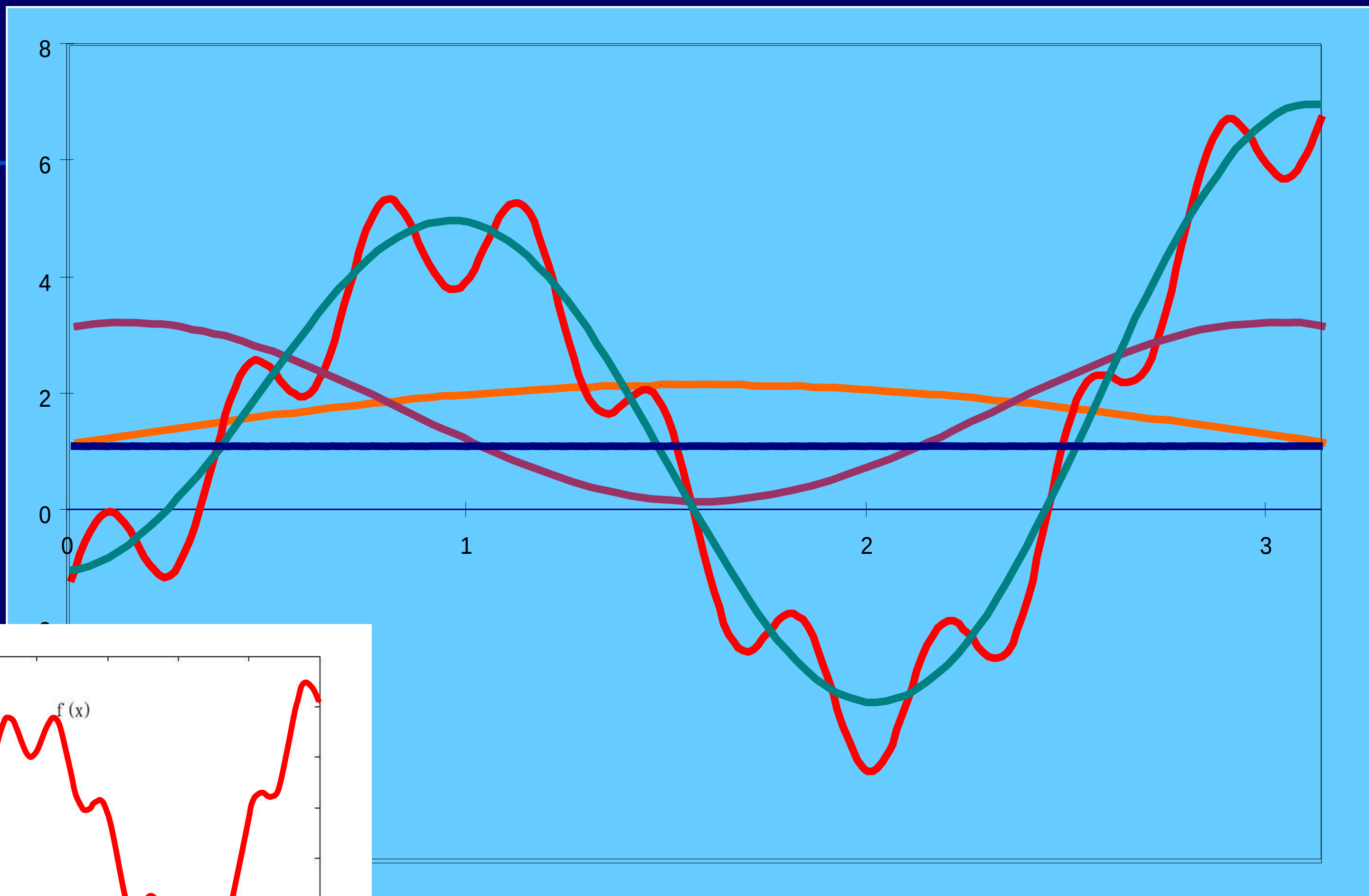
$f1(x) = \sin(x);$

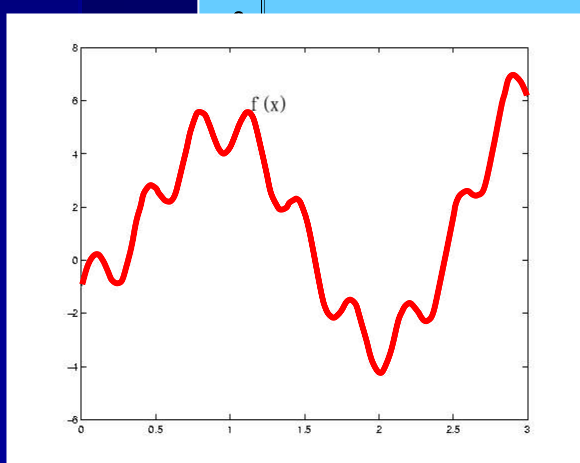
$f2(x) = \cos(2x);$

$f3(x) = \cos(3x);$

$f4(x) = \sin(18x);$

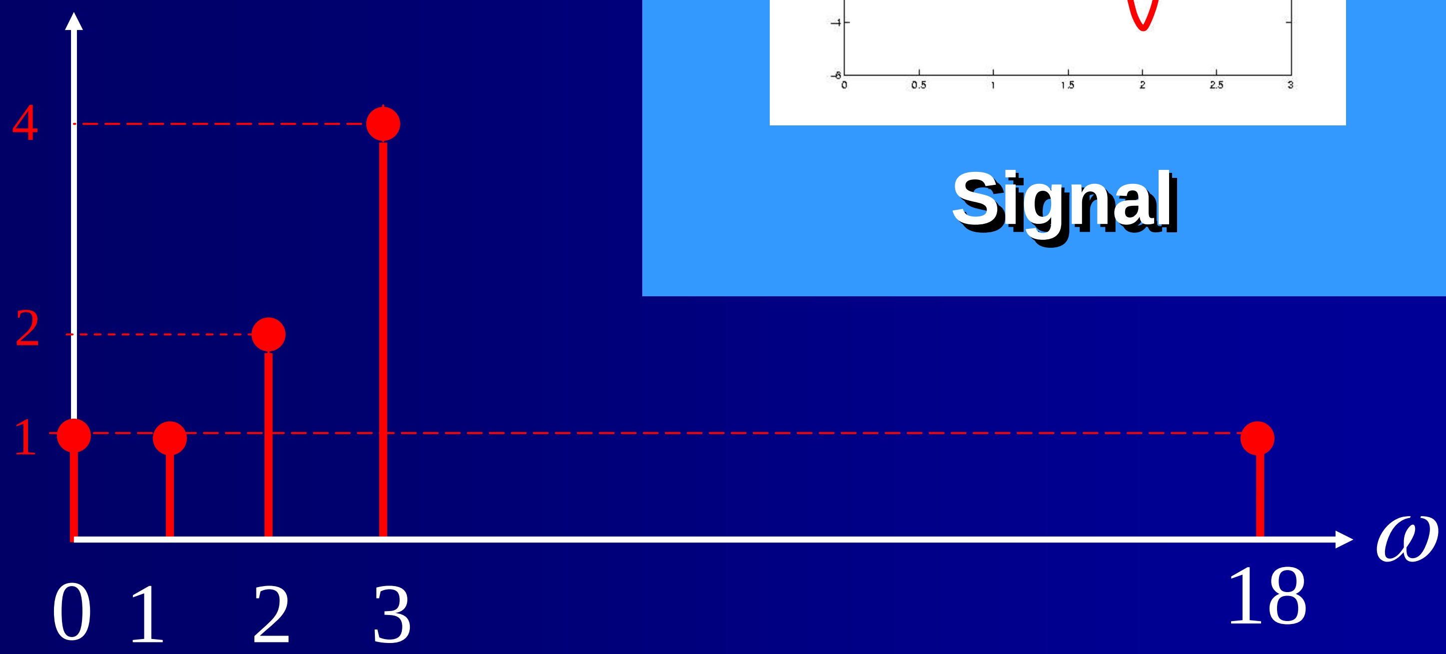
f = f0 + f1+2f2 - 4f3+ f4

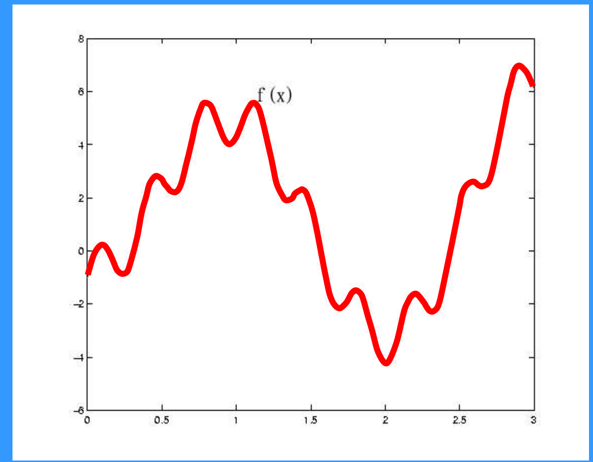




Wave Transform 波变换

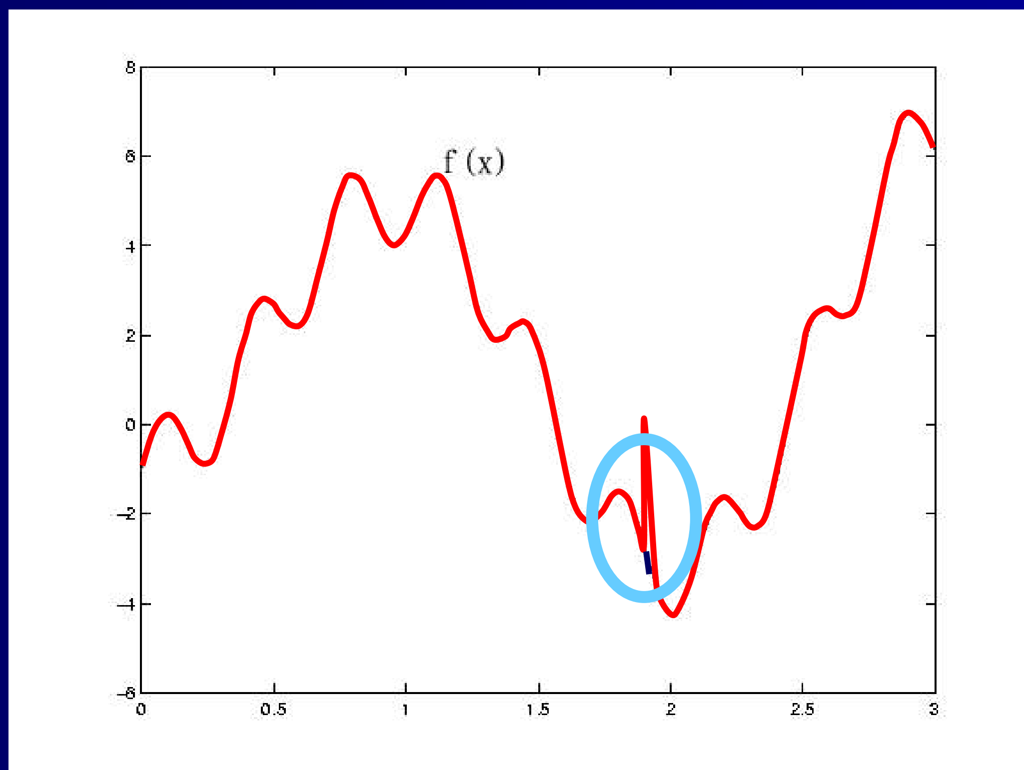
Spectrum



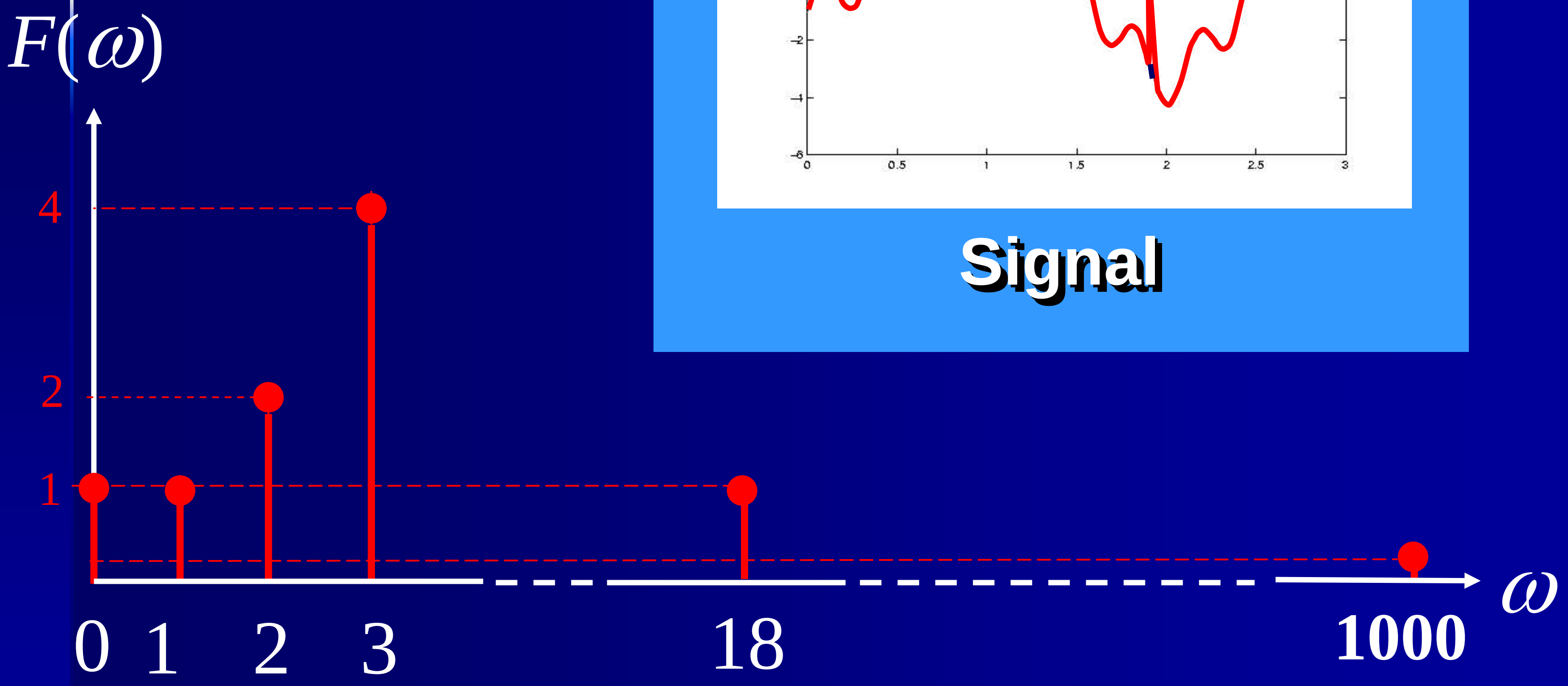


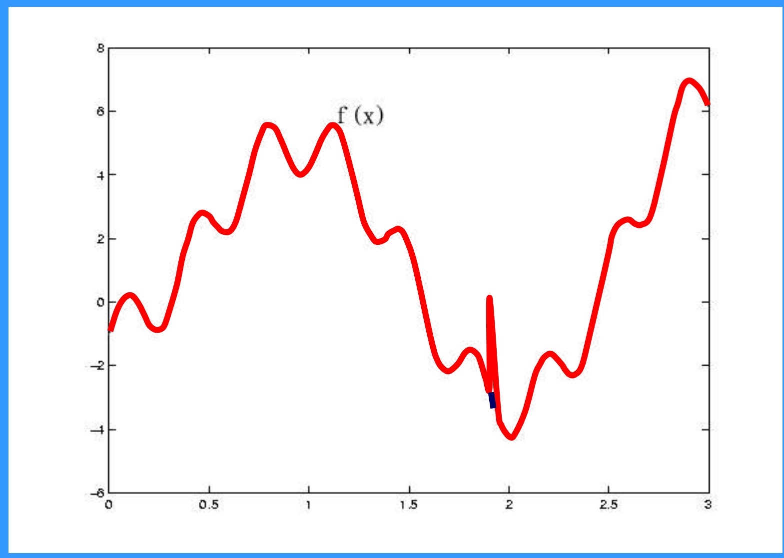
Signal

Fourier analysis, based on analyzing global frequency distribution of a signal, can not characterize the local behavior of the signal

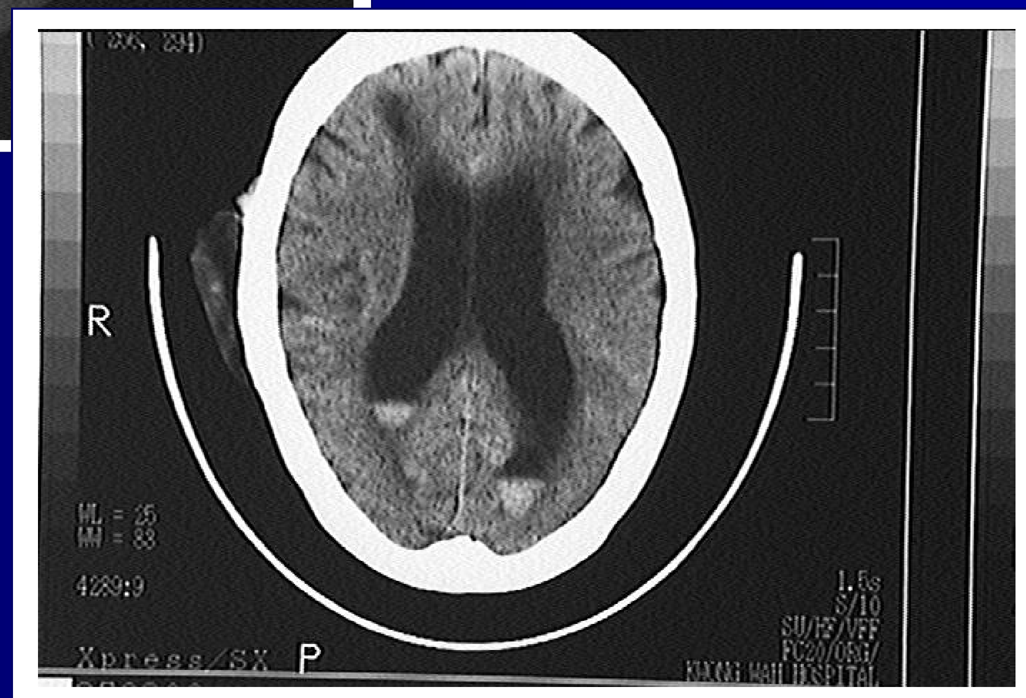


Spectrum

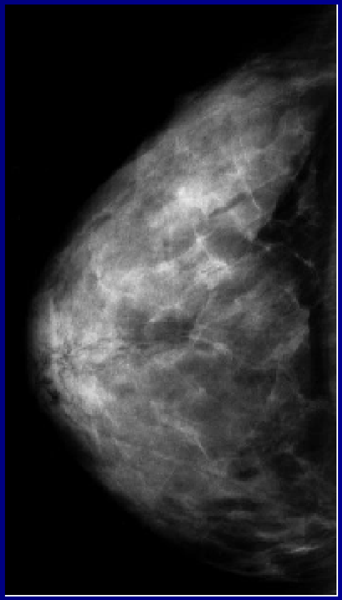




Signal


R
WL = 25
WW = 83
Xpress/SX
P
1.5s
S/10

Detection of Breast Cancer using Mammography



CC view **MLO view**

Mammography

Mammograms

High Risk of Breast Cancer

Estimated new breast cancer cases and deaths in women by age, United States, 1999

Age	In Situ	%	Invasive	%	Deaths	%
<30	100	0.3	800	0.5	100	0.2
30-39	1,400	3.5	7,400	4.2	1,200	2.8
40-49	9,000	22.6	32,100	18.3	5,600	12.9
50-59	10,000	25.1	37,400	21.4	7,000	16.2
60-69	8,500	21.3	32,600	18.6	7,100	16.4
70-79	8,200	20.6	40,700	23.2	11,000	25.4
80+	2,700	6.8	24,000	13.7	11,300	26.1
Total	39,900	100.0	175,000	100.0	43,300	100.0

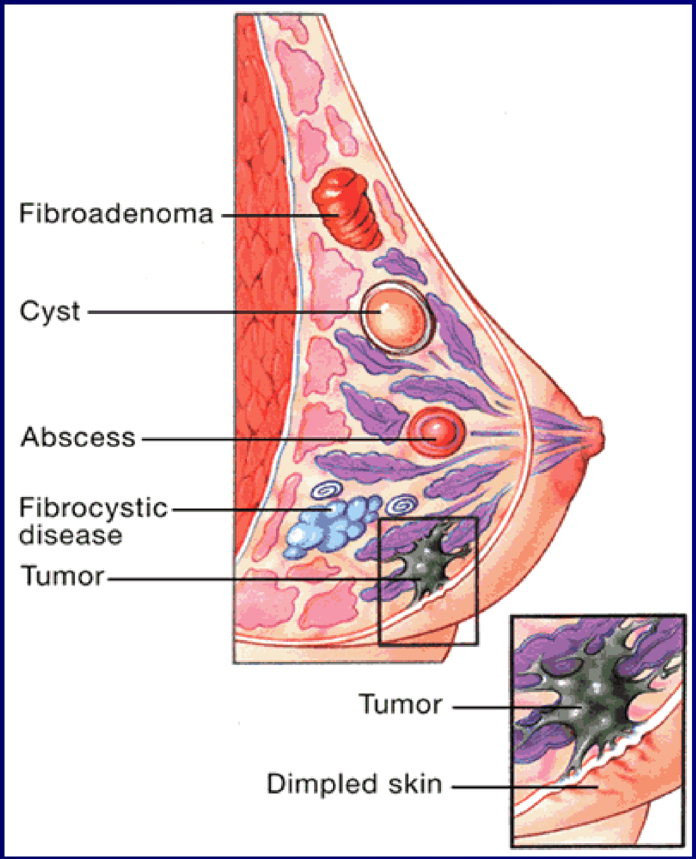
Due to rounding, percentages may not exactly total 100%.
American Cancer Society, Surveillance Research, 1999.

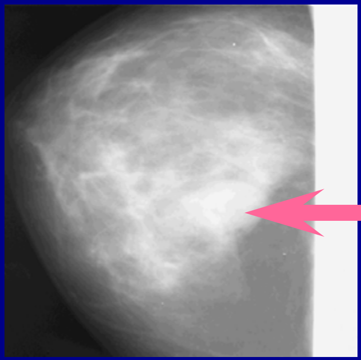
Expected survival rates for women diagnosed with breast cancer

- **85% five years after diagnosis**
  - 43% for leukemia
  - 14% for lung cancer
- **71% after 10 years**
- **57% after 15 years**
- **52% after 20 years**

Breast Cancer Facts & Figures 1999-2000
American Cancer Society

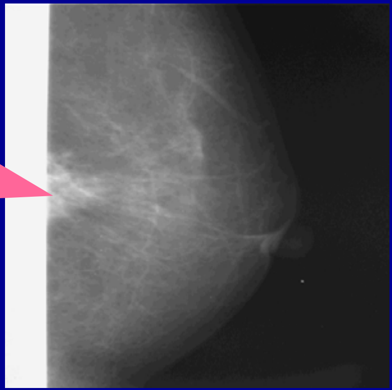
Lesions: Masses or Microcalcifications



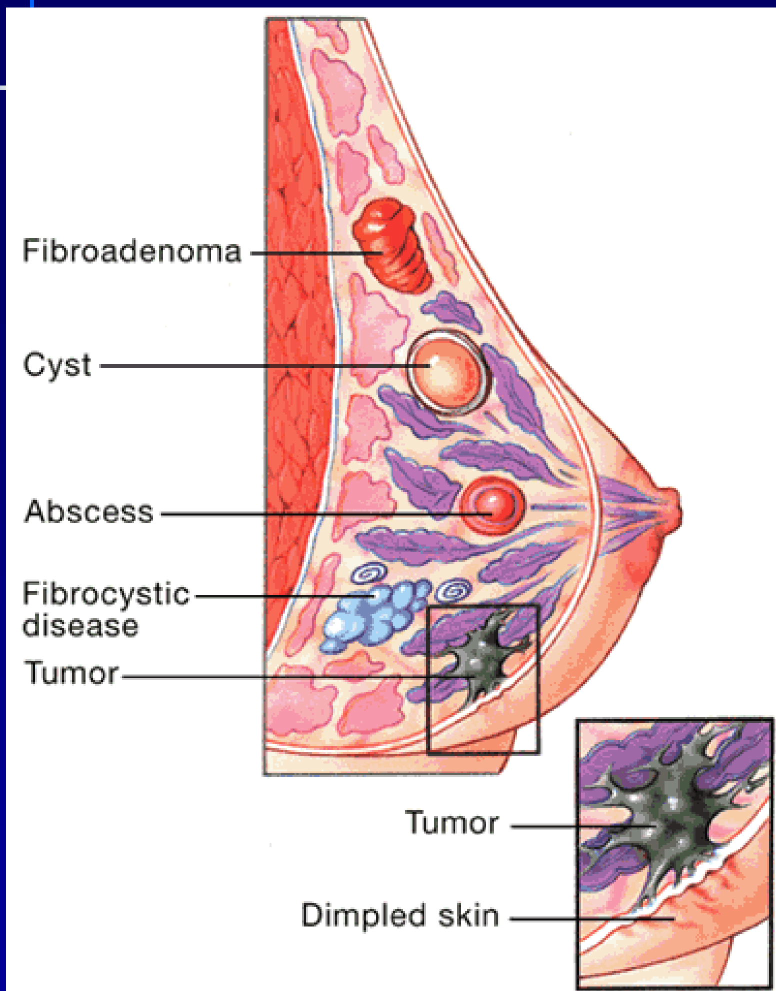


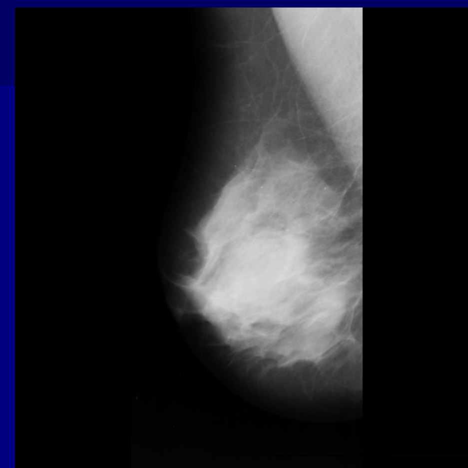
Mass

Microcalcifications



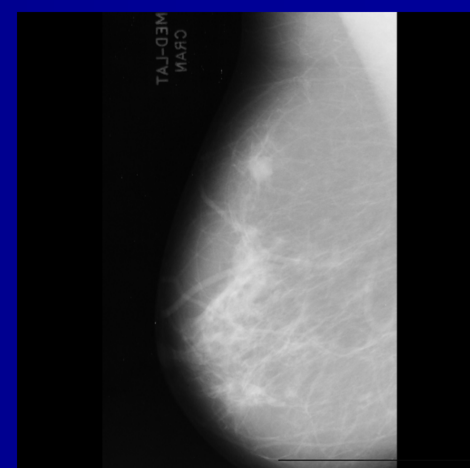
Tumors: Benign or Malignant





Benign

Malignant



函数 $\psi(t) \in R$ 小波函数，在$L^2(R)$空间，小波变换为

$$\left(W_{\psi} f\right)(a,b) = \frac{1}{\sqrt{a}} \int_R f(t)\psi\left(\frac{t-b}{a}\right)dt,$$

其中

a 是频率参数, b 是时间参数.

Wavelet Transform

小波变换

1986年

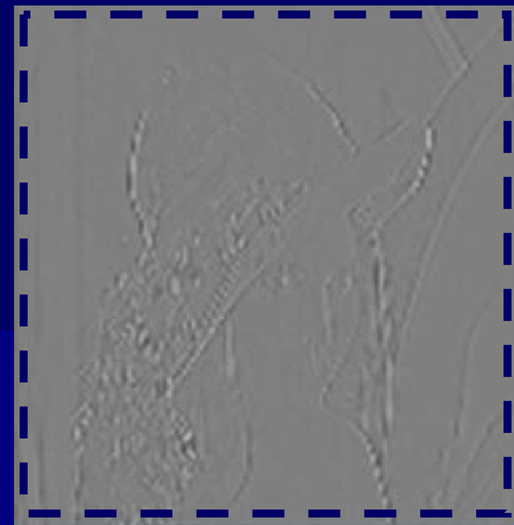
Wave Transform 1822年

波变换

w 是频率参数

$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt$$

$$V_j = V_{j+1} \oplus W_{j+1}$$

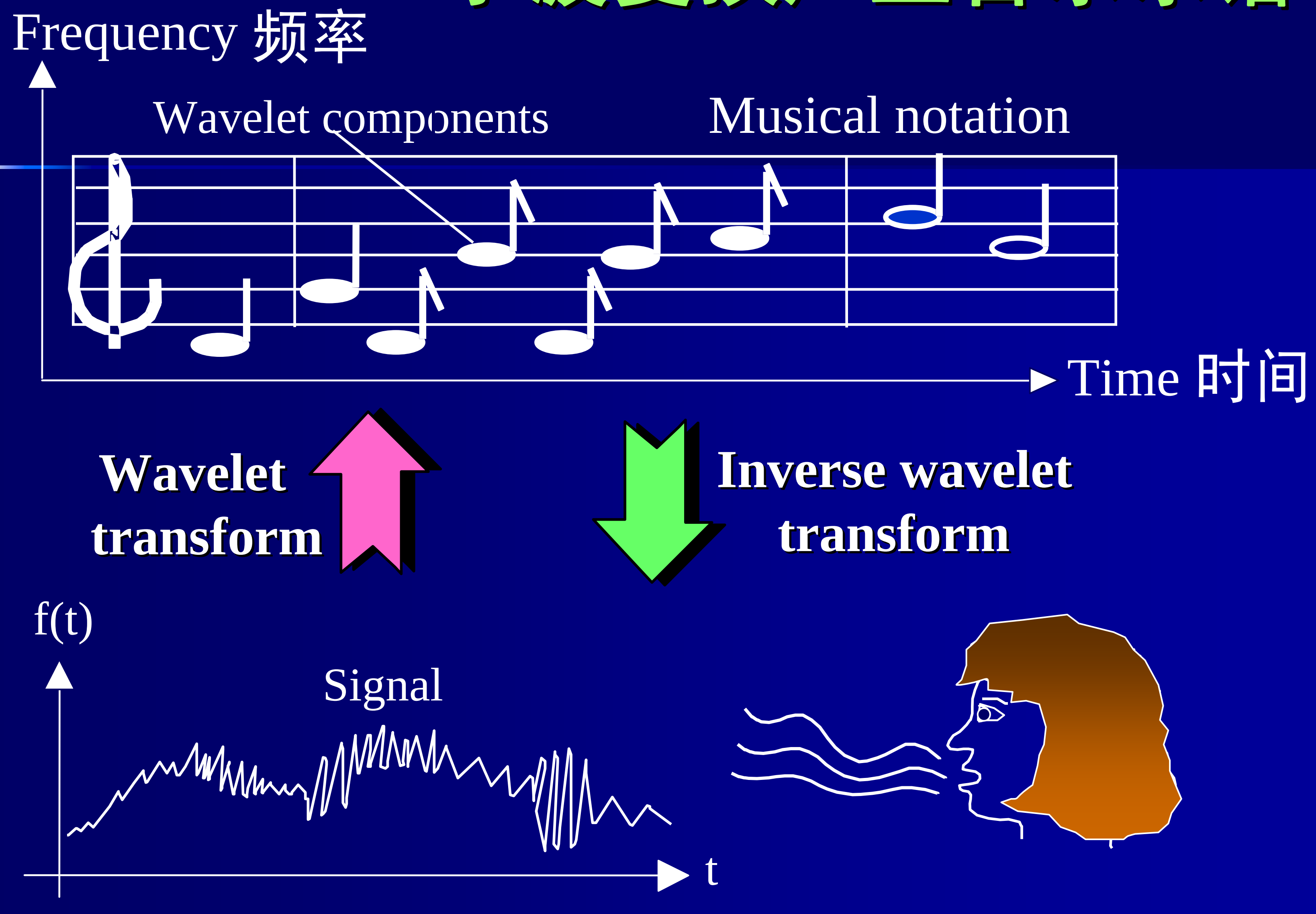


高频

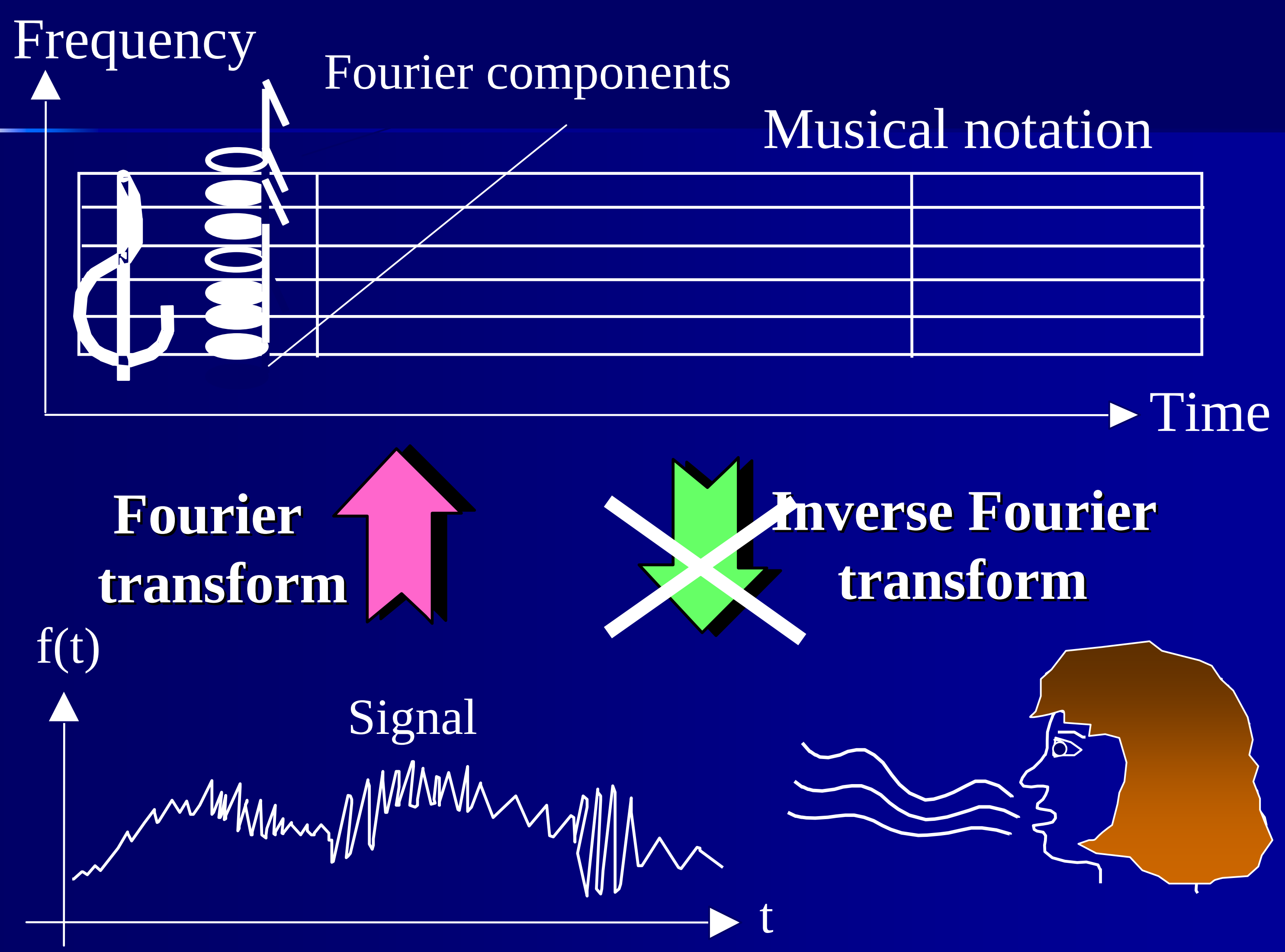
低频

Wavelet Transform 小波变换

小波变换产生音乐乐谱


Frequency 频率
Wavelet components
Musical notation
Time 时间
Wavelet transform
Inverse wavelet transform
f(t)
Signal
t

波变换不能产生音乐乐谱



多分辨分析 (MRA)

一个在$L^2(R)$空间的闭子空间系列 $\{V_j\}_{j\in Z}$ 如果满足以下条件，就称为多分辨分析 MRA:

1 $V_j \subseteq V_{j-1}$ for any $j \in Z$

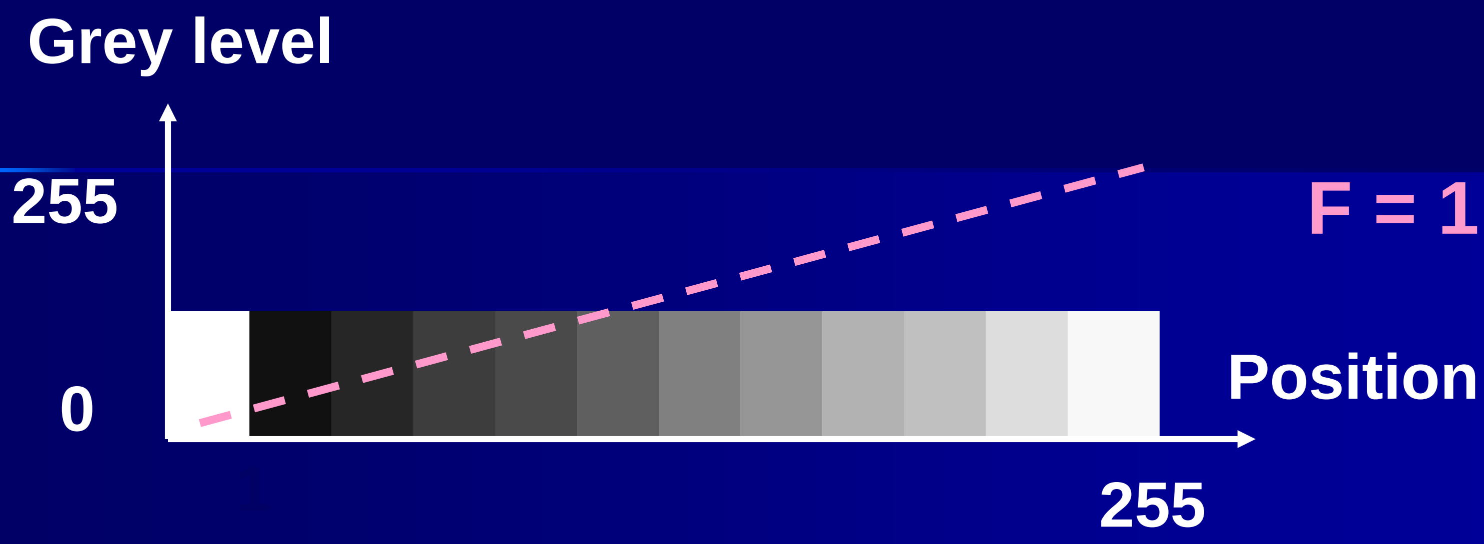
2 $\mathrm{clos}_{L^2(R)}(\cup V_j) = L^2(R)$, $\cap V_j = \{0\}$

3 $u(x) \in V_j \Leftrightarrow u(2x) \in V_{j-1}$

4 $u(x) \in V_0 \Leftrightarrow u(x-k) \in V_0$

5 存在一个生成函数 $g(x) \in V_0$ 它可以构成闭子空间 V_0 的 Riesz 基

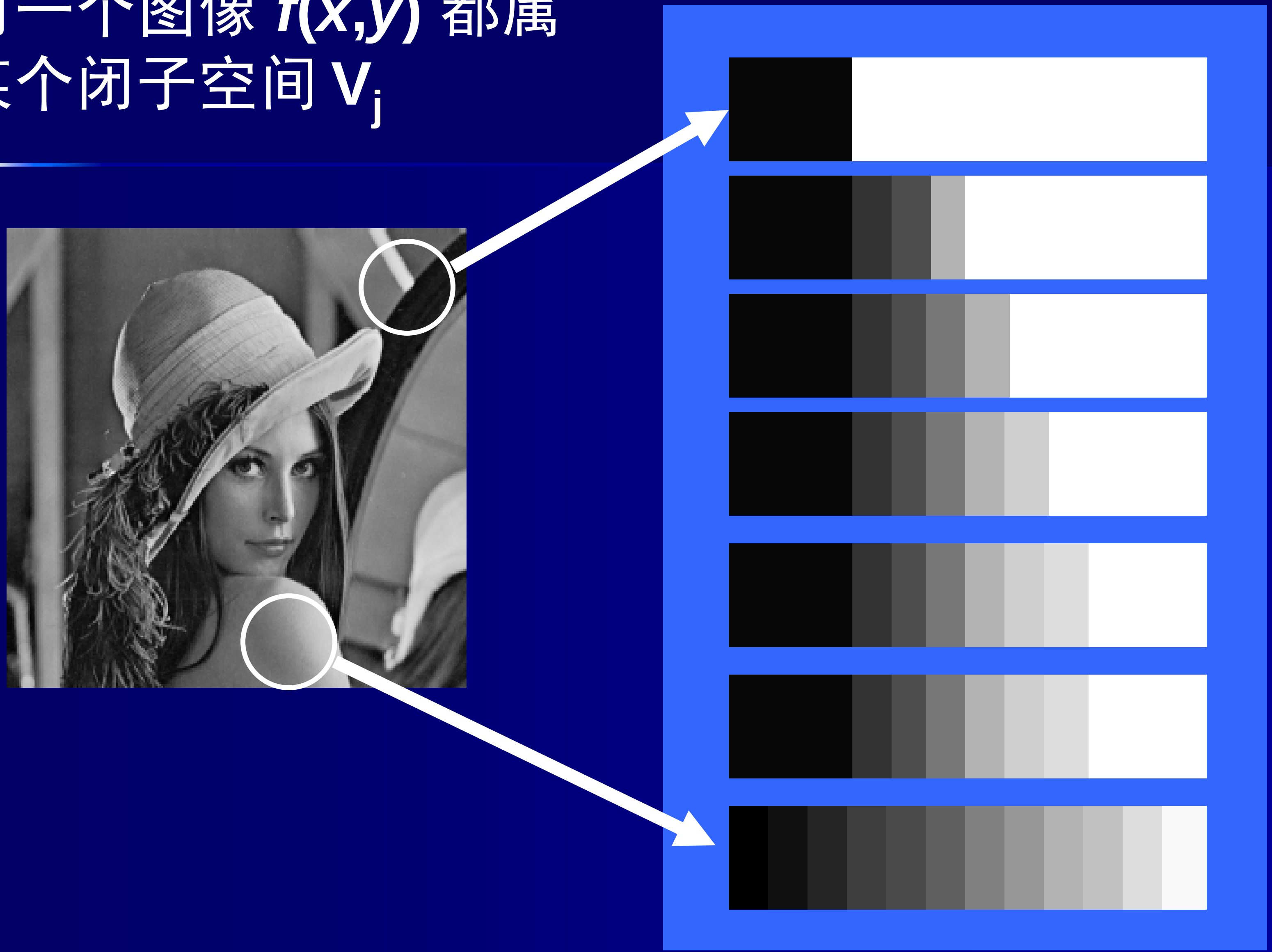
图像灰度的变化频率



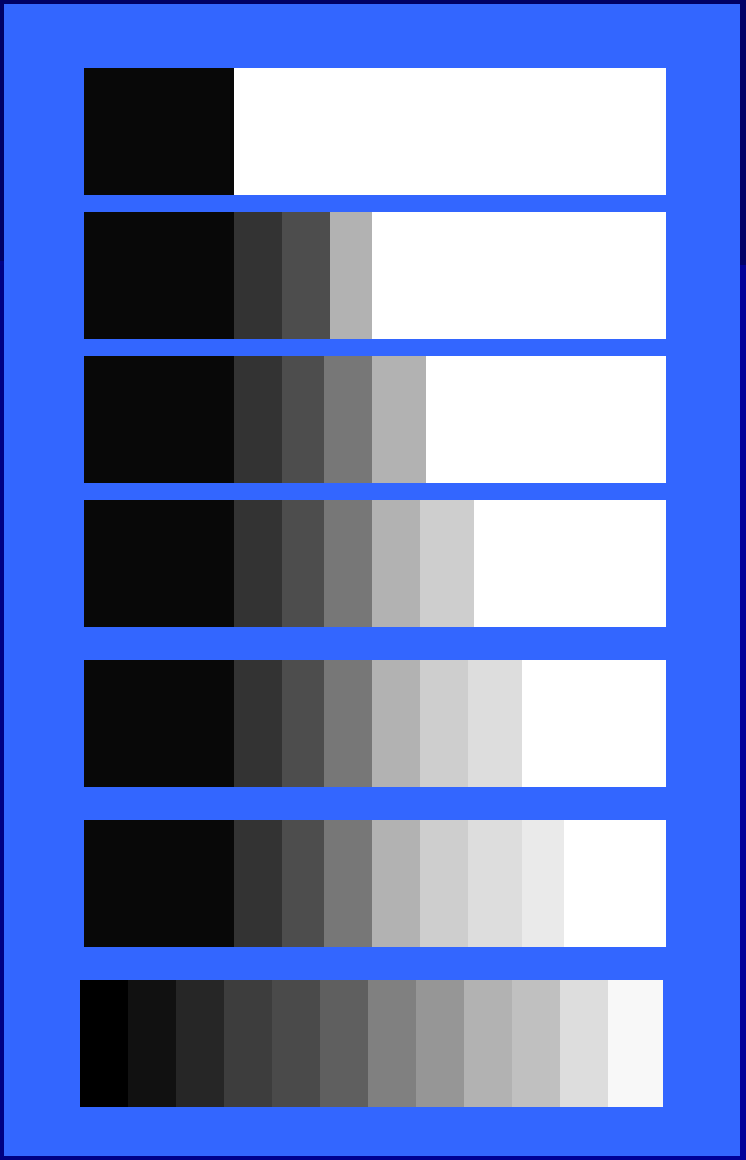
Grey level
255
F = 1
0
Position
255

Grey level
255
F = 256
0
Position
255

任何一个图像 ***f*(*x*,*y*)** 都属于某个闭子空间 V_j

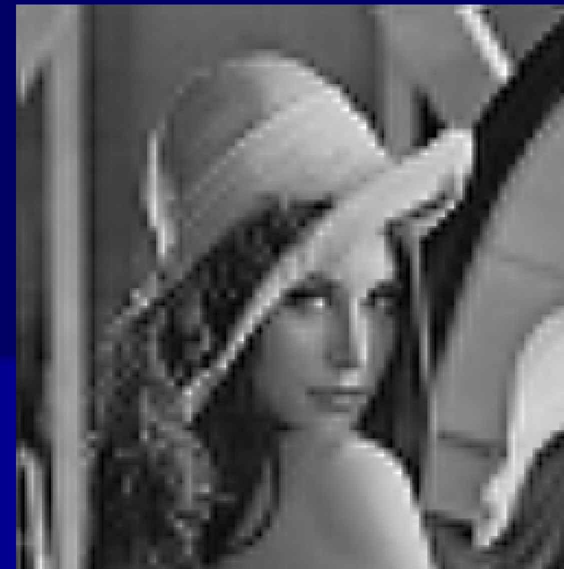


Grey level
255
0
Position

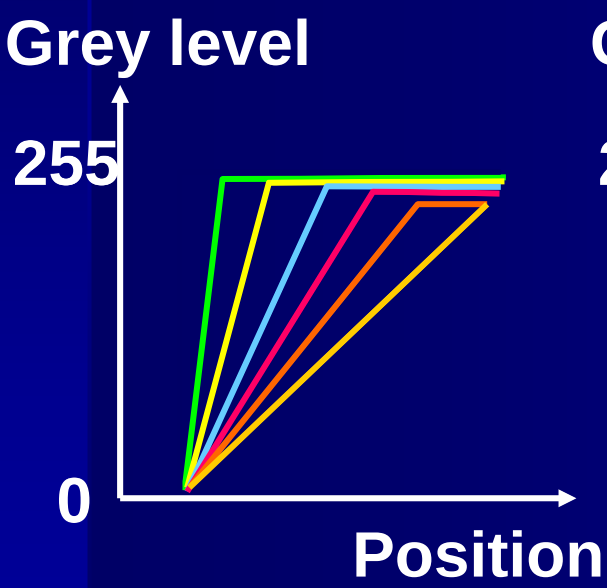


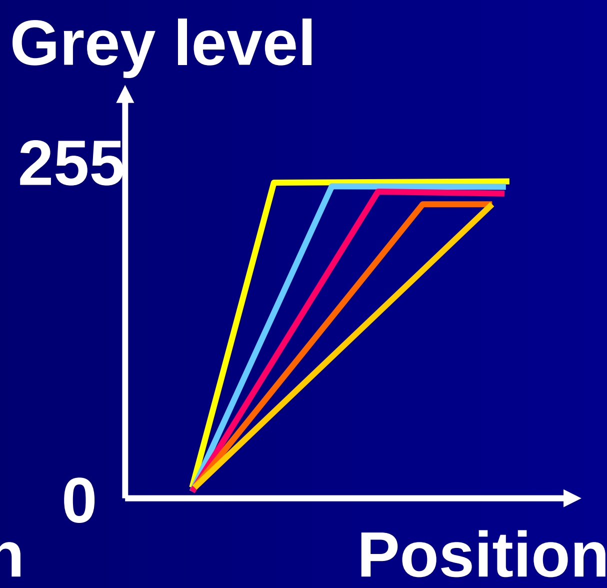
V_j

V_{j+1}



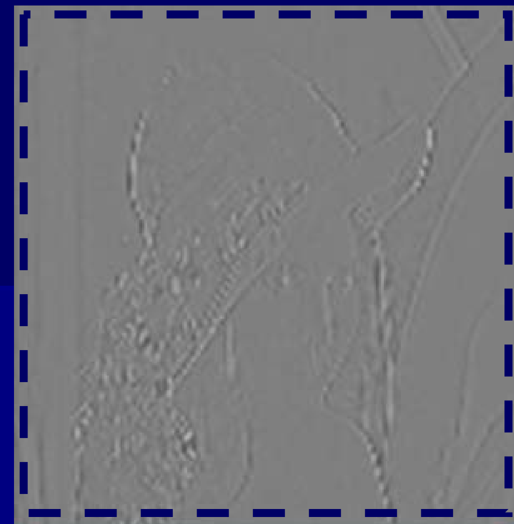
V_{j+2}





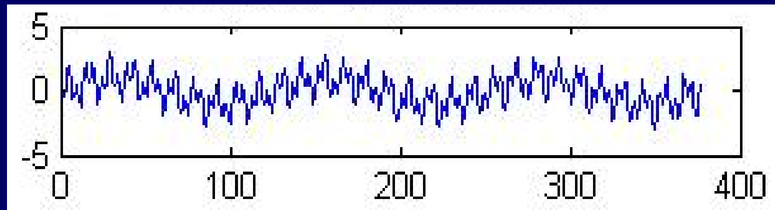
$$\ldots V_{j+2} \subset V_{j+1} \subset V_j$$

$$V_j = V_{j+1} \oplus W_{j+1}$$

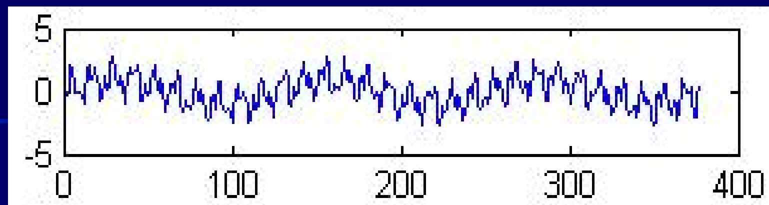


高频

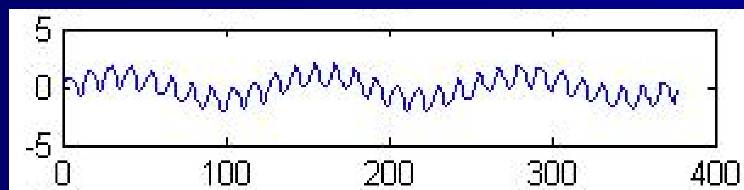
低频



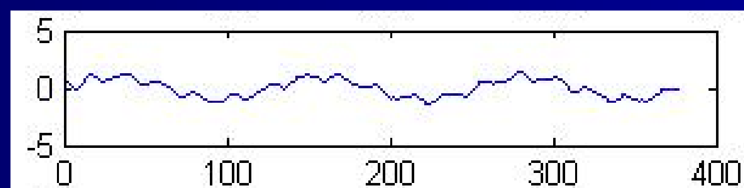
V_j



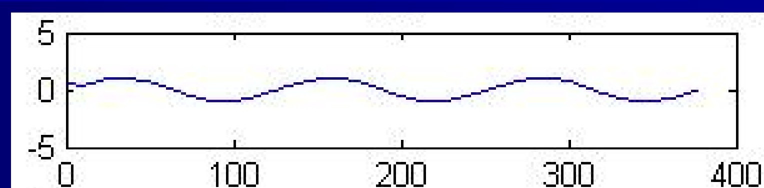
V_{j+1}



V_{j+2}

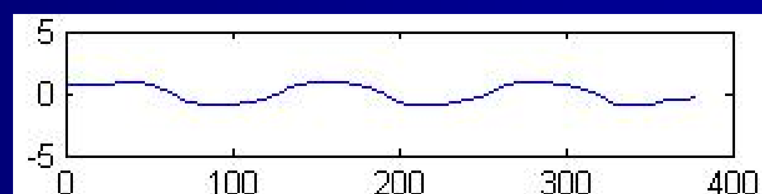


V_{j+3}



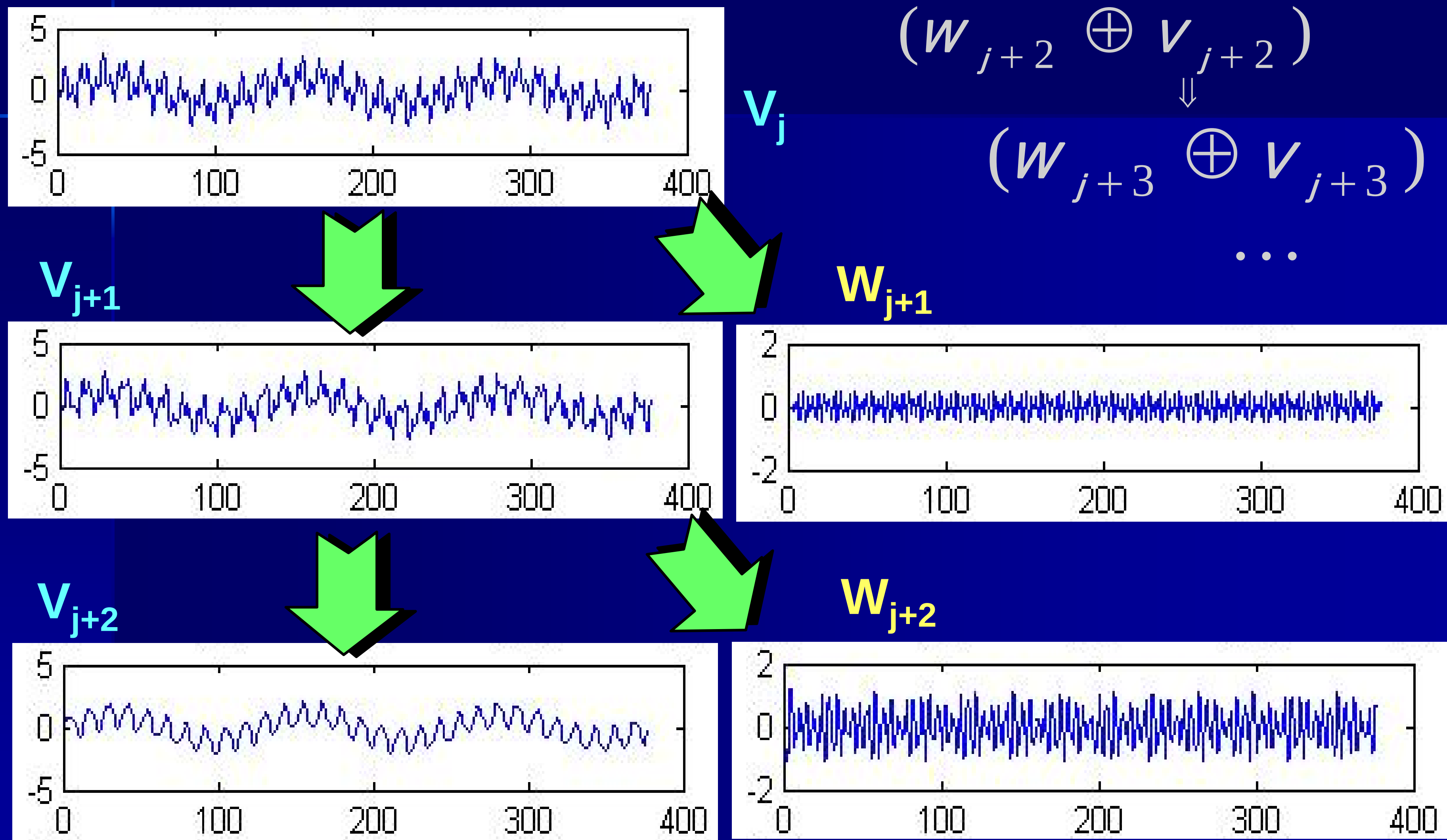
V_{j+4}

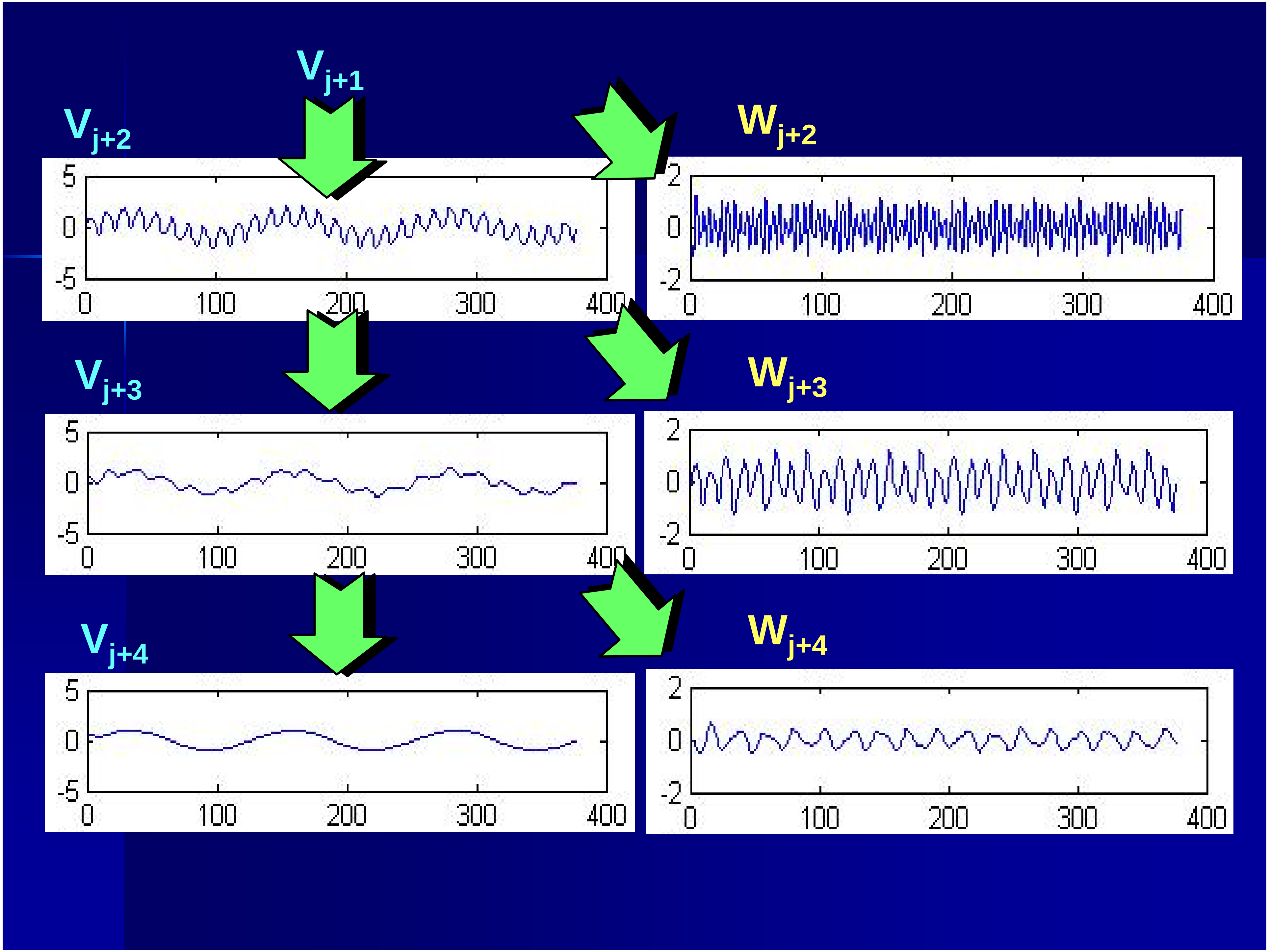
$\ldots V_{j+2} \subset V_{j+1} \subset V_j$



V_{j+5}

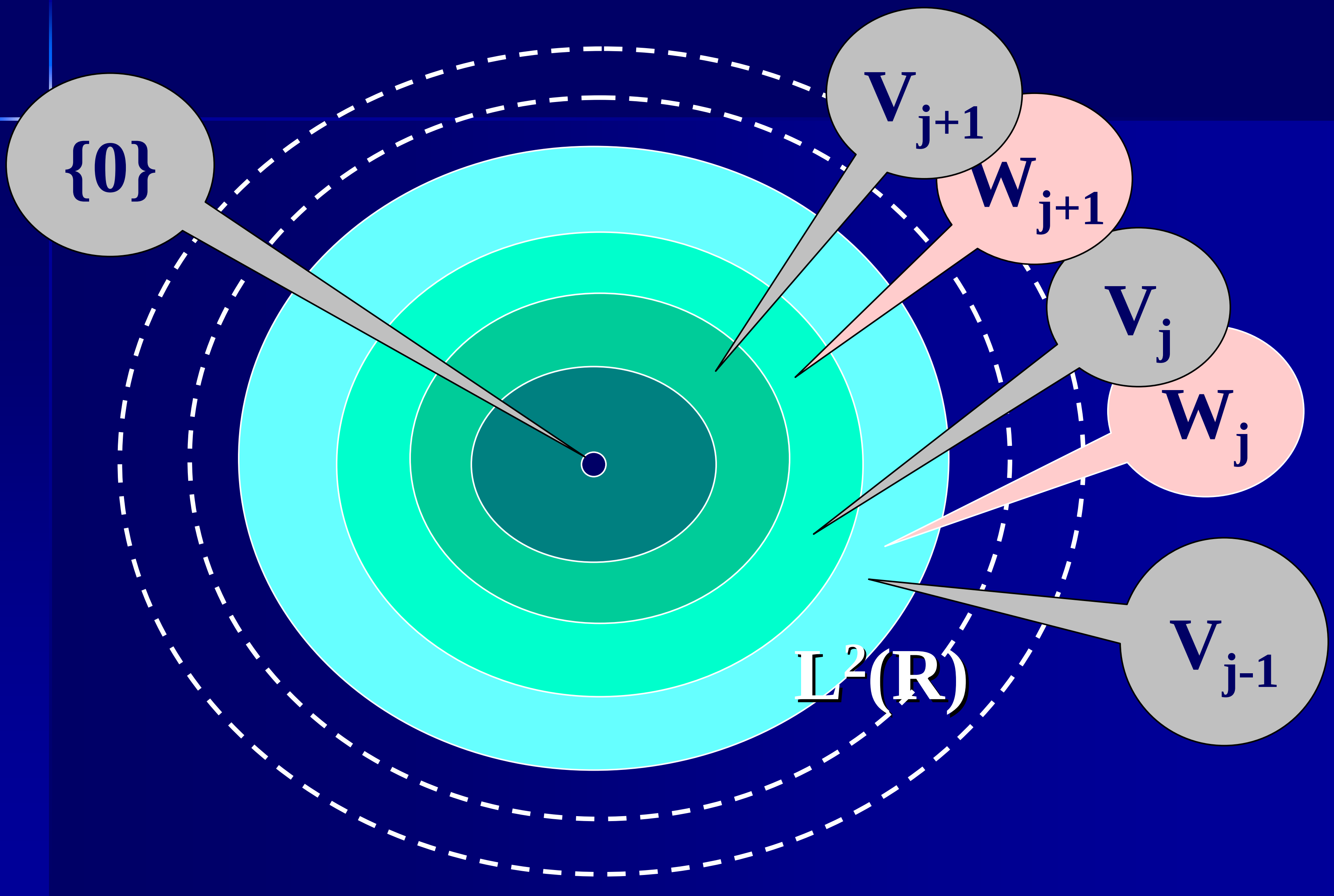
$$V_j = W_{j+1} \oplus V_{j+1}$$
$$\Downarrow$$
$$(W_{j+2} \oplus V_{j+2})$$
$$\Downarrow$$
$$(W_{j+3} \oplus V_{j+3})$$
$$\cdots$$





V_{j+1}
V_{j+2}
W_{j+2}
V_{j+3}
W_{j+3}
V_{j+4}
W_{j+4}

多分辨分析中的闭子空间

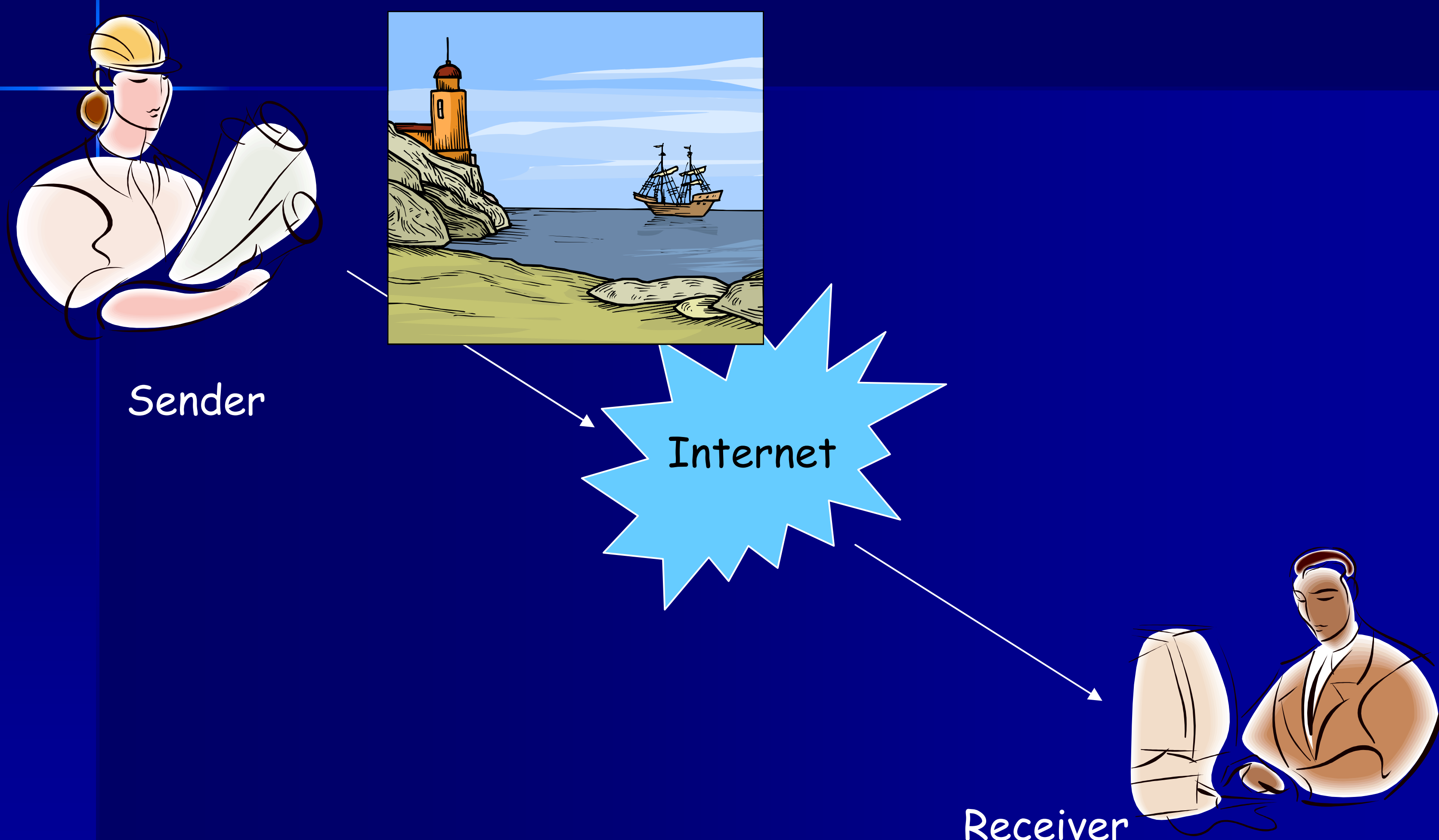


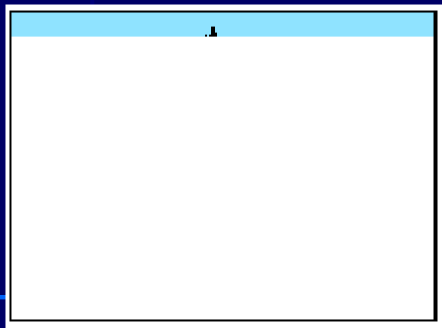
希尔伯特空间理论应用到图象传输

A Wavelet-based Progressive Digital Image Transmission Scheme
基于小波的累进图象传输(PIT)

Chin-Chen Chang,
Tzu-Chuen Lu
National Chung Cheng University

图象传输



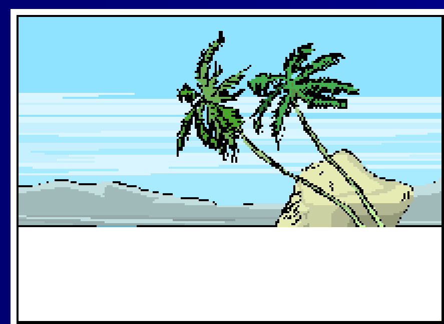


First Phase

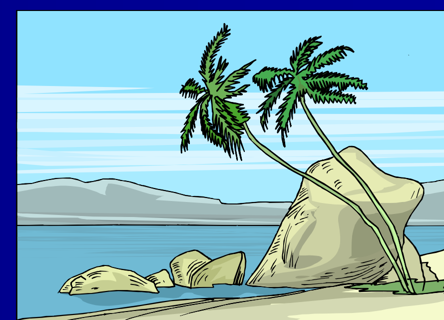
Second Phase

Third Phase

Fourth Phase



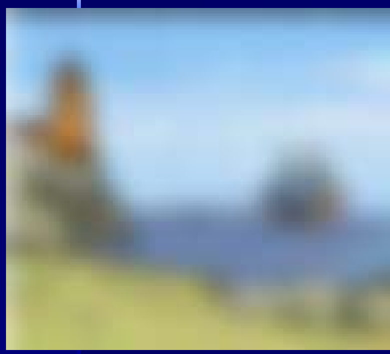
Fifth Phase



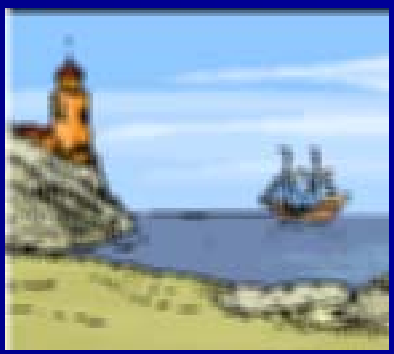
Sixth Phase

Receiver

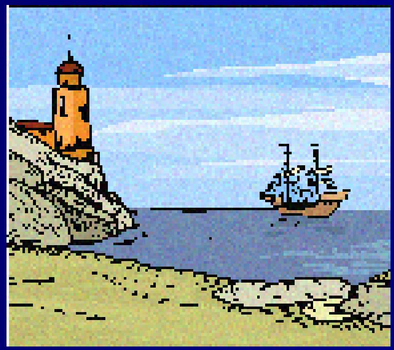
基于小波的累进图象传输(PIT)


First Phase


Second Phase


Third Phase

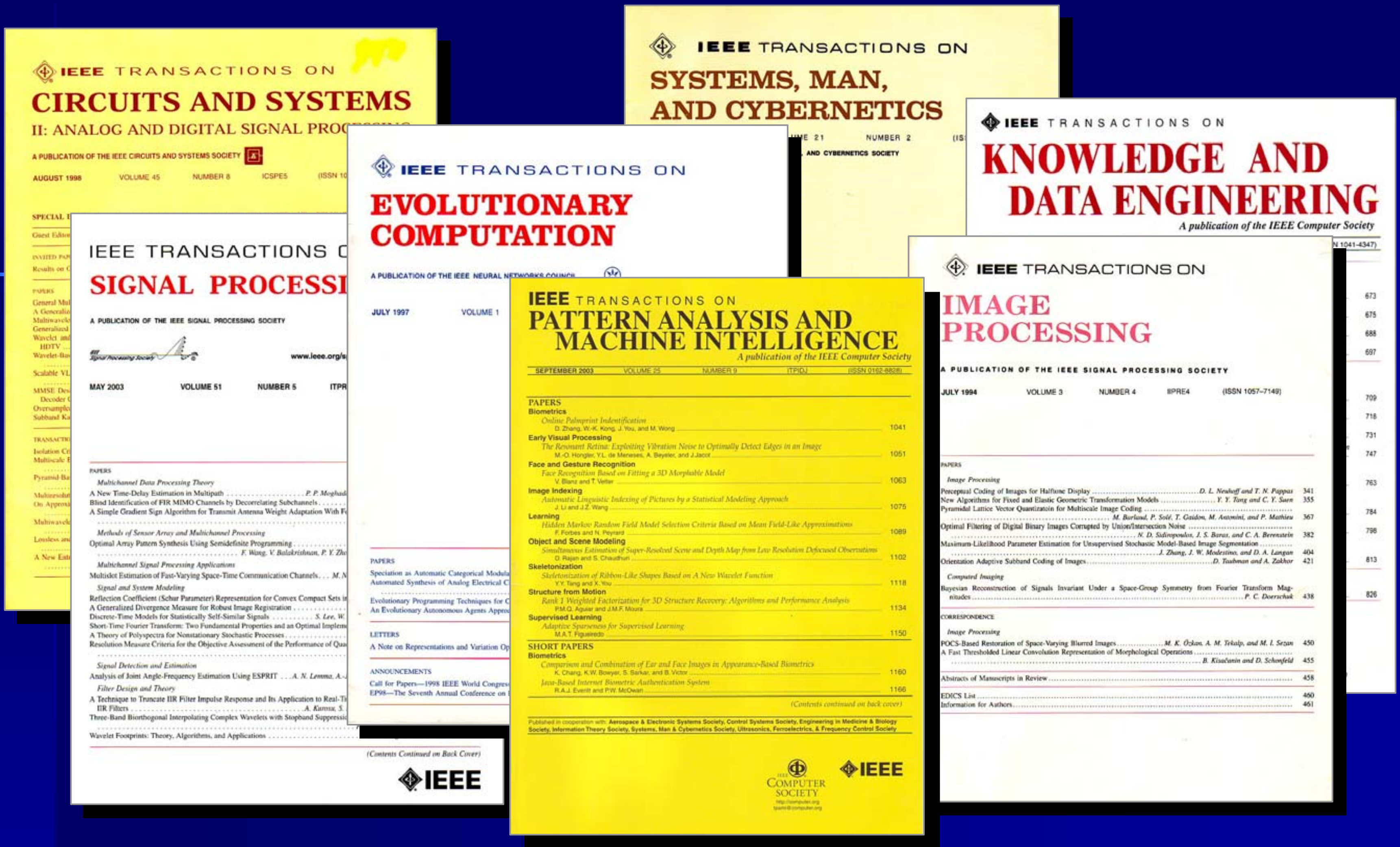

Fourth Phase


Fifth Phase


Sixth Phase

希尔伯特空间理论应用到模式识别、文本分析领域

- 文本分析的非层次理论
- 基于小波的文本分析理论



在国际一流的IEEE期刊、其他国际权威的期刊和重要的国际会议上发表论文

美国A.K. Jain教授对将《非层次理论》列为国际上目前公认的文本分析重要算法，给予了肯定评价：


IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE

A publication of the IEEE Computer Society

Document Representation and Its Application to Page Decomposition

Anil K. Jain, *Fellow, IEEE*, and Bin Yu, *Member, IEEE*

IEEE

国际著名模式识别专家、原IEEE Trans. on Pattern Analysis and Machine Intelligence主编、美国Michigan大学的 A. K. Jain教授在IEEE Trans PAMI的带总结性的论文中[1]，称这些理论“解决了高复杂度几何结构的文本分析问题”。

[1] IEEE Trans PAMI, 1998, Vol. 20(3):294-307,（评价处为第296,297页）

国际著名模式识别专家 George Nagy 在国际权威的IEEE PAMI总结性的论文《文本图像分析20年》[2]中，对我们的工作给予了高度评价：

"**论文[82]**提出了一个基于数据而不是基于模型的方法来去掉表格线条。它的创新点不在于如何去掉表格文本中的那些水平和垂直线条，而在于**打破了那些墨守成规的方法，**应用了二维多分辨率小波分析（MRA）。**实验的结果被三种金融文本所论证，**正如作者所述，这种新方法**展示了完美的性能**。"

[2] IEEE Trans PAMI, 2000, 22(1):38-62, 公开评价处为第**296,297**页

[82] IEEE Trans PAMI, 1997, 19(8):921-926

国际著名模式识别专家、美国Drexel大学、IMPACT 主任Meystel教授对“小波-文本分析理论”的高度评价[3]

- protect us from paradoxes (e.g. of the pitfalls of self-referencing);
- allow for interlevel disambiguation;
- determine true ontologies and definitions;
- outline symbol grounding activities.

As a result of performing computations, following steps 1–8, the multiresolutional representation of the system is being constructed (shown in field II of Fig. 5). Notice that both "information categorization" and construction of "nested system of cost-functions and preferences" would require, not only the top down steps of processing, described in the *algorithm of information organization*, but a similar string of bottom up steps that decompose the "Islands" of ERN into sub-islands and entities of their components. When the results of these two streams of processing converge, the system of representation can be considered satisfactory (no ambiguity can be detected). We will address this process of disambiguation in more detail in our discussion of the Field III in the subsequent sections (see S^3 search description in Section V).

IV. On the Similarities With and Differences From the Existing Systems With Elements of

Representation … based upon wavelet transforms can be used … within the MR-DSS methodology. The follow… observations might be voiced: most of the wavelet transforms presume the property of self-similarity [24]. This means that the system will lean toward having similar functions for representing processes at different levels of resolution. Another important comment: wavelets create a multi-bandwidth representation, but the accuracy of representing the process at each level should often be the same: the accuracy of the highest level of resolution. Thus, it does not necessarily leads to complexity

reduction in all cases. Nevertheless, there are advanced research results that demonstrate that this shortcoming can be avoided [25].

3) *Can the MRDS paradigm be applied if the system is represented by using the apparatus of multigrid systems from the finite elements representation?*

5) *Is the randomized search the same as dynamic programming?*

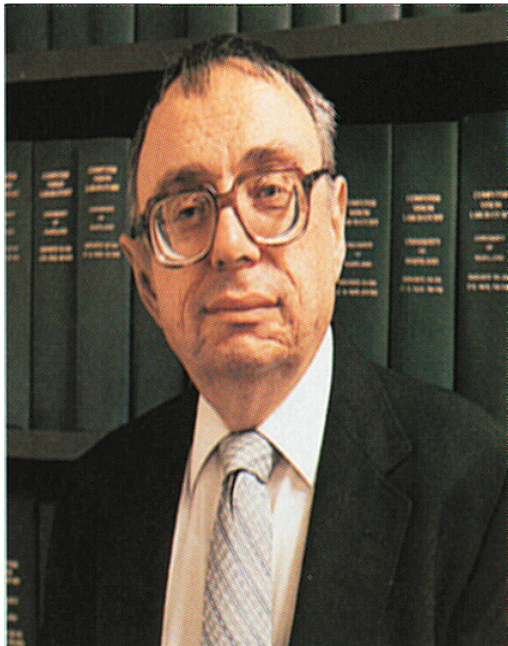
The paradigm of dynamic programming (DP) allows for the discrete computational simulation of the dynamic processes having the states vary dynamically. Thus, multiple results can be obtained which are required for choosing the most desirable alternative of the dynamic process [33]. However, if the space contains nonlinearities, and/or obstacles (as particular cases of nonlinearities), DP is not a promising tool and algorithms for search in the state space with successive increase of the resolution of representation (as described in this paper) demonstrate better results. An interesting phenomenon typical for DP is known: the process increases its resolution as the system approaches the final point. This is explained by the fact that the processes in DP are discretized in time (a single time interval is used through the whole process). Thus, as the system approaches the final point, and the speed of motion reduces, each unit of path (state) is also reducing. For the observer, it looks like a gradual increase of the resolution and

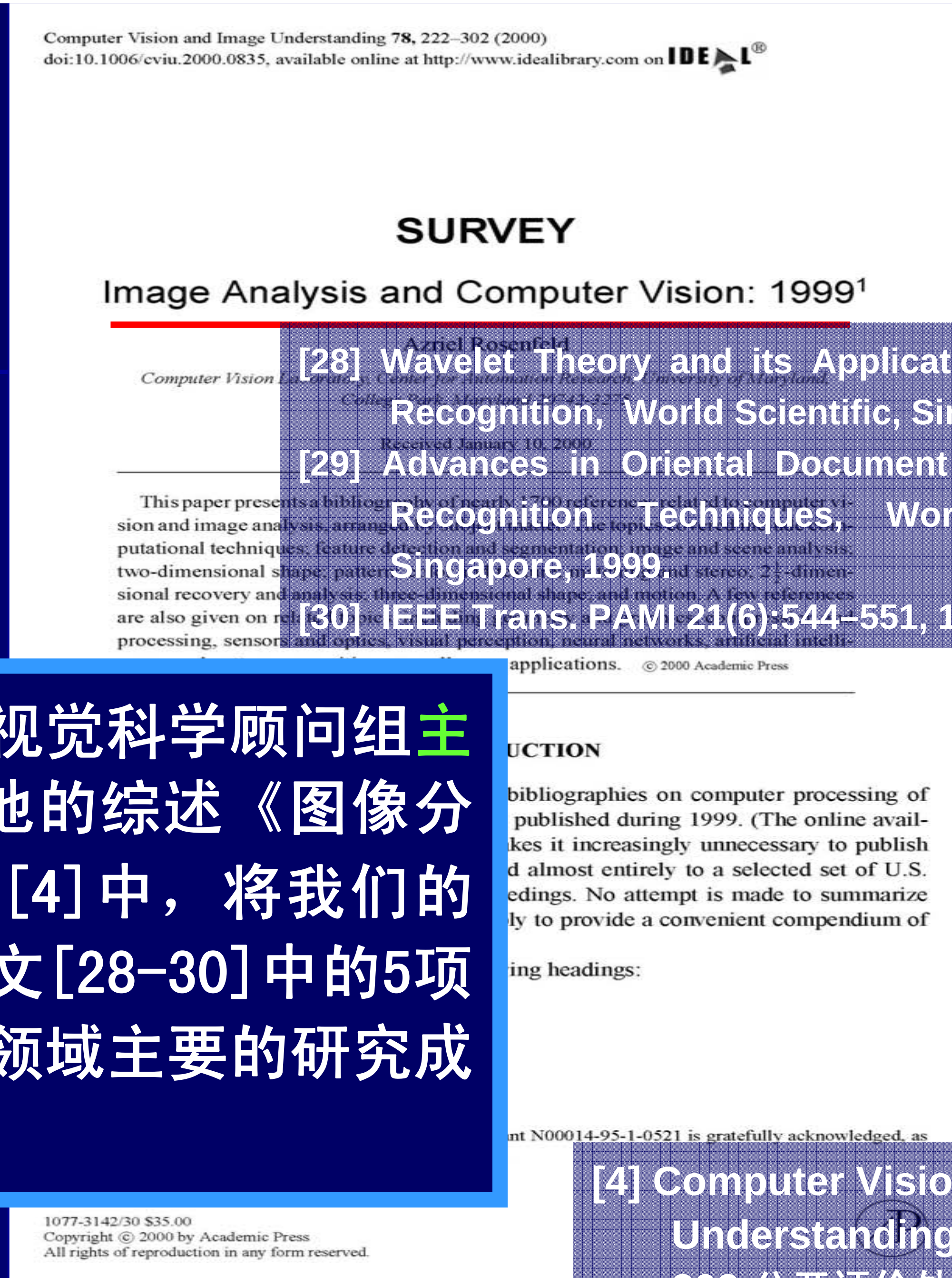
评价唐远炎的论文

“基于小波变换的理论…可能被下面的问题所困扰：大多数小波变换对不同解析层次的表示处理趋于相似的功效。另外一个重要的不足：每个层次处理的精度经常应该是一样的。这样它没有导致希望的在各种情况下复杂度下降。然而，**[25]的最新研究成果解决了上述问题。**”

[25] IEEE Trans PAMI, 1997, Vol. 19(8):921-926

[3] IEEE Trans SMC(C), 2003,Vol. 33(1):86-101,公开评价处为第92页




Computer Vision and Image Understanding 78, 222–302 (2000)
doi:10.1006/cviu.2000.0835, available online at http://www.idealibrary.com on IDEAL

SURVEY

Image Analysis and Computer Vision: 1999[1]

Azriel Rosenfeld

UCTION

bibliographies on computer processing of
published during 1999. (The online avail-
kes it increasingly unnecessary to publish
d almost entirely to a selected set of U.S.
edings. No attempt is made to summarize
ly to provide a convenient compendium of

ing headings:

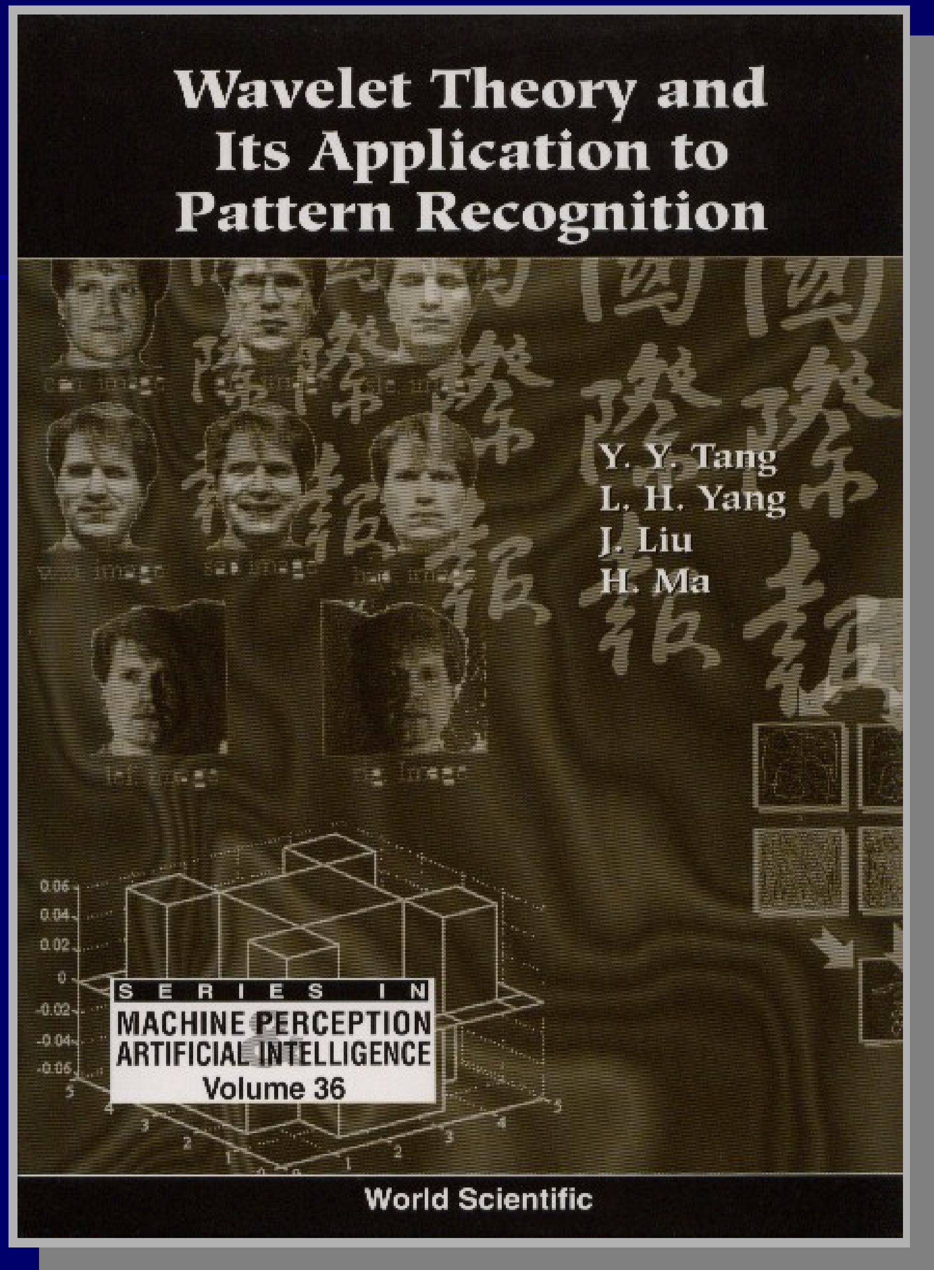
[28] Wavelet Theory and its Application to Pattern Recognition, World Scientific, Singapore, 1999.

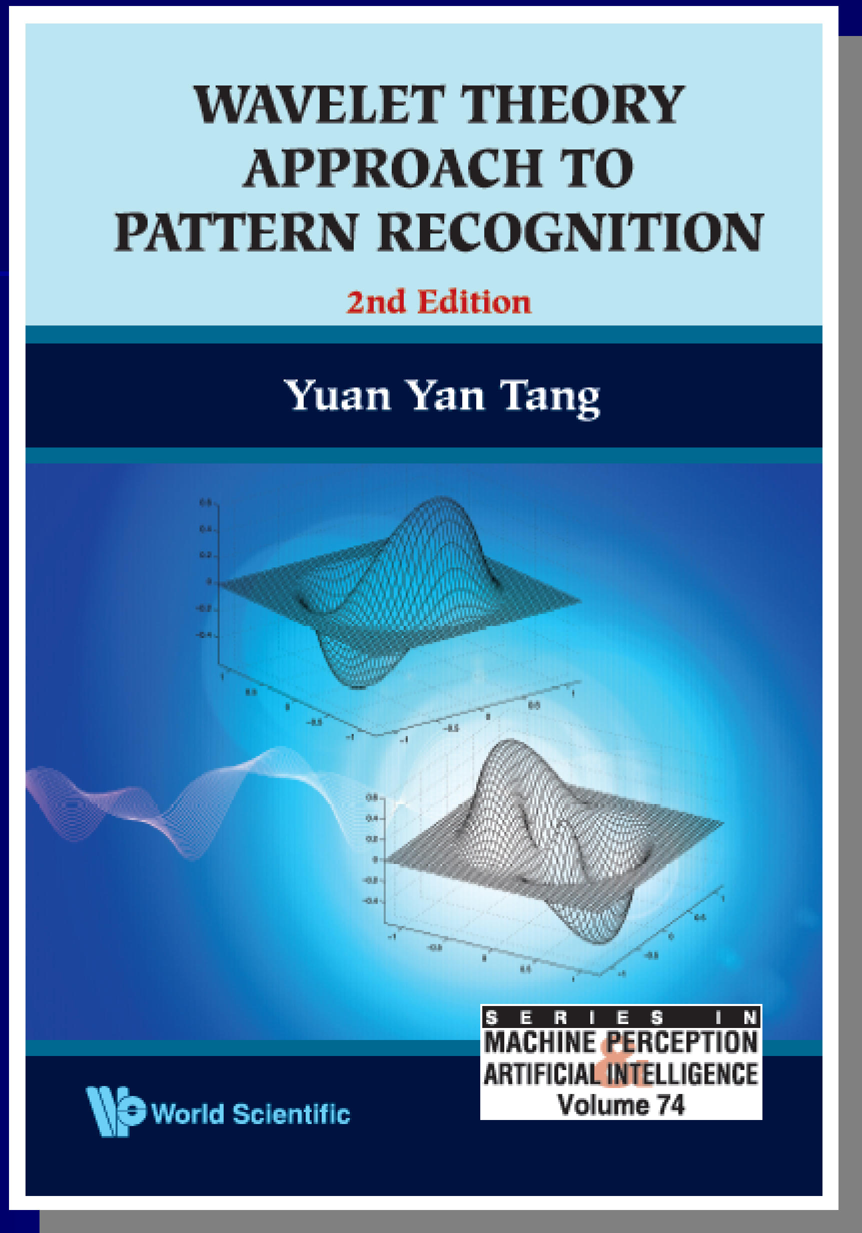
[29] Advances in Oriental Document Analysis and Recognition Techniques, World Scientific, Singapore, 1999.

[30] IEEE Trans. PAMI 21(6):544–551, 1999

原美国总统计算机视觉科学顾问组主席A.Rosenfeld在他的综述《图像分析与计算机视觉》[4]中，将我们的两本专著和一篇论文[28–30]中的5项成果列为国际上该领域主要的研究成果之一。

[4] Computer Vision and Image Understanding,1999, 78:222-302,公开评价处为第223, 224, 230, 253页


Wavelet Theory and Its Application to Pattern Recognition
Y. Y. Tang
L. H. Yang
J. Liu
H. Ma
SERIES IN
MACHINE PERCEPTION & ARTIFICIAL INTELLIGENCE
Volume 36
World Scientific


WAVELET THEORY
APPROACH TO
PATTERN RECOGNITION
2nd Edition
Yuan Yan Tang
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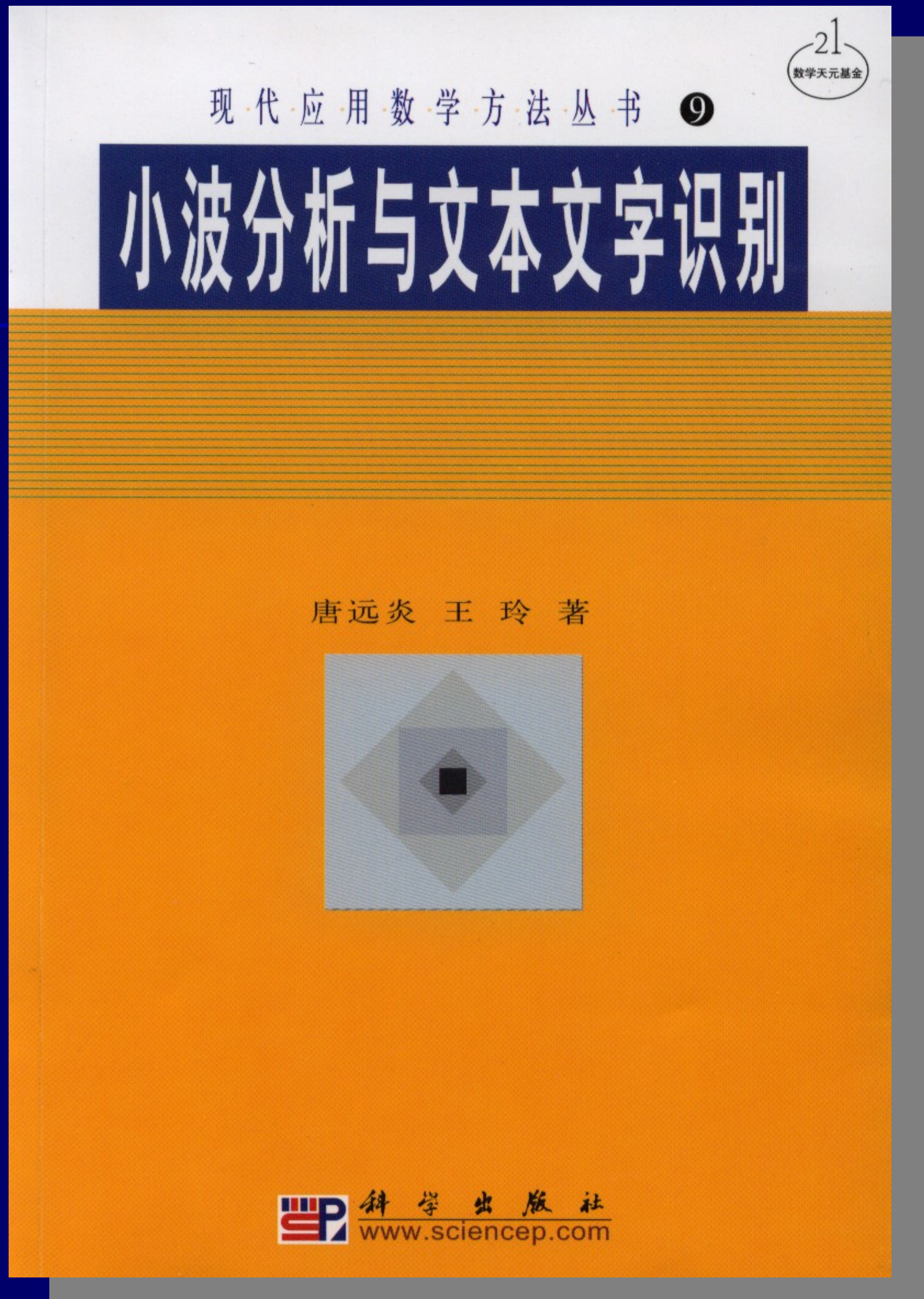
MACHINE PERCEPTION
ARTIFICIAL INTELLIGENCE
Volume 74
World Scientific


21
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小波分析与文本文字识别
唐远炎 王玲 著
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SCI Indexed Journal

International Journal of Wavelets, Multiresolution and Information Processing

Editor-in Chief

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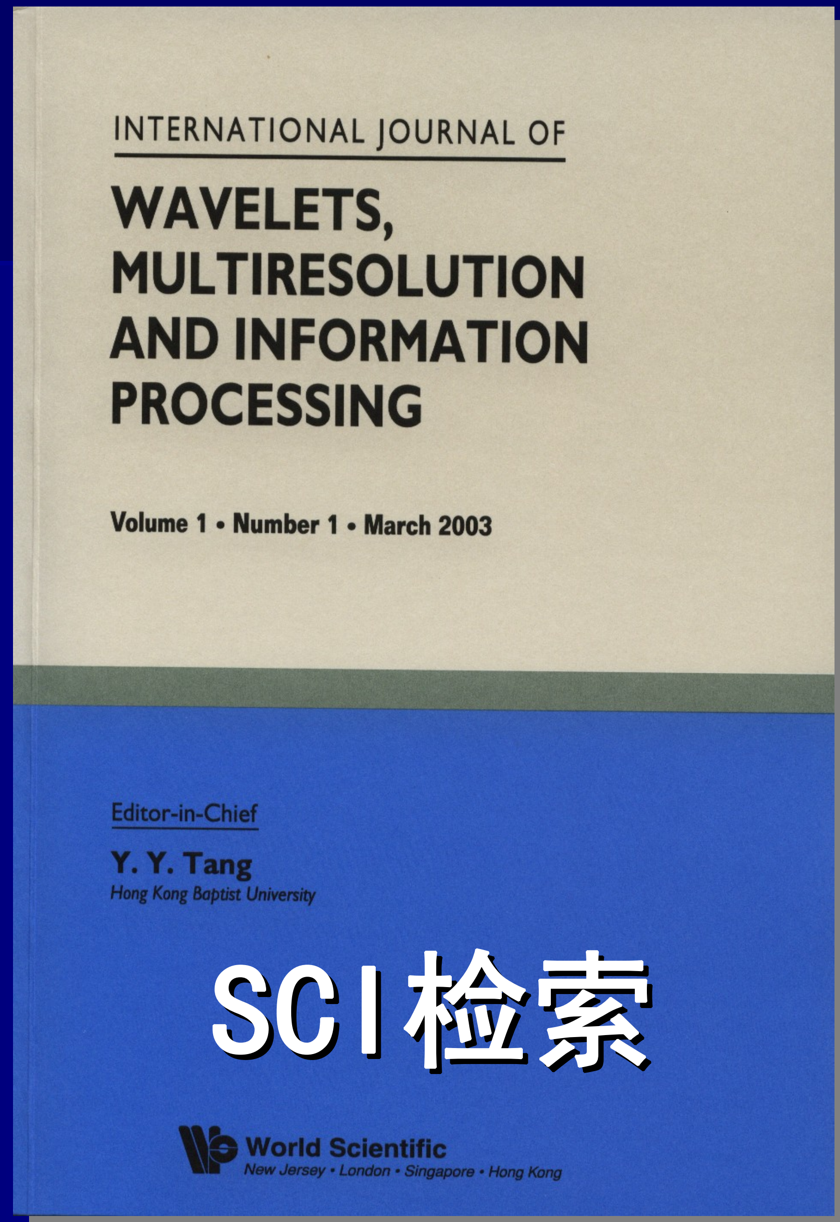

计算机科学前沿

主编:李未

执行主编：陆汝铃

副主编： 陈国良, 赵沁平, 唐远炎

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EI检索

2007年创刊

IEEE系列国际学术会议

International Conference on Wavelets Analysis and Pattern Recognition (ICWAPR)

EI检索

http://www.icwapr.org

International Conference on Wavelet Analysis and Pattern Recognition 2010

Qingdao, Shangdong, China 11 - 14 July 2010

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Preliminary Call for Papers

ICWAPR 2010 will be held on 11 – 14 July 2009 in Qingdao, Shangdong, China. This is the eighth conference of its kind on the subject of wavelet theory and its applications. The conference aims to bring together researchers in wavelet analysis and pattern recognition to explore the synergy in combining these closely related areas of study. This conference will build on our past experiences and network to provide a valuable forum for exchanges of significant ideas and publication of research results in these areas. The conference offers opportunity for selected works to be published first in the conference proceedings and possibly later in special issue of journals. The multiple themes and topics of interest include, but are not limited to:

Wavelet Analysis:

- General Theory
- Bases and Frames Theory
- Wavelets and Filter Banks
- Wavelet and Sampling
- Approximation Theory
- Spline Theory
- Equation
- Time-Frequency Analysis
- Integral Transforms
- Wavelet and Statistics
- Wavelet and Differential and Integral Equations
- Wavelet and Numerical Analysis
- Wavelet and Functional Analysis
- Wavelet Neural Network
- Hardware and Software Implementation of Wavelet Transforms
- Algorithms

Pattern Recognition & Related Fields:

- Visualization
- Watermarking
- Biometrics
- Signal Estimation
- Image Fusion
- Image Recovery
- Image Compression
- Segmentation
- Biomedical Imaging
- Document Analysis
- Learning Theory
- Noise Reduction
- Machine Vision
- Classification
- Feature Extraction
- Emotion Computation
- Cluster Analysis
- Deformation Analysis
- Descriptor of Shapes
- Diagnosis of Faults
- Intelligent Robot
- Medical Image Analysis
- Human Face Recognition
- Hand Gestures Classification
- Iris Pattern Recognition
- Invariant Representation of Patterns
- Image Indexing and Retrieval
- Range Imaging and Detection
- Seismological Signal Processing
- Stochastic Pattern Recognition
- Texture Analysis and Classification
- Animation Image Analysis
- Enhancement and Restoration
- Nonstationary Stochastic Processing
- Handwritten and Printed Character Recognition
- Analysis and Detection of Singularities
- Artificial Life
- Intelligent Control System
- Intelligent Human Machine Interface
- Information Safety

Submission Guidelines

Prospective authors should prepare a full paper and submit it on line through our website in PDF format. Each paper should not exceed 6 pages in A4 format. All papers should conform to the style guidelines outlined on the ICWAPR'09 website. All submissions must be original and have not been submitted to any other publications. Each paper will be reviewed by 2 referees. The papers should provide sufficient background information and should clearly indicate the original contribution to the subject studied. They should state and discuss the main results and provide adequate references. Paper submission implies that one of the authors will attend the conference if it is accepted.

Important Dates

Paper Submission Due:	1 March 2010
Notification of Paper Acceptance:	15 April 2010
Submission of Camera Ready Manuscripts:	5 May 2010

Publication

All papers will be:

- searchable by IEEE Xplore (http://ieeexplore.ieee.org/)
- submitted for indexing to EI Compendex
- Selected papers will be published in: International Journal of Wavelet, Multiresolution & Information Processing (IJWMIP) (SCI Indexed)

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谢谢 ！

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