Malcolm C. Smith
a third of a century
in Systems, Control & Circuits

personal reminiscences

Tryphon Georgiou
Univ. of California, Irvine

Cambridge, July 2017

Malcolm's birthday puzzle

Malcolm's birthday puzzle

Malcolm's birthday puzzle

Malcolm's birthday puzzle

Malcolm’s birthday puzzle

Happy 60th!

MCS @ Minnehaha Falls
Minnapolis, MTNS 2016

The Cambridge years

A Generalised Nyquist/Root-Locus Theory for Multi-Loop Feedback Systems (1982)
Smith, Malcolm C.

INT. J. CONTROL, 1981, VOL. 34, NO. 5, 885–920

On the generalized Nyquist stability criterion

M. C. SMITH†

The purpose of this paper is to provide a self-contained proof of the generalized Nyquist stability criterion. The frequency-dependent eigenvalues of a square transfer-function matrix $G(s)$ are defined directly from a matrix fraction decomposition of $G(s)$, and a discussion of the fixed modes and fixed gains is given. The theory of algebraic functions and Riemann surfaces is employed in the proof, and a detailed consideration is given to these theoretical ideas from the point of view of the stability result. The question of the relationship between the poles and zeros of an algebraic function (in the complex-variable sense) and the poles and zeros (in the Smith–McMillan sense) is carefully examined, and a proof of the argument principle for a regular region on a Riemann surface is given.

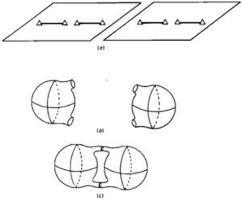

Figure 21. Two sheets of a Riemann surface (*a*) are compactified (*b*) and joined (*c*) to give a manifold which is topologically a torus.

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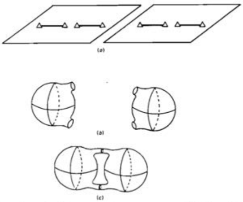

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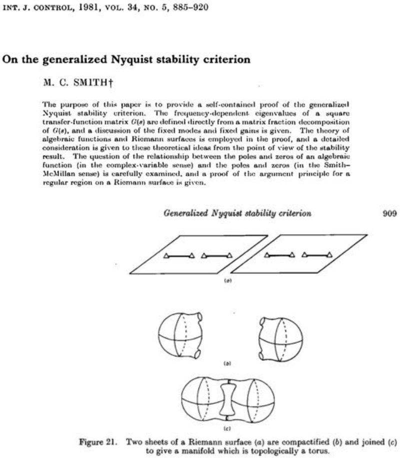

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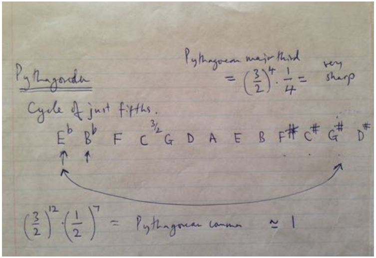


Malcolm's notes (circa 1990) – tutoring Tryphon

The adaptive years - Germany

Systems & Control Letters 7 (1986) 39–40
North-Holland
February 1986

On minimal order stabilization of single loop plants

Malcolm C. SMITH *
Department of Electrical Engineering, McGill University, Montreal, Quebec, Canada H3A 2A7

(2) Any $g(s)$ of order n with $a(s)$ Hurwitz can be stabilized by a compensator $k(s)$ of order $m \leq r - 1$ (a proof can be found, for example, in [1]).

IEEE TRANSACTIONS ON AUTOMATIC CONTROL, VOL. AC-31, NO. 4, APRIL 1986
299

Stable Adaptive Regulation of Arbitrary *n*th-Order Plants

GERHARD KREISSELMEIER AND MALCOLM C. SMITH

Abstract—**This paper presents an algorithm for adaptively stabilizing and asymptotically regulating an arbitrary single-input single-output linear time-invariant plant, which is controllable and observable, of known order *n*, and has unknown parameters. No further assumptions are made. No external probing signal is required.**

established without using an external probing signal, have until recently imposed more or less stringent additional requirements on the plant parameters. In the model reference approach [9]–[11] the plant is restricted to being minimum phase and to having known relative degree. In [12] a direct adaptive scheme based on input matching is obtained for a restricted class of plants

The H_∞ years - McGill

stabilizability $\Leftrightarrow$ existence of coprime fractions

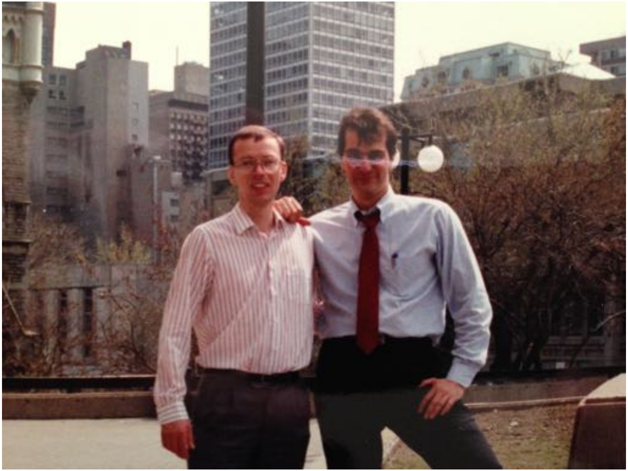
On Stabilization and the Existence of Coprime Factorizations

MALCOLM C. SMITH

Abstract—We show that any transfer function matrix whose elements belong to the quotient field of H_∞, and which is stabilizable, has a matrix fraction representation over H_∞ which is coprime in the sense that a matrix Bezout identity can be satisfied.

well-posedness of $\boldsymbol{H_\infty}$-design, etc.

Montreal 1986 & 1994



George Zames
Allen Tannenbaum

Malcolm & Tryphon

McGill, Ames, Columbus, Minneapolis, Cambridge

working with Malcom

McGill, Ames, Columbus, Minneapolis, Cambridge

working with Malcom
– a long list of ideas to work on

McGill, Ames, Columbus, Minneapolis, Cambridge

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– a long list of ideas to work on
– often overly optimistic plans on how much we can finish

McGill, Ames, Columbus, Minnepolis, Cambridge

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– working everywhere, in caffes, on the floor

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working with Malcom
– a long list of ideas to work on
– often overly optimistic plans on how much we can finish
– working everywhere, in caffes, on the floor

– taking walks

The Gap years

After half a year working rather intensely...
Dec. 1988 “we may be able to write a technical note”

The Gap years

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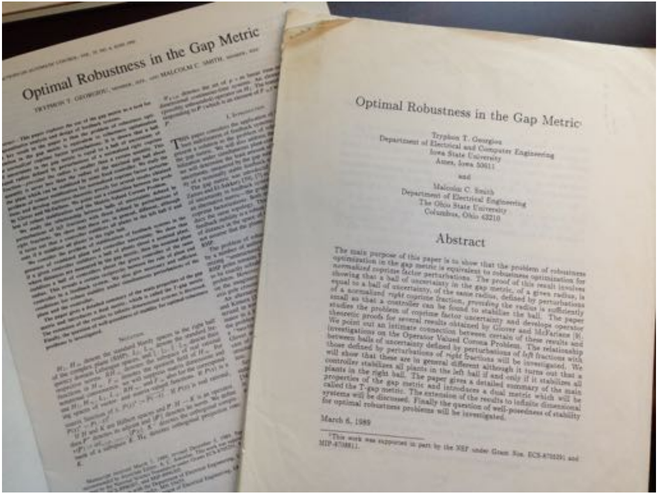
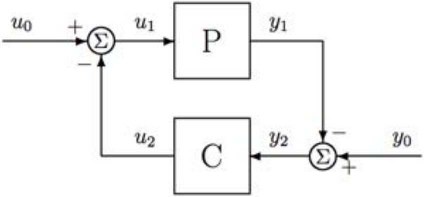


The Gap years



$$\mathbf{P}: u_1 \mapsto y_1 \quad \Leftrightarrow \quad \binom{u_1}{y_1} \in \mathcal{G}_{\mathbf{P}}$$
$$\mathbf{C}: y_2 \mapsto u_2 \quad \Leftrightarrow \quad \binom{u_2}{y_2} \in \mathcal{G}_{\mathbf{C}}$$

$$\delta(\mathbf{P}, \mathbf{P}_{\text{perturbed}}) = \text{gap metric} = \|\Pi_{\mathbf{P}} - \Pi_{\mathbf{P}_{\text{perturbed}}}\|$$
$$= \text{optimization via coprime fractions}$$

Robustness in the gap:

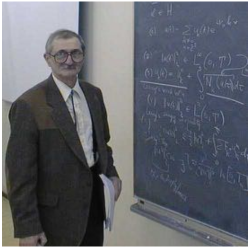
The feedback system remains stable with $\mathbf{P}$ replaced by $\mathbf{P}_{\text{perturbed}}$ for all $\mathbf{P}_{\text{perturbed}}$ such that $\delta(\mathbf{P}, \mathbf{P}_{\text{perturbed}}) < b$ if and only if

$$b \leq \left\| \begin{pmatrix} \mathbf{I} \\ \mathbf{P} \end{pmatrix} (\mathbf{I} - \mathbf{CP})^{-1} (\mathbf{I}, \; -\mathbf{C}) \right\|^{-1} =: b_{\mathbf{P},\mathbf{C}}$$

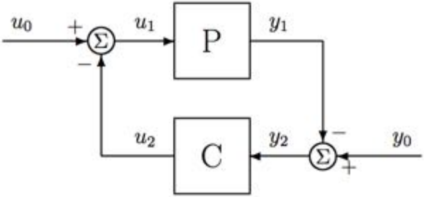
The Gap years

we need to finish the paper - July 5, 1990 (picture 1991)

The Gap years



Ciprian Foias



Geometry:

$$\begin{pmatrix} \mathbf{I} \\ \mathbf{P} \end{pmatrix} (\mathbf{I} - \mathbf{CP})^{-1}(\mathbf{I}, \ -\mathbf{C}) =: \Pi_{\mathbf{P},C}$$

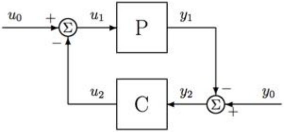
is a projection onto $\mathcal{G}_{\mathbf{P}}$ parallel to $\mathcal{G}_{\mathbf{C}}$

$b_{\mathbf{P},\mathbf{C}} =$ sine of the angle between the two graphs

The Gap years

Montreal 1994

John Doyle, Malcolm, Keith, Tryphon



more geometry, nonlinear, time-delays, etc.

Cambridge 1993

Harry Dym

Oropos & learning Greek

Oropos & learning Greek

ενα καφε με γαλα

Oropos & learning Greek

ενα καφε με γαλα

ενα καφε μεγαλο

Oropos & learning Greek

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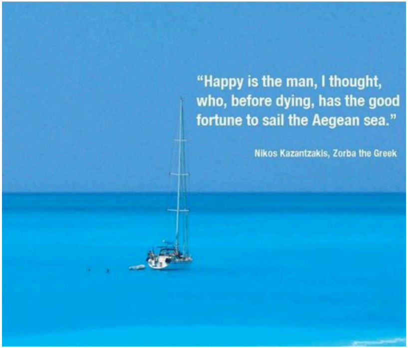
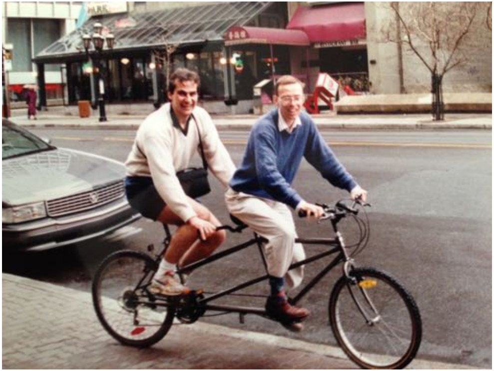


The bicycle years & the time arrow



McGill 1994

The bicycle years & the time arrow

Feedback control and the arrow of time

Tryphon T. Georgiou[a] and Malcolm C. Smith[b*]

[a]*Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, MN 55455, USA;* [b]*Department of Engineering, University of Cambridge, Cambridge, CB2 1PZ, UK*

(*Received 24 January 2009; final version received 7 February 2010*)

The purpose of this article is to highlight the central role that the time asymmetry of stability plays in feedback control. We show that this provides a new perspective on the use of doubly-infinite or semi-infinite time-axes for signal spaces in control theory. We then focus on the implication of this time asymmetry in modelling uncertainty, regulation and robust control. We point out that modelling uncertainty and the ease of control depend critically on the direction of time. We also discuss the relationship of this control-based time-arrow with the well-known arrows of time in physics.

Keywords: stability; feedback control; thermodynamics; time-asymmetry; robust control; reversibility

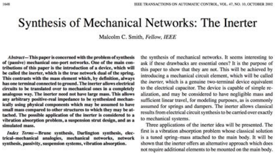
A basic model for rider-bicycle dynamics (Aström) has a (simplified) transfer function

$$\frac{s+V}{s^2-\gamma^2}$$

Riding the bicycle backwards, exactly at the "critical" speed $V = -\gamma$ is physically impossible to stabilize the bicycle!

with thanks to Anders Rantzer

The inerter years



1648 IEEE TRANSACTIONS ON AUTOMATIC CONTROL, VOL. 47, NO. 10, OCTOBER 2002

Synthesis of Mechanical Networks: The Inerter

Malcolm C. Smith, *Fellow, IEEE*

***Abstract*—This paper is concerned with the problem of synthesis of (passive) mechanical one-port networks. One of the main contributions of this paper is the introduction of a device, which will be called the inerter, which is the true network dual of the spring. This contrasts with the mass element which, by definition, always has one terminal connected to ground. The inerter allows electrical circuits to be translated over to mechanical ones in a completely analogous way. The inerter need not have large mass. This allows any arbitrary positive-real impedance to be synthesized mechanically using physical components which may be assumed to have small mass compared to other structures to which they may be attached. The possible application of the inerter is considered to a vibration absorption problem, a suspension strut design, and as a simulated mass.**

***Index Terms*—Brune synthesis, Darlington synthesis, electrical-mechanical analogies, mechanical networks, network synthesis, passivity, suspension systems, vibration absorption.**

the synthesis of mechanical networks. It seems interesting to ask if these drawbacks are essential ones? It is the purpose of this paper to show that they are not. This will be achieved by introducing a mechanical circuit element, which will be called the *inerter*, which is a genuine two-terminal device equivalent to the electrical capacitor. The device is capable of simple realization, and may be considered to have negligible mass and sufficient linear travel, for modeling purposes, as is commonly assumed for springs and dampers. The inerter allows classical results from electrical circuit synthesis to be carried over exactly to mechanical systems.

Three applications of the inerter idea will be presented. The first is a vibration absorption problem whose classical solution is a tuned spring–mass attached to the main body. It will be shown that the inerter offers an alternative approach which does not require additional elements to be mounted on the main body.

The inerter concept - Malcom Smith 1997

– published by an “obscure” journal called

IEEE Transactions on Automatic Control in 2002

– raced by McLaren in 2005 with Kimi Raikkonen

– took the Formula-1 world by surprise

For years, the mysterious “J-Damper,” a vehicle suspension device described as the F-1 technical innovation of the year, was carefully codenamed and concealed to prevent it from being copied by rivals.

... buzz with speculation about what the device actually was.

Now, with the lifting of the confidentiality agreement, the secret of the “J-Damper” can finally be revealed...

The inerter years

From Wikipedia, the free encyclopedia

In the study of mechanical networks in control theory, an **inerter** is a two-terminal device in which the forces applied at the terminals are equal opposite, and proportional to relative acceleration between the nodes. Under the name of **J-damper** the concept has been used in Formula 1 racing car suspension systems.

It can be constructed with a flywheel mounted on a rack and pinion. It has a similar effect to increasing the inertia of the sprung object.

Contents [hide]

1 Discovery
2 Construction
3 Applications
4 References
5 External links

Discovery [edit]

Malcolm C. Smith, a control engineering professor at the University of Cambridge, first introduced inerters in a 2002 paper.[1] Smith extended the analogy between electrical and mechanical networks (the mobility analogy). He observed that the analogy was incomplete, since it was missing a mechanical device playing the same role as an electrical capacitor. It was found that it is possible to construct such a device using gears.

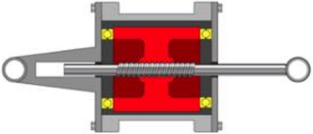
Secrets of the inerter revealed

A Cambridge University invention which was kept a closely-guarded secret because of the hidden advantage it offered to a Formula 1 racing team is finally being made available for widespread use.

single-handedly resurrected classical circuit theory!

Malcolm’s birthday puzzle

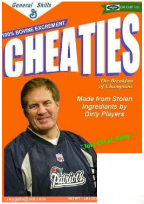
Malcolm's birthday puzzle



Malcolm's birthday puzzle

2007 Italian Grand Prix

Malcolm’s birthday puzzle



spygate

Malcolm’s birthday puzzle

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paraphrasing AE's comments:

paper on inerter didn't reference recent CAS publications...

Editorial by Chief Editor on policy:

... I have been receiving as many as three papers per day...

Malcolm’s birthday puzzle

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paper on inerter didn't reference recent CAS publications...

Editorial by Chief Editor on policy:

… I have been receiving as many as three papers per day…

missed out:

CAS being the “obscure” journal having published such an impactful work

need to decide what to do next!

via skype - 2017

Happy birthday Malcolm!

Happy birthday Malcolm!