Planting, Growing, and Pruning Trees: Connected Filters Applied to Document Image Analysis

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April 8, 2014
Reviewer 1:

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...yet, today you just need to understand \( \leq \) and \( \subset \)...
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...yet, today you just need to understand $\leq$ and $\subset$...
We know that \textit{mathematical morphology} can often look impressive...

...yet, today you just need to understand \(\leq\) and \(\subset\)...
Sample uses of connected operators. Top: input images; Bottom: filtered images (results).
Why this talk? MM filters are good for DIA people!

Why is that interesting? Connected filters are little known.

How does this work? By planting, growing and pruning trees.

What can it be used for? Denoising, image simplification, object identification, etc.
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Evangelization from the Church of Mathematical Morphology :-)
Three Messages from the Church

Regarding...

\ldots \textbf{Mathematical Morphology (MM)}

Refresh your vision of MM \rightarrow forget \varepsilon and \delta!

\ldots \textbf{Connected Filters}

Powerful, simple, and well-suited to DIA.

\ldots \textbf{Methodology}

Advocate gray-level morphological strategies
(vs approaches based on “binarize first”).
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   Advocate gray-level morphological strategies
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Departing From this Typical DIA Workflow

1. Document image
2. Binarization
3. Binary image
4. Connected component labeling
5. Label image
6. Low-level analysis of components
7. Component "classification"
8. High-level analysis
9. Page segmentation
Starting by binarization is hell!
Components and Decomposition Principle

A connected component of the set $[u \leq 1] = \{ p \in \mathcal{D}, u(p) \leq 1 \}$ is included (so $\subset$) into a component of the set $[u \leq 2]$ so connected components can be arranged into trees...
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Components and Trees

(a) image

(b) max-tree

(c) tree of shapes

(d) min-tree

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G. Lazzara, T. Géraud, R. Levillain (EPITA)  Connected Filters Applied to Document Image Analysis  2014-04-08
An interesting class of filters:

- Not based on structuring elements (so not like $\varepsilon$ or $\delta$)
- Considering all the connected components obtained by thresholding the image.
- Don’t shift contours; don’t create new ones.
- Intuitive, powerful, and efficient.
- Can be implemented as tree filtering.
Min/Max-Tree Implementation [Berger et al., 2007]

**FIND-ROOT(x)**
1. if \( zpar(x) = x \) then return \( x \)
2. else \( zpar(x) \leftarrow \text{FIND-ROOT}(zpar(x)) \); return \( zpar(x) \) \}

**COMPUTE-TREE(f)**
1. for each \( p \), \( zpar(p) \leftarrow \text{undef} \)
2. \( R \leftarrow \text{REVERSE-SORT}(f) \) // maps \( R \) into an array
3. for each \( p \in R \) in direct order
4. \( \text{parent}(p) \leftarrow p \); \( zpar(p) \leftarrow p \)
5. for each \( n \in N(p) \) such as \( zpar(n) \neq \text{undef} \)
6. \( r \leftarrow \text{FIND-ROOT}(n) \)
7. if \( r \neq p \) then \{ \text{parent}(r) \leftarrow p \); \( zpar(r) \leftarrow p \} \)
8. DEALLOCATE(\( zpar \))
9. return pair(\( R, \text{parent} \)) // a ‘‘parent’’ function

**CANONIZE-TREE(parent,f)**
1. for each \( p \in R \) in reverse order
2. \( q \leftarrow \text{parent}(p) \)
3. if \( f(\text{parent}(q)) = f(q) \) then \( \text{parent}(p) \leftarrow \text{parent}(q) \)
4. return \( \text{parent} \) // a ‘‘canonized’’ parent function

arrow tree computation (no code missing!)
Min/Max-Tree Implementation [Berger et al., 2007]

```
FIND-ROOT(x)
1   if zpar(x) = x  then return  x
2       else {  zpar(x) ← FIND-ROOT(zpar(x)) ;  return  zpar(x)  }

COMPUTE TREE(f)
1       for each p, zpar(p) ← undef
2         R ← REVERSE-SORT(f) // maps R into an array
3       for each p ∈ R in direct order
4         parent(p) ← p ;  zpar(p) ← p
5       for each n ∈ N(p) such as zpar(n) ≠ undef
6           r ← FIND-ROOT(n)
7           if  r ≠ p then {  parent(r) ← p ;  zpar(r) ← p  }
8       DEALLOCATE(zpar)
9       return pair(R,parent) // a ‘‘parent’’ function

CANONIZE TREE(parent, f)
1       for each p ∈ R in reverse order
2         q ← parent(p)
3         if  f(parent(q)) = f(q) then parent(p) ← parent(q)
4       return parent // a ‘‘canonized’’ parent function
```

image filtering  →  add about 10 lignes of code...
Connected Operators as Tree Filtering

input image → tree construction → attribute computation → tree with attributed nodes → attribute-based tree pruning → pruned tree

filtered image
Tree Pruning and Morphological Operations

Various trees leading to various operators.

- Pruning a max-tree Algebraic opening.
- Pruning a min-tree Algebraic closing.
- Pruning a tree of shapes Grain filter.
Structural vs Algebraic Openings

Initial image.

Structural opening with a disk \((r = 15)\).

Algebraic opening \((\lambda = \pi r^2)\).
Structural vs Algebraic Openings

Initial image.

Structural opening with a disk ($r = 15$).

Algebraic opening ($\lambda = \pi r^2$).
Application: Filtering Everything But Boxes

future. According to Dealogic, 87 SPACs have begun trading in the U.S. since the end of 2007, trading some well-known companies like eBay and PayPal for lower prices. Last year alone, 49 SPACs worth $3.4 billion were announced, up from $844 million two years earlier. SPACs are essentially shell companies. They go public with little more than a management team and an agreement that the money raised will be used to fund an acquisition in a particular sector, such as retail, or in a new emerging market like China. Ergo, a SPAC is a roll of the dice. “Imagine paying $50 to go to a Broadway show, and you have no idea what’s behind the curtain,” says lawyer Mitchell Litman of Litman Knoops LLP, who works with a lot of SPACs. “You are relying on the trust and integrity of the management team.” Once a deal is completed, the SPAC’s managers (who typically receive 20% of the public share as compensation) are free to sell their holdings, usually after a 180-day lockup period.

Today’s SPAC bloom harkens back to the flurry of “blank check” companies that sprang up in the 1980s. These were wildly discrepant by a wave of scrutiny in which fraudsters would use a shelf company to announce a merger, pump the stock, and then dump it before everyone realized that the so-called target company was anything but. Investors have a lot more protection with SPACs, which must hold almost all the money in escrow until a deal is done.

From Charnley’s perspective, there is no downside to the arrangement. It lets him raise cash relatively quickly, retain the largest shareholder, and avoid having to sell other investors on his vision until after his company is already publicly traded.” I’m in a hurry to get the money,” he says, citing his plan to expand beyond his current 47 stores. “What’s great about the SPAC is, it’s kind of in reverse. First you get publicly traded, then you do the compliance stuff. And if you brought in private equity, you might want to run the company in a more [exacted] manne [n]”; he says, referring to American Apparel’s recent image.

Keeping control is particularly important for a guy who is the creative force behind the brand, as well as one whose flamboyant management style—one is sexual harassment suit outstanding against him by a former employee; two others have been dismissed—might scare off many investors. “He is very talented,” says former J.C. Penney CEO Alan unlocked Quantum, a partner in private equity firm Lee Equity Partners. “but he is a neologism (read nutty) type guy. It’s very difficult to see him in a public sphere.” (Charnley, for his part, dismisses the talk about his reputation as “all talk.”)

Charnley’s new BebeStore doesn’t appear concerned, even if they’re less likely to wear dark suits than American Apparel’s colorful leggins. Endurance’s president, Jonathan Ledecky, is familiar with unusual financing vehicles: he founded U.S. Office Products, the once-hot roll-up that went bankrupt in 2001 (long after Ledecky cashed out). Boldfaced names on the boards include Kerry Kennedy, Bobbi’s daughter, and Edward Matthews, a managing director at the Carlyle Group. On Jan. 31 the same group formed a new $250 million SPAC, Victory Acquisition, underwritten by Citi. The filing notes that it could compete directly with Endurance. As with Endurance, once Victory goes public it will pay Ledecky “affiliates” $7.5 million to run its Manhattan office.

Unhealthy Return
Since Ledecky’s move public in November via a SPAC, its shares have fallen 19%.

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Application: Showing Filtered Lines

AFRICA

Emotional Intelligence

Soul City, South Africa’s wildly popular soap opera, spreads public-health messages across the continent

By PETER HAWTHORNE JOHANNESBURG

It’s 5:30 on a Thursday night and millions of South Africans are tuning in to find out if the white social worker, Karen, will be able to adopt six orphan boys. “People love to hear stories of heroes who overcome obstacles,” he says. “No, it’s not Malawi Place or Er in any of the other imported dramas that fills the country’s airwaves. It’s a show about South Africans themselves.” Soul City, the local soap opera that began as a good deed, is now an award-winning, multi-award-winning, internationally-recognized show. It has won over the world with its stories of human life.

Soul City was launched nationwide on the South African Broadcasting Corporation’s TV service in 1994. “We realized that if we were to affect people and be an example to them, we had to keep it going and we had to be as good as or even better than any other product.” says Jabat. Since then, Soul City has continued to spread its stories.

On June 18, the show received a special award from Britain’s Global World Broadcasters Trust for its role in “illuminating the concerns of developing societies.”

Soul City reflects the life and hard times of people in a typical South African urban black township. In fact, most of the series’ location shots are taken in Alexandra, one of the oldest and most populated of South Africa’s black towns, just outside Johannesburb, and Soul City’s city, where much of the drama is centered, is based on an actual clinic in Alexandra.

That medical theme is not surprising, since the idea for the show came from two young white South African doctors, Garth Japar and Shernon Udoh, who had studied and worked in township hospitals and clinics, including in Alexandra. They envisioned a dramatic program that would also highlight the social and health problems—particularly HIV/AIDS—in the townships. They planned a long list of diseases.

Because AIDS is a huge problem in South Africa—almost 10% of the population is infected with it—the subject is featured in every installment of the show. Other topics include violence against women, drug abuse, child abuse, sexual conduct, occupational health, disability, nutrition, illness, and selling a used car. This is not just about reality in life; it’s about real-life skills,” says Japar, who is executive director of the non-governmental organization Health and Development Communications, which produces the show. Soul City also has a radio version broadcast daily in nine of South Africa’s 11 official languages, as well as weekly newspaper columns and a series of educational booklets. Characters speak in several of South Africa’s official languages, and the series is subtitled in English. It has been shown in Zimbabwe, Zambia, Nigeria, Namibia, Malawi, and Botswana and has been dubbed into French and Portuguese for showing in Ivory Coast, Mozambique and other countries. “This concept has got legs,” says Jabat. “It moves. It has also gone off Soul Buddies, a show for younger viewers, which began a 28-episode run on SABC-3 last year. Much of Soul City does for adults, but only a few of the series deal with HIV/AIDS.

What makes Soul City so successful is not merely its authentic portrayal of township life but also its intimacy with viewers. Many of the series are now in the townships. “That sometimes presents a problem,” says Loko Ramahaba, producer of the latest series. “Our actors are seen by real people. They have to become the advocates and counsellors they portray on the screen.” Some of the cast members have been discovered through Soul City’s annual “Search for a Star” initiative. Among them is Darren Kobedi-Pitie, a blind woman who plays the part of a radio talk-show coordinator. Kobedi-Pitie lost her sight as a result of domestic violence, an issue frequently raised by Soul City. “It made us all aware how unfortunately close we are to real life,” says Ramahaba.

Soul City is affecting the way South Africans lead their real lives. A study sponsored by the E.U. says there is evidence that the program has played a “major role” in increasing public knowledge of HIV/AIDS and safer sexual behavior. Researchers say, for instance, that there is a “significant” association of the use of condoms with people who watch Soul City. The survey did not say whether viewing increased the number of people who watched Soul City. The survey did not say whether viewing increased the number of people who watch Soul City.

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2014-04-08
Verbatim

‘Nobody is going to be allowed to do anything here.’

NAWED AHMAD, Pakistani Major General, an opponent that the U.S. may expand military and CIA authority to pursue Islamic militants in Pakistan.

‘If you are a believer in miracles, this would be one.’

PHILIP S. BARRE, chief of the division of critical care at New York-Presbyterian Hospital, on the resuscitation of Alfie Evans, a 23-year-old window washer who fell 47 stories last month.

‘We should not resort to violence even if we have differences.’

MAHMOOD GAYDOR, President of the Maldives, after an attempt to assassinate him was failed when he was found waiting to greet the island nation’s leader grabbed the attacker’s knife as he leaped out of a crowd.

This is who I am. This is my life.

REFEREND MARIANZA, U.S. Army medic and a decorated veteran of Iraq, discussing his homosexuality in a Jan. 6 press conference. Mariana has been openly gay since August 2000, despite the military’s “Don’t ask, don’t tell” policy. Critics have argued that his case proves the policy is arbitrarily enforced.

‘They should either kill me or organize a second round of elections.’

LENNY GACHEMAGASE, Georgian opposition leader, after his re-announcing defeat by pro-Western incumbent Mikhail Saakashvili in the country’s Jan. 5 Presidential elections. Gachechiladze claimed the voting was rigged.

This is the first red carpet that I’ve really walked down where I didn’t have to think about holding in my stomach.

HALLE BERRY, on being pregnant, while accepting the Desert Palm Achievement Award at the Palm Springs International Film Festival on Jan. 5.

Briefing

CENSORSHIP
16,600% Percentage by which government authorities have increased the license fee to receive websites TV, the country’s only broadcast news service not controlled by the state.

300% Percentage of the new fee—about $400—represents the annual salary of a Burmese schoolteacher. The increase is seen as a move to block access to news critical of the ruling military junta.

65% Percentage of U.S. adults who are exercising, drinking or smoking any non-cigarette-related habit.

29 Number of pounds (13 kg) that at least 25% of American adults currently on a diet would like to lose. Regular exercisers said they want to drop an average of 14 lbs. (6.3 kg).

$884 Recent price per ounce of gold set on Jan. 8, an increase rooted to market turbulence and high oil prices, beating the previous all-time record of $867 set in 1980.

$2,200 Monthly price per gold, when adjusted for inflation.

$46,380 The U.S. gold market’s new domestic product this year, $500 more than the U.S. per capita GDP. For the first time since the 1990s, the average Briton will earn more than the average American.

1993 The year following Britain’s last major financial crash, when the country’s per capita GDP was 34% less than that of the U.S.

Wealth

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Benefits

- Non destructive (preserve contours).
- Sound and strong mathematical properties [Soille, 2004, Najman and Talbot, 2010].
- Take into account all components.
- Really intuitive to use.
- Very extensible (many attributes).
- Efficient.

Applications in Document Image Analysis.

- Page segmentation.
- Text identification.
- Object recognition.
- “Smart” binarization.
- Etc.
Implementation: The Olena Platform

Code and tools available in Olena, a free software image processing platform.

http://olena.lrde.epita.fr

Milena
A generic and efficient C++ image processing library [Levillain et al., 2010].

Scribo
A framework for Document Image Analysis [Lazzara et al., 2011].
Thank You!

