Innovative Methods for Numerical Solutions of Partial Differential Equations

edited by
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World Scientific

The AMS/SIAM summer Seminar on
Large-Scale Computations in Fluid Dynamics
La Jolla, CA, June 27 - July 8. 1983

A one-sided view

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Abstract: A critical study is made of the tricks of the upwinding trade. Five lines, it would seem, can describe any scheme of the class that the authors surveyed.

1 Introduction

I said to my darling; "I may go
to meet at U.C. San Diego
the full upwind clan
invited by Stan,
for a boost of the mutual ego.

By often escaping detection
the sun caused no marked defection.
To swim the Pacific
ain't all that terrific
if you must get dry by convection.

2 Basic numerical techniques

2.1 Conservative difference schemes

Conventional difference equations
give shocks that induce oscillations.
By adding some logic
we get monotonic
numerical representations.

Research was supported in part by agencies with. a kind heart. No proposals were rated, no funds allocated; in fact, no one knew this would start.

A characteristic equation
when differenced defies conservation,
which so badly we need.
But at last we were freed
by the grace of Roe's linearization.

To the podium many will hustle
to enter their claim in the tussle.
For the issue is fame
and it seems such a shame
we can't all take credit for MUSCL.

It's really not easy outsmartin'
the TVD schemes of A. Harten.
The name of the game
is they're all the same
so you'd better give up before startin'.

The sight of the slides of Colella
turns all his competitors yella.
Where others may fail
he's got the detail,
cause the grids are paid for by Ed Teller.

In spite of the entropy glitch
those contracts are making Stan rich.
He claims Engquist-Osher
is totally kosher
and runs like a son-of-a-bitch.

2.2 The state of the art in related areas

The conference could not have been better
except for the following matter:
that out of those listed
some speakers insisted
that they'd give a talk on the weather.

"We all know the problem of Riemann,
the basis of all of our schemin'."
This assertion will get
uninitiates upset
and the meteorologists steamin'.

So, medium-term weather prediction
turns out to be merely a fiction.
It's just anyone's guess,
if you ask how to dress
it will offer no useful restriction.

2.3 Auxiliary techniques

To sort out a boundary procedure
just talk to this elegant Swede here.
Your results will look nice
in the sense of Heinz Kreiss
and your program may even be speedier.

When exhausted by over-refinin'
don't throw up your hands and start whinin'.
No sense in postponin',
just go for rezonin'
(for details please talk to Mac Hyman).

Approximate factorizations
applied to the Euler equations,
are not all that fast,
in fact, they're surpassed
by classical point relaxations.

Now listen and please do not mock:
the spectral technique I'll unlock.
A hundred harmonics
make quite good transonics,
though fifty must die for the shock.

3 Theoretical results

Full proofs are exceedingly rare
except in the simple case where
the f is convex
in $u_t + f_x$
such as $f = \frac{1}{2}u^2$

At dinner on day number three
the cook said to my friend and me:
"You've had burgers enough,
try more variable stuff:
may I offer you eggs and Roe tea?"

4 An observation of Sweby

Now look who we have over here:
it's Roe and LeVeque and Van Leer.
They put all their time
into making things rhyme.
Will their paper [1] get written this year?

5 Conclusions

On returning from sunny La Jolla
I was summoned to see my employer.
"Once out of my reach
your went straight to Black's Beach.
Don't deny it 'cause everyone saw ya."

Acknowledgement

We offer our thanks to Pete Sweby who handed us many a freebee. With a line and a rhyme he was there all the time. You may ask: without him, where would we be?

References

[1] Roe, R. LeVeque, B. van Leer, "Limericks for the bored engineer", in: SIAM Review (1992), submitted, perhaps to appear.

J-D Müller, **P.L.Roe**, H.Deconinck, A Frontal Approach for Node Generation in Unstructured Grids, AGARD R787 (Proceedings of AGARD/NASA Special Course), 1992.

H.Deconinck, R.Struijs, H.Bourgeois, **P.L.Roe**, *Compact Advection Schemes on Unstructured Grids*, von Karman Institute Lecture Series 1993-04.

P.L.Roe, Multidimensional upwinding, motivation and concepts, von Karman Institute Lecture Series 1994-04.

P.L.Roe, Upwinding without dissipation, von Karman Institute Lecture Series 1994-04.

P.L.Roe, New aplications of upwind differencing, von Karman Institute Lecture Series 1994-04.

"A One-Sided View:" the real story

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with a post-script by

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Abstract

The circumstances under which the paper "A One-Sided View" by Roe, LeV and Van Leer (1983), consisting entirely of limericks, was produced, and its fa to get published, are scrutinized. The paper then follows, after all these yea

1 Historic backdrop

It is 1983, a great year for CFD. The concepts of approximate Rie solvers and limiters have empowered numerical analysts, and resear these subjects is burgeoning. TVD conditions[1] have just been introd the Harten-Lax-Van Leer review[2] on upwind differencing and Godunov schemes is appearing in SIAM Review, and the Woodward-Colella re on computing flows with strong shocks, submitted to JCP, is circulatin preprint. In the footsteps of an active "older" generation - Van Leer, W ward, Harten, Colella, Roe, Osher, Engquist - a new generation of b numerical analysts is emerging, dedicating their careers to CFD: LeV Sweby, Tadmor, Berger, Mulder. And at NASA's research centers, engi actually are *listening* to all these numerical types and their fancy ideas.

[1] A. Harten, "High-resolution schemes for hyperbolic conservation laws," *J. put. Phys.* **49** (1983), pp. 357-393.

[2] A. Harten, P. D. Lax and B. van Leer, "On upstream differencing and Godunc schemes for hyperbolic conservation laws," *SIAM Review* **25** (1993), pp. 35-61.

[3] P. R. Woodward and P. Colella, "The numerical simulation of two-dimensiona flow with strong shocks," *J. Comput. Phys.* **54** (1994), pp. 115-173.

year at NASA Langley, for instance, the basis of the CFL3D code is laid by Jim Thomas and Kyle Anderson[4].

These are ideal conditions for a grand inspirational gathering of all the new talent and ideas. The opportunity for such a meeting arrives with the *15th AMS-SIAM Summer Seminar on Large-Scale Computations in Fluid Mechanics*, to be held in La Jolla, June 27 - July 8, 1983. The organizers are Björn Engquist and Stan Osher of UCLA, and Richard Somerville of the Scripps Institution of Oceanography, La Jolla. Engquist and Osher invite all their friends[5], including all members of the upwind-differencing clan, and almost all appear. As a counterweight some innocent computational meteorologists[6] are added, creating an odd mix that leads to some interesting moments[7] during the Seminar.

2 A new passion: limericks

It is at this meeting that a new passtime emerges: *composing CFD limericks.* The exact date of birth of this activity has not been recorded, but the whole thing started with Phil Roe reciting at luncheon the one and only CFD limerick [8] he had ever made (and not a flawless one). This created a challenge among the intelligent, witty and enthousiastic Seminar participants, and soon new limericks on all possible subjects of CFD and numerical analysis in general were being drafted on paper napkins. I volunteered to collect these, copy them neatly and compile them. We soon outgrew the improvisational napkin-stage and I brought a note pad to breakfast and luncheon.

Yes, this became serious business: we started with limericks at the crack of dawn. The La Jolla campus cafetaria offered a splendid Californian breakfast with lots of fresh fruit and other wholesome things, motivating the most active participants to appear at its doorstep at opening time, 7.00 am, and staying in the cafetaria inventing limericks until the lectures would start, two hours later.

Only once was a limerick session held elsewhere, namely, on Black's Beach; my 1983 Calender shows this happened on Saturday, July 2. Black's B had the reputation that people would bathe there in the nude. We didn' anything of the sort, but, admittedly, the weather wasn't great that day sun was defecting[9] and now and then there was a slight drizzle. Still, like a nerd, bringing a note pad to the beach. This session stands very cl in my mind, in particular because David Gottlieb was with us, that is, Roe, Randy LeVeque, Pete Sweby and I. David inspired two great lime the one on the spectral technique[10] and the one in which the main rl is "La Jolla.[11]" That rhyme was David's challenge to Phil when we leaving the beach. While walking up the sloping path, after some thin Phil produced the full limerick without hesitating once. Ah, a great mo in the history of CFD, and I was there.

I also vividly recall the luncheon session where Randy presented his fect limerick[12] about the scalar conservation law $u_t + f_x = 0$, which in inspired me to start one[13] about the system case. This is the most nious limerick we made; the cook's nutritional advice: "You've had bu enough, / try more variable stuff: / may I offer you eggs and Roe tea?" double meaning, with the punchline verbalizing the expression $u_x + \rho_t$. limerick was not perfected until weeks after the La Jolla meeting, at IC where I was spending the rest of the summer.

3 "A One-Sided View"

At ICASE I scrutinized all limericks we had produced, arranged th the form of a paper, and had it typed. We had been very systema our coverage of CFD, the Seminar and its participants, and already Jolla we had produced some of the extras that characterize a real p one reference, an acknowledgement and a funding blurb. An abstract graciously mailed to me later by Phil. The title became: "A One- View;" authors were Roe, LeVeque and Van Leer, with an acknowledgen of substantial assistance by Sweby.

[4] W. K. Anderson, J. L. Thomas and B. van Leer, "A comparison of finite-volume flux-vector splittings for the Euler equations," AIAA Paper AIAA 95-0122.

[5] "A One-Sided View," 1.i

[6] "A One-Sided View," 2.2.i

[7] "A One-Sided View," 2.2.ii

[8] "A One-Sided View," 2.1.i

[9] "A One-Sided View," 1.ii

[10] "A One-Sided View," 2.3.iv

[11] "A One-Sided View," 5.i

[12] "A One-Sided View," 3.i

[13] "A One-Sided View," 3.ii

[14] "A One-Sided View," Abstract

[15] "A One-Sided View," Acknowledgement

The paper appeared in preprint format as an *ICASE Special Internal Report*, number 2 in the so-called *Pink Grundlehrer Series*, established by ICASE Director Milt Rose to absorb the more frivolous creations by ICASE staff. These reports were for private distribution only; on the cover the reader is warned: "Reports in the ICASE Grundlehrer Series have no intrinsic value, scientific or otherwise."

4 Getting it (not) published

I submitted "A One-Sided View" to AMS for inclusion in the Seminar proceedings, along with my regular Seminar contribution. The manuscript proceeded smoothly through the editorial system; I received an edited version for approval of changes made by the text-editor. For instance, the first sentence of the funding acknowledgement[16], "Research was supported in part / by agencies with a kind heart," was altered into "Research was supported in part / by agencies with kind hearts." A grammatical zealot, the editor had not noticed there were a rhyme and a meter to be preserved.

Eventually the paper landed on the desk of Stan Osher, co-editor of the proceedings, who immediately blocked its publication. In the belated rejection letter I received from the Manager of Editorial Services she writes: "[..] the editors [..] believe that it is better suited for some other journal - perhaps, National Lampoon or Punch." Stan's comment per telephone was that the paper was not serious enough for inclusion in the proceedings of a seminar funded by NSF, NASA and, particularly, ARO. He obviously did not want to jeopardize his relations with funding agencies.

It was not until twelve years later that Stan finally admitted to me the paper should have been published. The only real objection he had had was the language in the limerick[17] about himself: "He claims Engquist-Osher / is totally kosher / and runs like a son-of-a-bitch." In La Jolla we thought this was a great pastiche of Stan's manner of speaking; Stan's own suggestion of reworking the limerick such that its last line would become: "and his lifestyle gets posher and posher," was firmly rejected.

In retrospect the non-publication of "A One-Sided View" appears to be the regrettable result of a lack of communication, more precisely, a lack of experience in negotiating on both sides. May we all learn from tragedies this.

[16] "A One-Sided View," title page, footnote

[17] "A One-Sided View," 2.1.vi

5 Epilogue

Thus, "A One-Sided View" was never officially published, not in 1985 v the Seminar proceedings[18] appeared (two volumes that are still superb erences on many topics), and not in SIAM Review, 1992, as the paper's reference[19] boasted. May the current volume, dedicated to Phil Roe o sixtieth birthday, finally provide a haven for this elegant piece of CFD t and at the same time pay homage to Phil's unique spirituality.

One last, apologetic word to the reader. Some of the limericks ap to be self-congratulating, although they were not intended as such. Th the result of our ardor to cover important topics in CFD, combined the multiple authorship. For instance, a limerick on Roe's linearizat absolutely needed to be included; it was composed by me as a tribute to Likewise, the limerick on MUSCL[21] was Randy's way of complimenting

6 Post-script

The paper "A One-Sided View"
was rejected as frivolous when new.
But by happenstance
it was published in France
after only a decade or two.

KEN POWELL

[18] "Large-Scale computations in Fluid Mechanics," B. Engquist, S. Oshe R. 'C. J. Somerville (Eds.), Lectures in Applied Mathematics, Vol. 22, Part 1 and I American Mathematical Society, Providence, RI, 1985.

[19] "A One-Sided View," Reference 1

[20] "A One-Sided View," 2.1.ii

[21] "A One-Sided View," 2.1.iii