

Image Restoration

Homomorphic filtering.

Blind Deconvolution



Minimize $E[(f - \hat{f})^2]$.

3 methods:

- ① Inverse filters.
- ② Least Squares filters
- ③ Iterative Technique.

Weiner

Constrained least square.

Key Assumption: We know d .
blurring fn.

How about if we don't know d .
⇒ Blind Deconvolution.

2 Step process: ① Estimate d
② use "classical" Restoration.

How To do this?

① Estimate parameters of The blur function
Knowing what kind of Blur → Atmospheric
→ Depth of focus
→ motion.

Approach: look at F.T of g .

Guess of $G(w, w_1) \rightarrow$ Deduce the
parameters of blur fn. $\rightarrow R$ is out of focus
 $\rightarrow L, \Phi \rightarrow$ motion blur

② Maximum Likelihood Blur Estimation.

ML \rightarrow used for parameter estimation.

Given observation, find parameter of the model for that observation that maximizes the likelihood.

~~Blind deconvolution~~

$$\theta = \{ \sigma_w^2, d(n_1, n_2), \sigma_v^2, a_{ij} \}$$

Parameters in our case: θ = { $\sigma_w^2, d(n_1, n_2), \sigma_v^2, a_{ij}$ }

a_{ij}, σ_v^2 relate to the autoregressive model for f :

$$f(n_1, n_2) = \underline{a_{01}} f(n_1, n_2 - 1) + \underline{a_{11}} f(n_1 - 1, n_2 - 1) + \underline{a_{10}} f(n_1 - 1, n_2) + \underline{v(n_1, n_2)} \quad \checkmark \text{ vs } \sigma_{vii}$$

σ_w^2 = variance of the added noise $\checkmark \sigma_{vii}$

Maximize log likelihood function:

$$\textcircled{*} L(\theta) = - \sum_{w_1, w_2} \left(\log P(w_1, w_2) + \frac{|\sigma(w_1, w_2)|^2}{P(w_1, w_2)} \right)$$

where $P(w_1, w_2) = \sigma_v^2 \frac{|A(w_1, w_2)|^2}{|1 - A(w_1, w_2)|^2} + \sigma_w^2$

$A(w_1, w_2) \rightarrow$ 2D DTFT of a_{ij}

Issues associated with solving ②

① Must ~~be~~ apply regularization techniques to make it "well conditioned".

Add constraints.

(a) Energy conservation.

$$\sum \sum d(h_1, h_2) = 1$$

i.e P.C value $D(w_1, w_2)$ is 1

$$[D(w_1, w_2)]_{(w_1, w_2) = (0, 0)} = 1$$

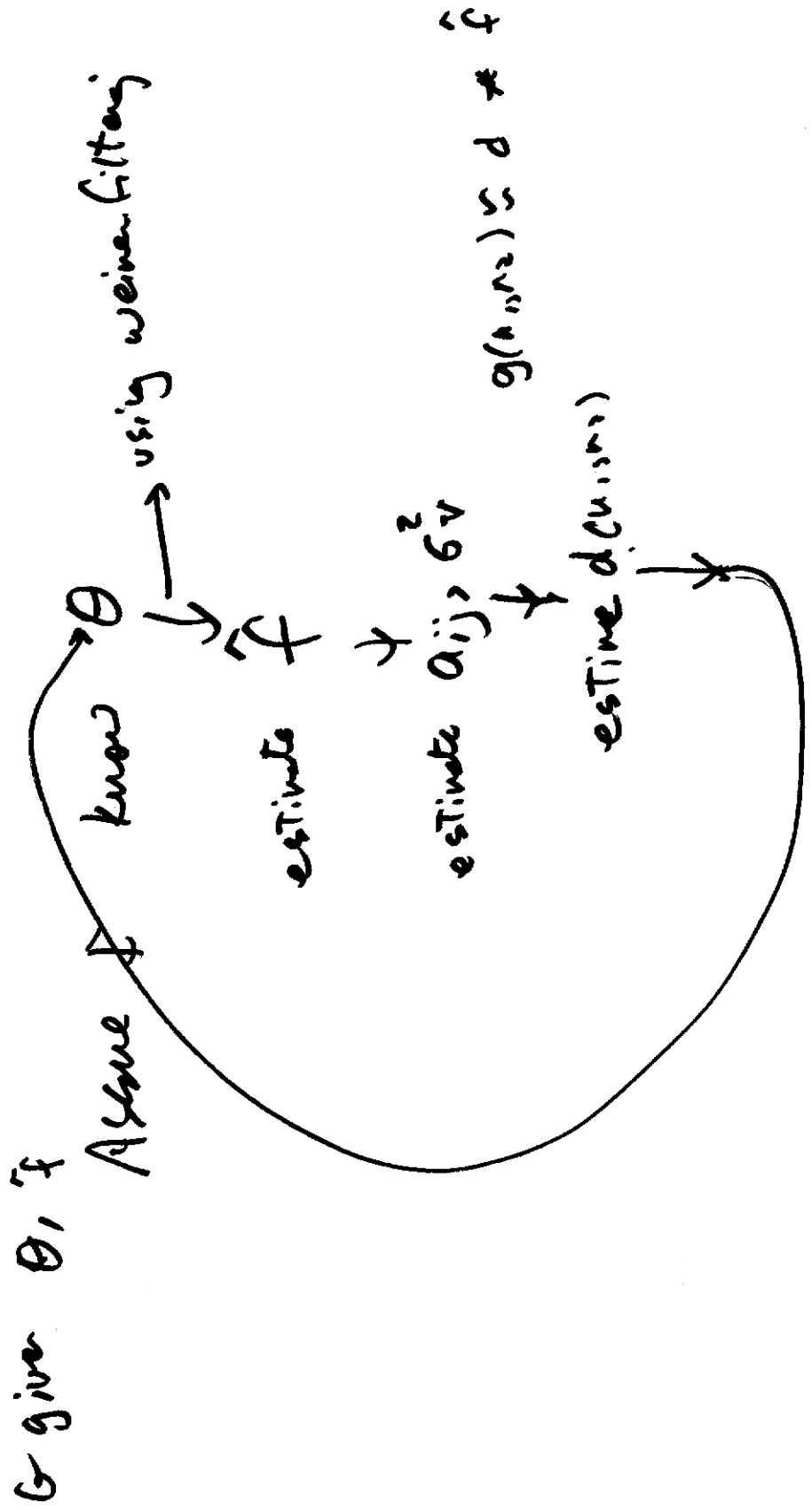
⇒ ~~P.C.~~ Blurring was passive process
no energy was either generated
nor absorbed.

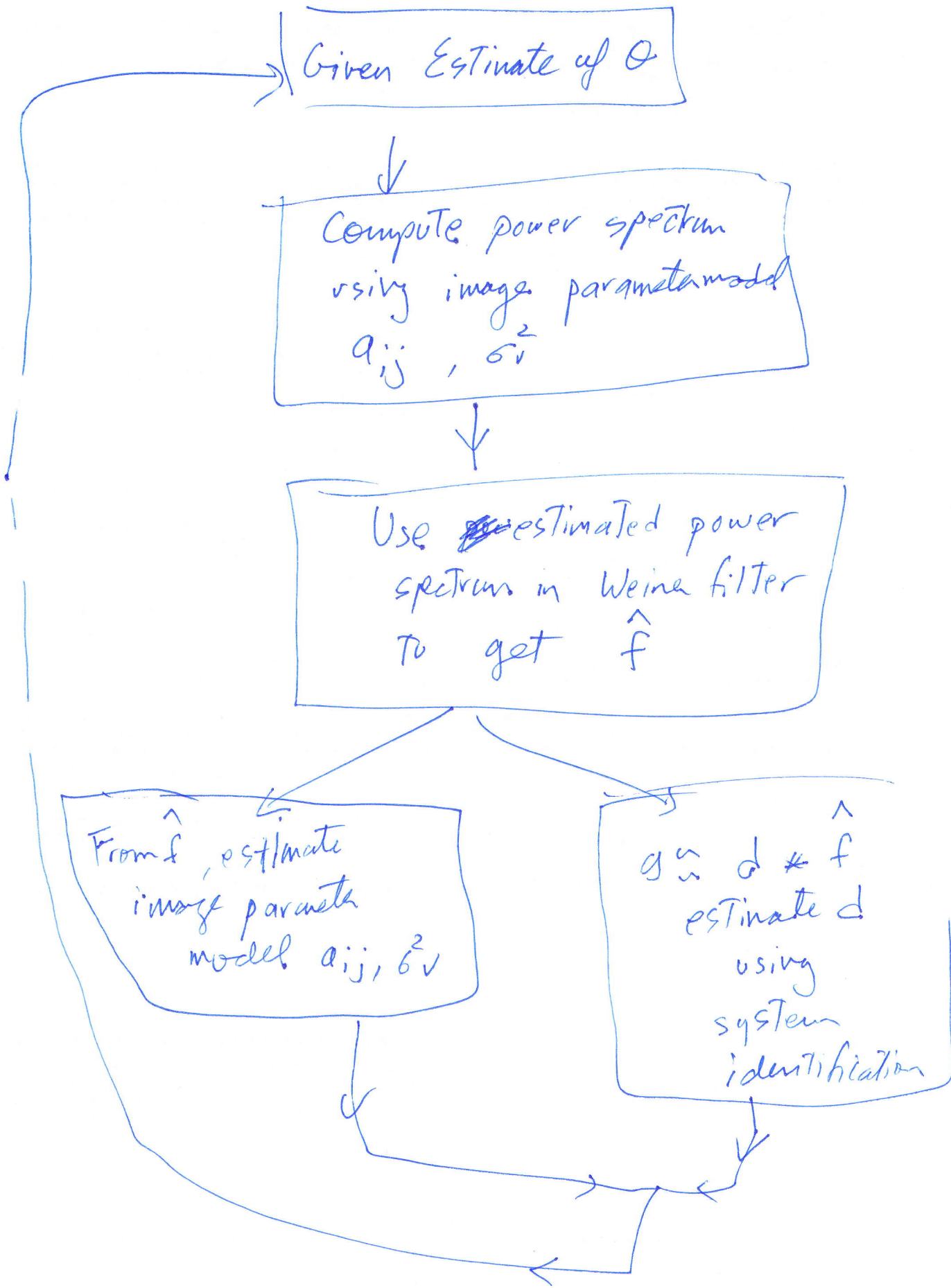
(b) $d(h_1, h_2) = d(-h_1, -h_2)$, i.e. blur
P.S.F is symmetric.

② Optimization of a nonlinear fn.
→ steepest descent ⇒ local minima.
⇒ steepest descent ⇒ global



Gre. Gradient descent Technique → EM
EM = Expectation Maximization.





Given Estimate of Q

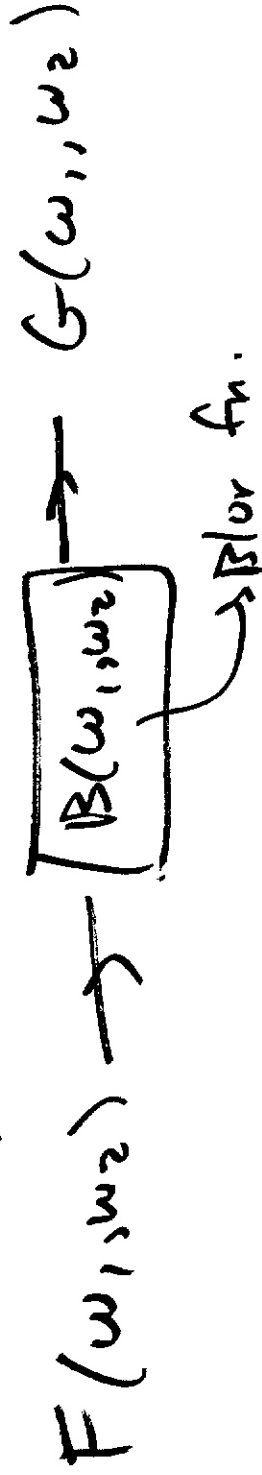
Compute power spectrum
using image parameter model
 a_{ij}, σ_v^2

Use ~~the~~ estimated power
spectrum in Wiener filter
to get \hat{f}

From \hat{f} , estimate
image parameter
model a_{ij}, σ_v^2

estimate \hat{d}
using
system
identification

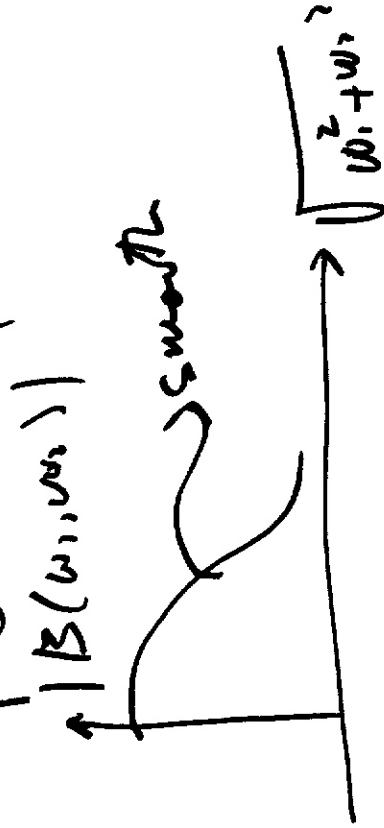
Blind Deconvolution



Assumption $|B(\omega_1, \omega_2)|$ is smooth.

$$G(\omega_1, \omega_2) = F(\omega_1, \omega_2) B(\omega_1, \omega_2)$$

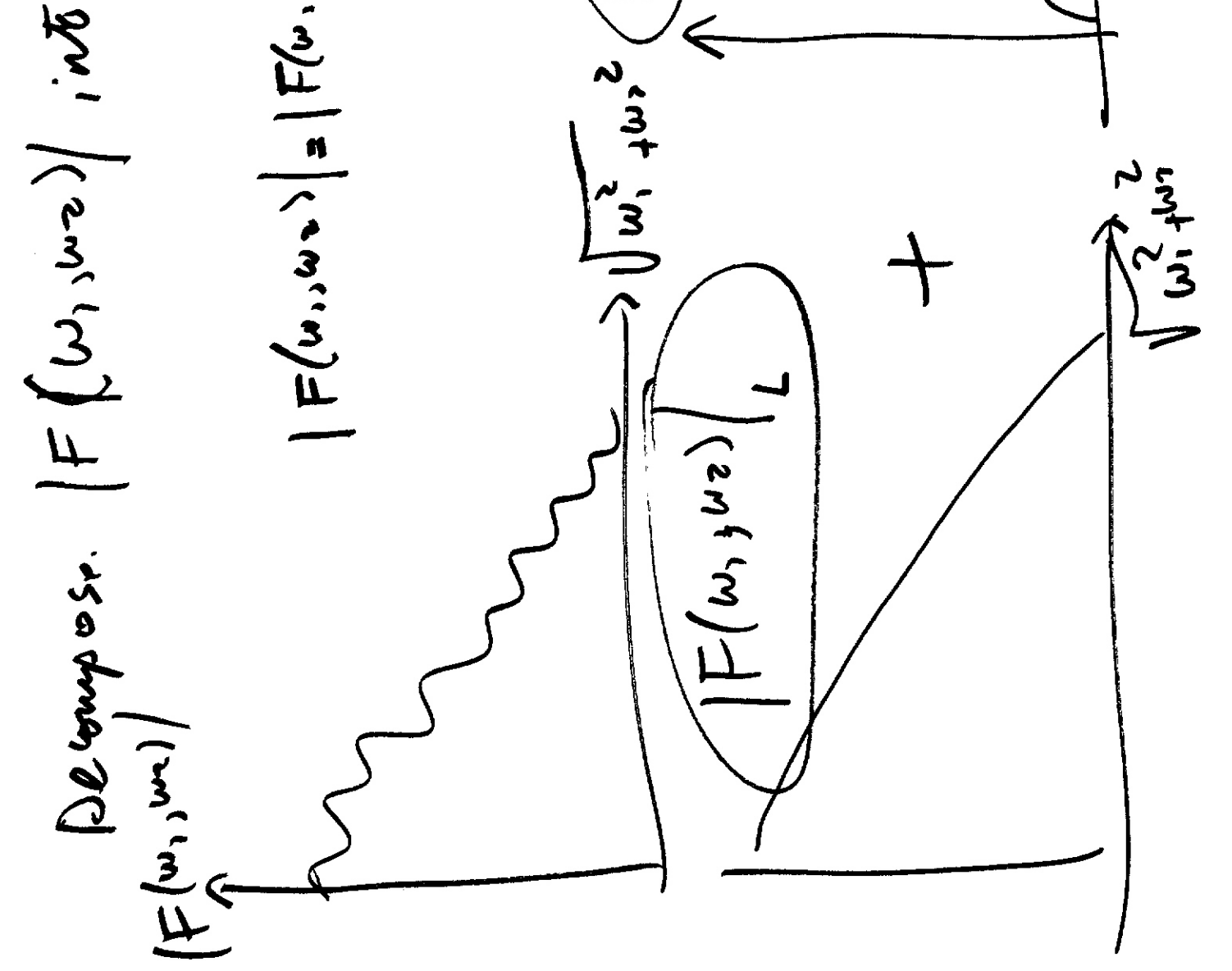
$$|G(\omega_1, \omega_2)| = |F(\omega_1, \omega_2)| |B(\omega_1, \omega_2)|$$

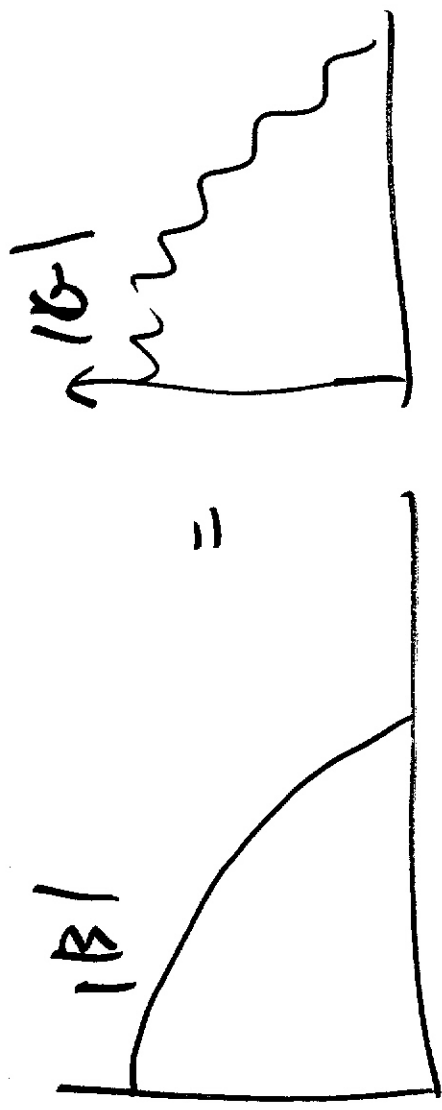
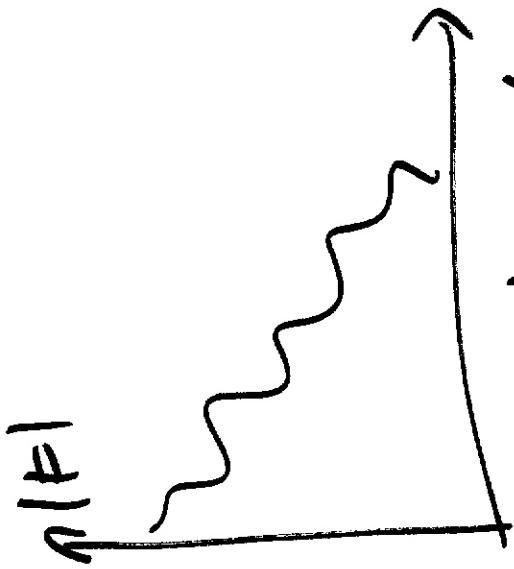


Decompose $|F(\omega_1, \omega_2)|$ into $\left\{ \begin{array}{l} \text{slowly varying} \\ \text{fast varying} \\ \text{constant} \end{array} \right.$

$$|F(\omega_1, \omega_2)| = |F(\omega_1, \omega_2)|_L + |F(\omega_1, \omega_2)|_H$$

=



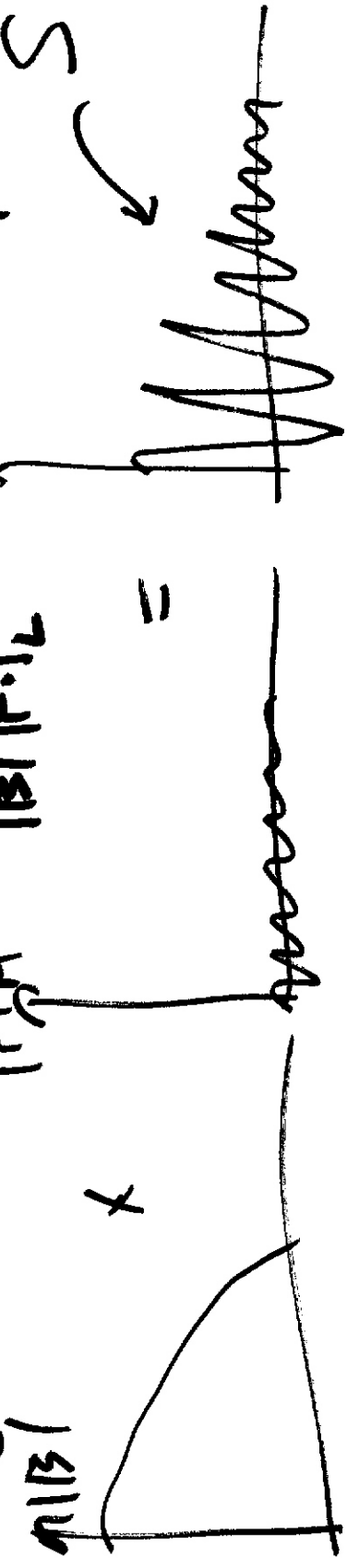


$$|G(\omega_1, \omega_2)| = |B(\omega_1, \omega_2)| (|F(\omega_1)|_L + |F(\omega_2)|_H)$$

$$|G| = |B| |F|_L + |B| |F|_H$$

Apply "Smoothing Operator" to Bits sides $\rightarrow S$

$$S \{ |G| \} = \underbrace{S \{ |B| |F|_L \}}_{|F|_H} + \underbrace{S \{ |B| |F|_H \}}_{\emptyset}$$



$$S \{ |G| \} \approx |B| |F|_L$$

$$\Rightarrow |B| \approx \frac{S \{ |G| \}}{|F|_L}$$

Estimate $|F|_L$ by using an ensemble of

$$\text{traces } |F'|_L \approx \frac{S \{ |G| \}}{|F'|_L}$$

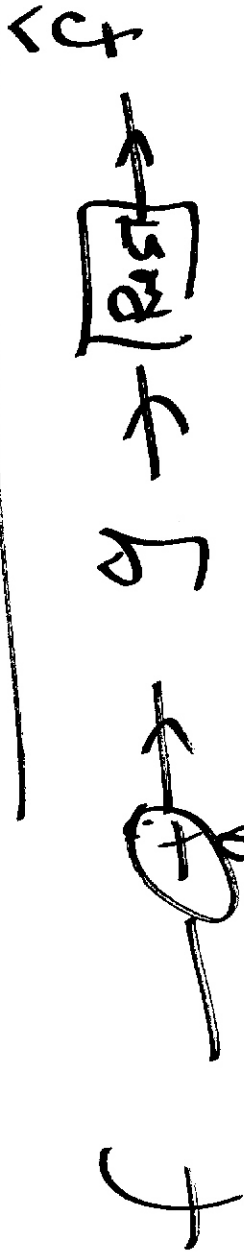
How about Phase:

$$\angle B(\omega, \omega) \approx 0 \rightarrow \text{Zero phase filter.}$$

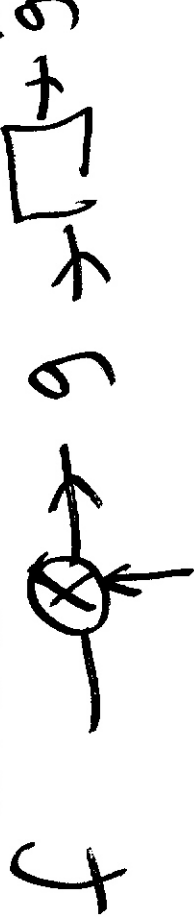
Fig 9.21 \rightarrow Shows Blind deconvolution to estimate B
+ Iterative.)

$$\hat{f}_{k+1}(u_1, u_2) = \hat{f}_k(u_1, u_2) + \lambda (g(u_1, u_2) - \hat{f}_k(u_1, u_2) + b(u_1, u_2))$$

Homomorphic Processing



Film grain noise is multiplicative.



$$g \approx f \cdot w$$

$$\log(g) \approx \log(f) + \log(w)$$

$$g \approx f' + w'$$

↓
 Apply any additive noise restoration
 Alg to restore \hat{f}

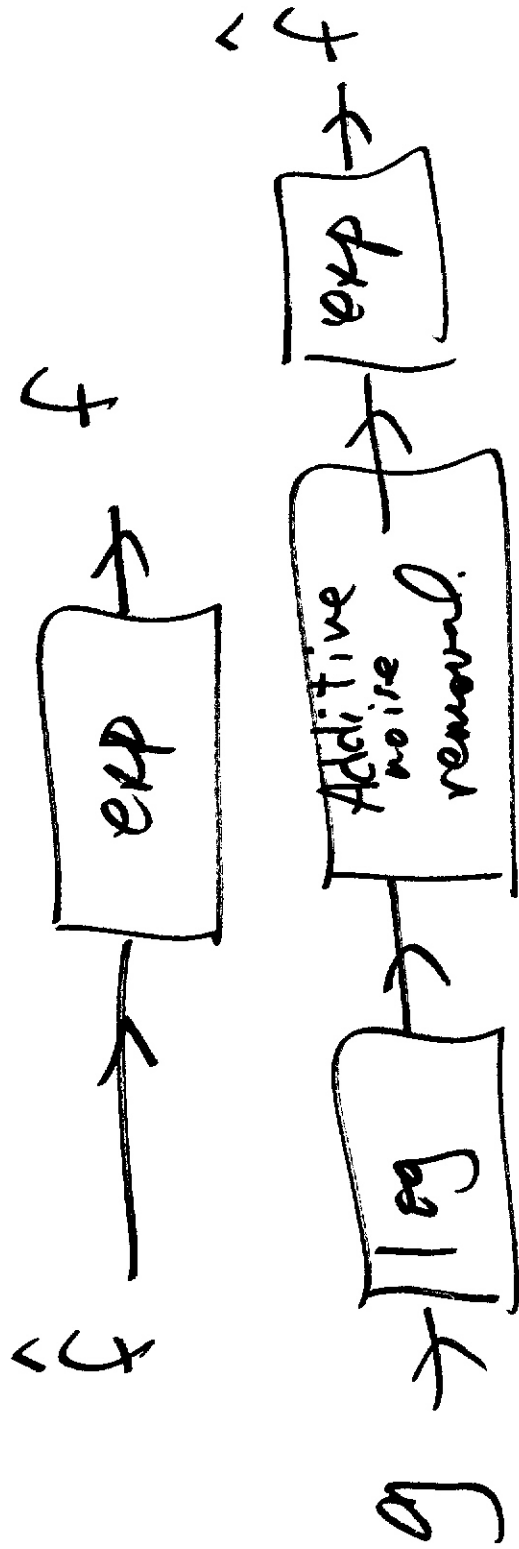
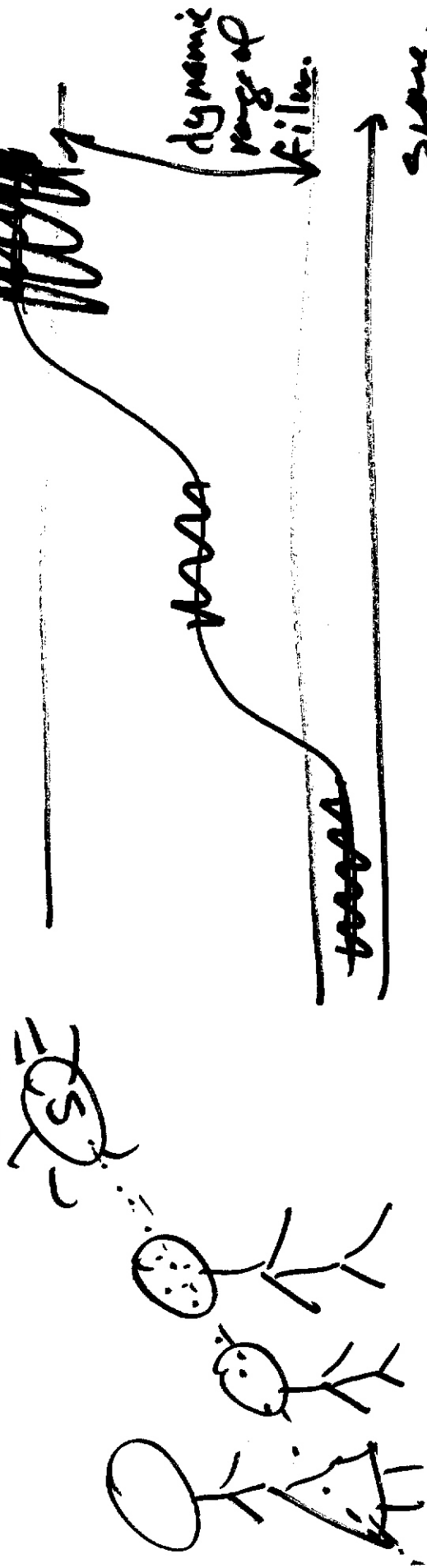


Fig 9.27 S. C. in

Another App of Homomorphic filtering



recorded signal

$$f(n_1, n_2) =$$

$$r(n_1, n_2) \cdot i(n_1, n_2)$$

reflectance
due to objects

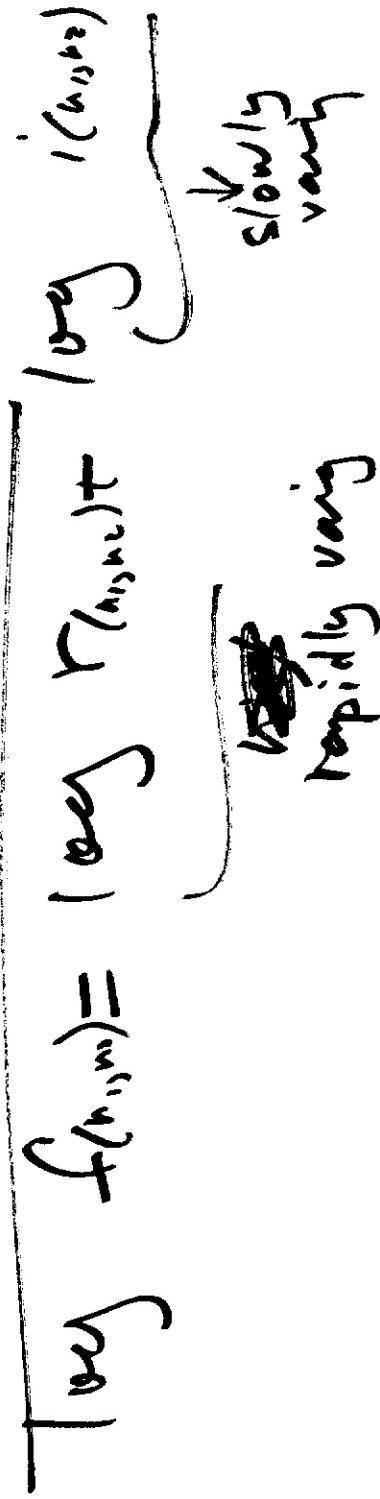
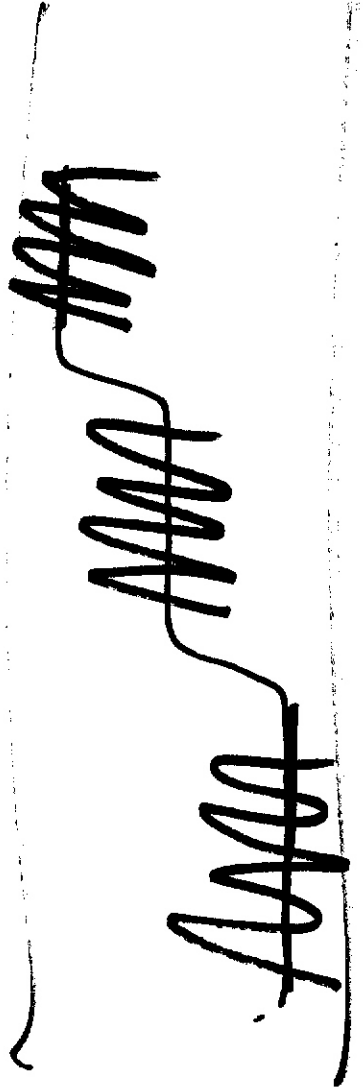
illumination
due to light source

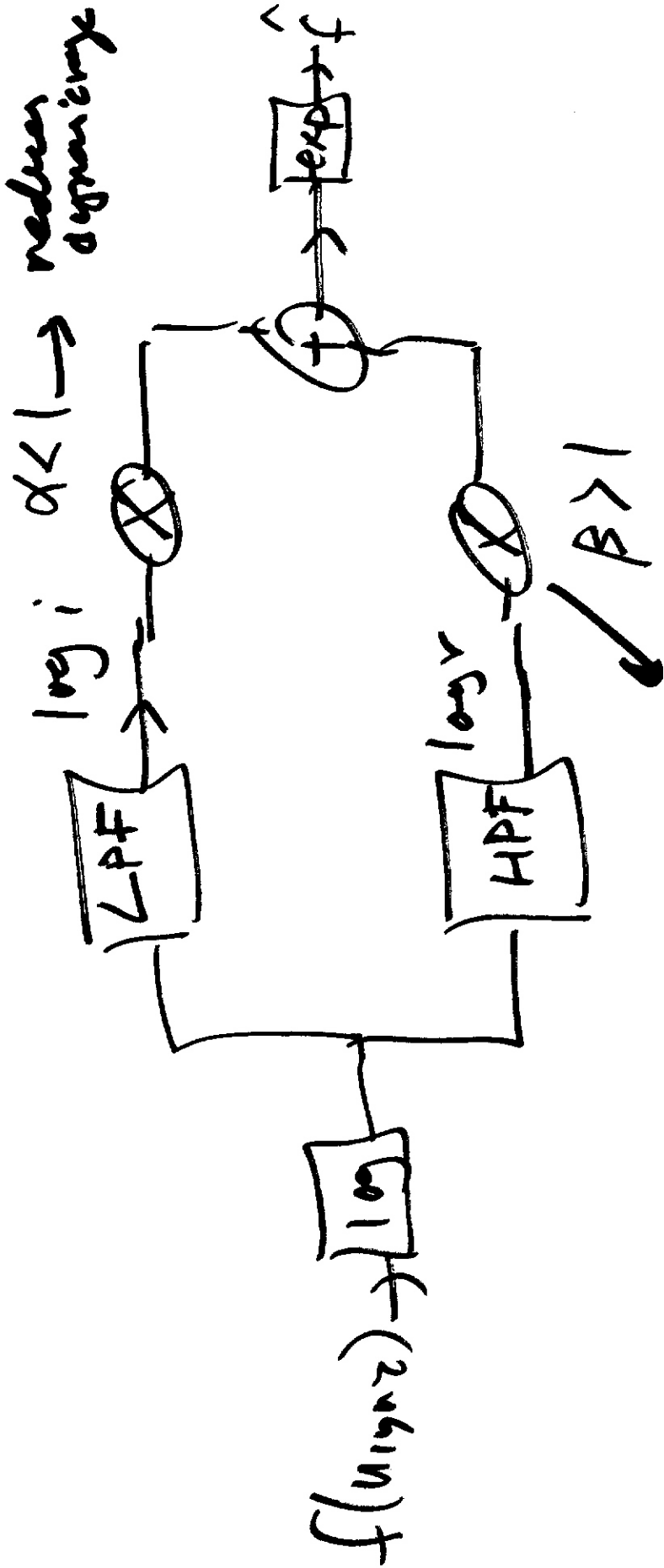
varies fast

slowly vary
as a f of
space

dynamic range

local contrast enhancement + dynamic range reduction.





increase local contrast

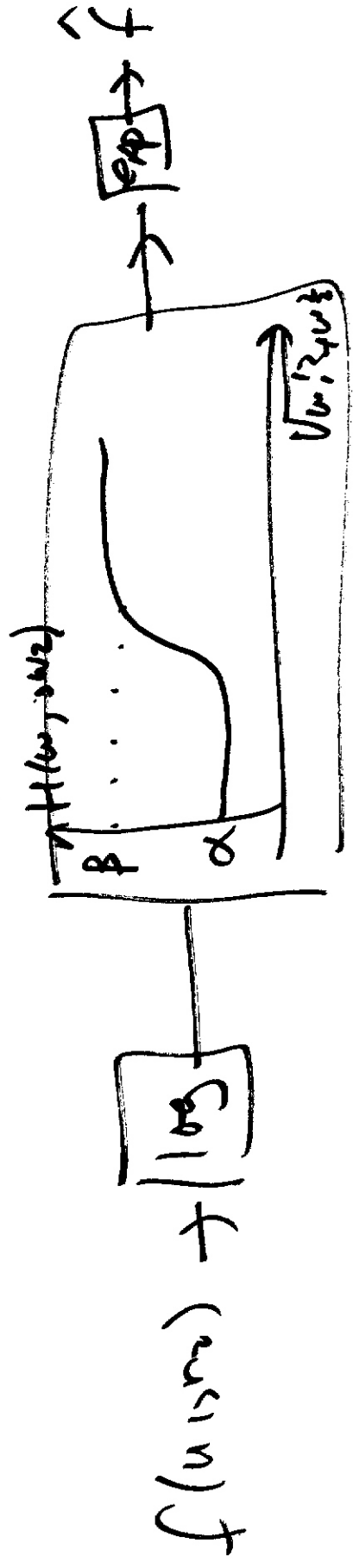


Fig 8.11 S. Lin