Some Personal Reminisces about Bruce Allen Francis

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The purpose of this article is to pay tribute to a remarkable colleague who left an indelible mark in the birth and development of the modern theory of robust control and a lasting impact
on our own lives and academic careers. We (Tryphon Georgiou and Allen Tannenbaum) first met Bruce in the early 1980's and have shared wonderful as well as testing times together. Thus, we
decided to share this space and join in providing personal reminisces and expressing our deep loss of our dearest friend, Professor Bruce Allen Francis of blessed memory.

8 Reminisces of Allen Tannenbaum

I first met Bruce at the University of Waterloo in 1983. He was a guest of Sagar
(Mathukumalli Vidyasagar). That was when I also met Abie Feintuch from Ben-Gurion University who was working with Bruce on an H[∞] type theory for general linear time-varying
systems using results of William Arveson on nested algebra [3]. I spent a lot of time with Bruce that week, talking about control, mathematics, philosophy, and life. It was really the
beginning of a wonderful life-long friendship. Bruce at that time was very much engrossed with George Zames on working on H[∞] problems, and in fact, it was Bruce who first formulated
a constructive solution based on H[∞]/L¹ duality to the sensitivity minimization problem [9]. I had already been using Nevanlinna-Pick type interpolation for the gain margin problem [8], and
after a conversation with Bill Helton, Bruce and George Zames had realized that this would give

a solution to H^{∞} sensitivity minimization as well [5]. Bruce and I discussed the fact that the

two problems may be in fact closely related, a result that was formally formulated and proved in subsequent work of Pramod Khargonekar and me [6] using conformal mapping theory and
 non-Euclidean metrics.

I spent the 1985-1986 academic year in Montreal (McGill University) as a guest of George Zames. Bruce came to visit several times, and on occasions, we were joined by Tryphon. Bruce

would stay with our family in Westmount. Our children, Manny and Sarah loved him. Manny at

- ² the time was 6 years old, and it was Bruce who taught him (and actually the entire family) how to snow ski. Bruce was actually an excellent athlete: superb bicyclist, aerobic master, and runner.
- ⁴ Bruce, John Doyle, and I (and sometimes Tryphon) would go to various gyms at conferences around the world to test and compare our strength; please see the image (1(a))! Typically, Bruce
- ⁶ and I would be roommates at these conferences. Bruce would always wear earplugs (to muffle my snoring).

In 1991-1992, the Institute for Mathematics and Its Applications (IMA) had a year of 8 workshops dedicated to advances in the field of control. Bruce was a long term visitor at IMA for that year. He had met Jingwen previously in Japan, and she came to visit him in Minneapolis. 10 The rest is history. Jing and Bruce lived in the same building as my family and I for about three months, and the families spent a lot of time together. Among Bruce's many talents was an ability 12 to make spaghetti and a delicious sauce without spilling anything. After cooking, the kitchen was cleaner than before Bruce started preparing the meal! Bruce and Jing married soon after 14 they returned to Toronto (where Bruce was a professor). They have a beautiful daughter Lian who was Bruce's pride and joy, and in many ways is the copy of Bruce! During that period 16 at the IMA, Bruce and I spent some time finishing up a book that we were writing with John Doyle on feedback theory [2] as well as doing some joint work on sampled data systems.

We met a number of times over the years. I visited Bruce several times in Toronto (the
last time in 2012), and Bruce visited Georgia Tech in 2005 where he gave a great talk on cyclic pursuit problems [7]. He was particularly interested in problems in curve shortening and the
geometric heat equation [4] and the profound connections with the pursuit problems in which he was interested. Tryphon and I also spent quite a bit of time with Bruce (image (1c)) in India
in 2007 when we celebrated Sagar's 60th birthday in Hyderabad, India.

In the fall of 2015, Bruce came to visit us in New York City. It was clear that the disease had progressed. At times the body tremors were quite severe and Bruce just had to lie down. Nevertheless, at other times, Bruce seemed almost normal, and in fact, we enjoyed several long walks by the East River. Bruce was quite stoic about his situation, and understood that only drastic action could hope to ameliorate his debilitating condition. This was the deep brain stimulation procedure that he underwent several months later that apparently did not work as we had hoped. Bruce as usual was extremely strong and brave, and accepting of his situation. One

³² of my fondest memories was seeing him play with our granddaughter Maya during the visit. She immediately took to Bruce. Toddlers have an instinctive feel for who is a good person, and

³⁴ Bruce was a very good person. That was the last time that I saw my friend.

Reminisces of Tryphon Georgiou

I first met Bruce at the Fort Lauderdale 24th CDC in 1985. I introduced myself but there was not much of a chance to talk as we were in a large group. The next time it was at the 25th
 CDC in Athens, in December 1986. He was chatting with Allen in the lobby of the Atheneum Intercontinental Hotel where the CDC was being held. I walked up to them and Allen introduced
 me. Bruce was kind and engaging. At the time I was interested in periodic and sampled data control. The topic resonated with Bruce. We talked on the subject for about twenty minutes and

⁸ then he invited me to visit him in Toronto, which I gladly accepted.

Earlier that day at the conference, Allen and I had made plans to visit the ancient temple of Poseidon at Sounio and so we invited Bruce to join us. Sounio is the tip of a peninsula–a truly majestic place at sunset with Poseidon's temple overlooking the Aegean sea. We took some nice sunset pictures as well as some silly ones, pretending to be modern Goliaths with the temple pillars. Those moments were the start of a deep friendship that continued to the end.

The following day I suggested that we take up an offer by my sister Eleni to host a dinner at her house which was nearby. Bruce and Allen agreed, and on the way we roped in George
 Zames and John Doyle who were happy to join. It was a truly delightful evening.

I visited Bruce in Toronto shortly afterwards. I gave a seminar and, on the spur of the moment, Bruce asked me to give an impromptu "guest lecture" to his class. One cannot help 18 but smile when remembering those early formative experiences, and the nervousness I felt in lecturing without preparation in front of a colleague for whom I had such an immense respect. 20 Later on that day we began working on sampled-data control but ended up focusing on periodic control and gain-margin first, before looking at the mix of continuous and discrete, in an H_{∞} 22 context, which looked more difficult at the time. We scribbled a few things on the board and then I returned to Iowa. We spoke regularly on the phone after that, often daily. At some point 24 Bruce thought that we should begin writing a "draft in troff" (I was still using a typewriter) and volunteered to take a first shot and send it to me "via bitnet" (to which my reaction was "what's 26 that?"). It was 1987. The paper was published a year later [10]. We had plans to write more but

²⁸ for one reason or another we never did.

Bruce visited me in Ames twice. Whenever Bruce was there, my wife Efi, Bruce and I would go running in the morning and after work we would go to the movies or to a theater play-the only one in Ames at the time. Besides bitnet, troff and his superb expository style, I learned a great deal from Bruce about life too.

Bruce always had a quick retort and dry sense of humor; image (1(b)). Years later, when

the announcement came about the new "Pope Francis" and I congratulated him, he duly sent
me his blessings. Bruce was keenly interested to understand every detail in a paper and to work everything out himself. In later years, when I sent him a joint paper by Malcolm and myself
on the "arrow of time" in feedback theory, we exchanged emails daily for a week while he was dissecting the various points, at one point emailing me, "I'm still stuck. You're going to regret

⁶ giving me that paper ..."

I saw Bruce at the 53rd CDC in Los Angeles. After his plenary lecture we sat outside the hotel and talked about the past. His disease had progressed but was still under control. We spoke a few more times over the phone but did not see each other again. December 2014 was the last time I saw my friend.

Concluding thoughts

- ¹² Bruce Francis had a profound impact in Control Theory and Control Engineering. He will always be remembered as one of the fathers of Modern Robust Control. Besides his foundational
- ¹⁴ work throughout the 1980's, his creativity continued on unabated until almost the end. From his early student days until the sunset of his life, Bruce produced a wealth of scholarly works that
- ¹⁶ will inspire and educate future generations of control engineers and scientists. At a personal level, Bruce had a profound impact on our lives and careers, and for that we will be eternally grateful.
- ¹⁸ Bruce was a scholar and a gentleman, and most importantly, a deeply caring compassionate person. We deeply miss our dearest friend Bruce.





(a) Lifting

(b) Laughing



(c) Reading

Figure 1: Images of Bruce

References

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Biographies

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