

# *Jan Willems*

*sept. 18 1939 – aug. 31 2013*

*Scholar - Mentor - Friend*

# Life and work

- **1939: Born in Bruges september 18 as twin brother of Jacques Willems**
- **Studied Engineering @ U Gent**
- **1965: Master EE @ U Rhode Island**
- **1968: PhD EE @ MIT**
- **1971: PhD on I/O stability appeared as 'The analysis of feedback systems', MIT Press**
- **1968-1973: Ass. Prof. EE @ MIT: Groundbreaking work**
  - **Linear Quadratic control – ARE**
  - **Dissipative systems and Linear Matrix Inequalities – Robust control**



1944



1946



1948



1950



1953



1963



ON BOARD S.S. ROTTERDAM  
*Holland-America Line*



1964



**Lenny Gould, Sanjoy Mitter, Mike Athans, Fred Schweppe, and Jan Willems**

# Life and work

- **1973: Prof. Systems and Control Dept. Math/CS @ U Groningen**
  - Differential games
  - Realization theory
  - Physical dynamical systems
  - Geometric approach to control; Disturbance decoupling by high gain feedback
- **'Unavoidable' administrative positions @ U Groningen**
- **1980: Behaviors**
  - Develops the behavioral approach to system theory: dynamical systems as a family of trajectories; latent and manifest variables, control and feedback as interconnection
- **1986: Founder/Chair of Dutch Network of Systems and Control**
  - One of Jan's dreams: national graduate school
  - Evolved into DISC (Dutch Institute of Systems and Control) in 1995

Problem 1: Let  $\dot{x} = Ax + bu$   $y = cx$  be a ~~single input / single output~~ system <sup>where  $n$  is dimension</sup>

Assume that  $(A, b, c)$  is minimal ~~that and let~~

~~let~~  $g(s) \triangleq c (sI - A)^{-1} b = \frac{q(s)}{p(s)}$

*discuss  
the  
zeros  
of  
the  
transfer  
function.*

with  $q$  and  $p$  relatively ~~prime~~ polynomials without common factors.

Prove that: (i)  $(A + bf, b)$  is controllable for all  $f$ ;

(ii)  $(A + bxc, b, c)$  is minimal for all  $x \in \mathbb{R}$ .

(iii)  $(A + bf, b, c)$  is minimal for all  $f$  if and only if

$q(s) = \alpha_0$  (a scalar), i.e.,  $f$  and only if  $\Sigma$  has no zeros;

Hint: Use standard controllable form representation for  $\Sigma$ .

Problem 2: (i) Prove that a necessary condition for

$p(s) = s^n + p_{n-1}s^{n-1} + \dots + p_0$  to have all its roots in  $\text{Re } s < 0$

is that  $p_i > 0$  for all  $i$ .

(ii) give the necessary and sufficient conditions for the flow

Problem 3:

$\dot{x} = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ a & b & c \end{pmatrix} x$  to be asymptotically stable

Problem 3: Let  $F: \mathbb{R}^n \rightarrow \mathbb{R}$  be ~~twice continuously differentiable~~ <sup>is sufficiently smooth</sup> and  $D$  a constant  $(n \times n)$  matrix. ~~with  $\lim_{|x| \rightarrow \infty} F(x) = \infty$~~

Prove that all (i) ~~characterize~~ <sup>What are</sup> the ~~rate equilibrium solutions~~ <sup>points</sup> of the flow

$\dot{x} + Dx + \frac{\partial F}{\partial x}(x) = 0$

(ii) Assume that  $F(x) \rightarrow +\infty$  as  $|x| \rightarrow \infty$  and that

$D + D^T > 0$ . Prove that all solutions of the above flow approach the set of equilibrium points.

1976

nieuwe  
blz

## Koncept

### Mathematische systeemtheorie en Lineaire systemen

#### Doelstelling:

In dit college zal een kader worden geschetst dat kan dienen als wiskundige basis voor de analyse en synthese van dynamische systemen. Dit college verruimt een brugfunctie. Enerzijds worden begrippen die <sup>enigzins</sup> <sup>zullen</sup> bekend zijn uit de eerste fase in een axiomatisch en formeel wiskundig kader geplaatst en anderzijds worden ~~model~~problemen aangesneden die in een later stadium <sup>van</sup> het tweede fase curriculum zullen worden uitgediept.

#### Specifieke onderwerpen:

1. Dynamische systemen. Algemene definities. ~~Toe~~ De toestand van een systeem. Veel voorbeelden.
2. Lineaire systemen: externe variabelen, input, output, en toestand. Hun interplay.
3. Wiskundige ~~digressie~~ ~~over~~ digressie over polynoommatrices
4. Polynoombeschrijvingen van systemen. Regelbaarheid en waarneembaarheid. De transfer functie
5. Toestandsmodellen. Realisatietheorie. Eindwaardigheid van toestandsmodellen voor lineaire systemen. De Hankel matrix.
6. Exact modelleren. Klassieke realisatiealgoritmen via de Hankel matrix
7. Wiskundige digressie over  $L_p$ , Fourier, en Laplace
8. Modelreductie: probleemstelling. Uitwerking van de basisideeën van de algoritmen van gebalanceerde realisatie.

1986



# Life and work

- **Journals:**
  - 1981-1994: Cofounder/Editor of 'Systems and Control Letters'
  - 1989-1993: Editor-in-chief SIAM J. Control and Optimization
  - 1993: Co-founder European Journal of Control
- **1988-1997: Chair of Johan Bernoulli  
Foundation for Mathematics**
- **1993: Chaired ECC in Groningen**
- **1993-1995: Cofounder/President  
of European Union Control Association**
- **1994-1996: President Dutch Mathematical  
Society**



# Life and work



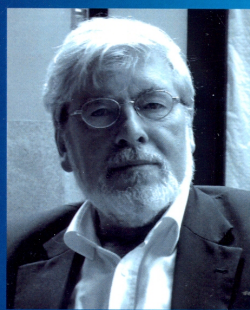
- **2001: Jan and Doke move from Groningen to Antwerp**
- **2003: Emeritus professor in Groningen**
  - Farewell lecture on January 13, 2004
- **2003: Guest professor @ KU Leuven, ESAT**
- **Many visiting appointments worldwide**
- **Tens of (co-)publications after his 'retirement'**
- **2009: Celebration of Jan's 70th birthday in Bruges**

# Liber Amicorum

Jan Willems

On the occasion of his 70th Birthday

Brugge, 16-17 Sept. 2009



# Publications

<http://homes.esat.kuleuven.be/~jwillems/Publications.html>

All Publications

Books

Journal Articles

Chapters in Books and Festschrifts

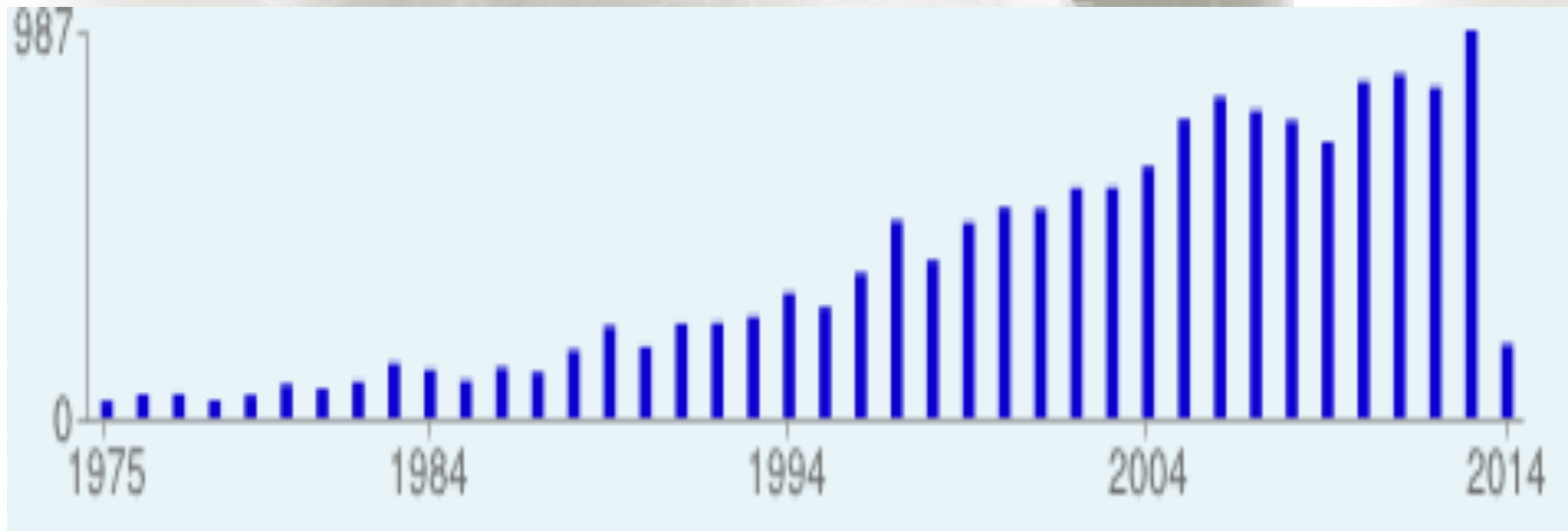
Conference Articles

Edited Books

All Publications

2013 2012 2011 2010  
2009 2008 2007 2006 2005 2004 2003 2002 2001  
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1999 1998 1997 1996 1995 1994 1993 1992 1991  
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1970  
● 1969 1968 1967 1966

# Publications



**Citations 15 679**

**H-index 54**

## **Dissipative dynamical systems part I: General theory**

**JC Willems**

**Archive for rational mechanics and analysis 45 (5), 321-351 1927 1972**

## **Least squares stationary optimal control and the algebraic Riccati equation**

**JC Willems**

**Automatic Control, IEEE Transactions on 16 (6), 621-634 1016 1971**

## **Paradigms and puzzles in the theory of dynamical systems**

**JC Willems**

**Automatic Control, IEEE Transactions on 36 (3), 259-294 995 1991**

## **Passivity, feedback equivalence, and the global stabilization of minimum**

**Phase nonlinear systems**

**CI Byrnes, A Isidori, JC Willems**

**Automatic Control, IEEE Transactions on 36 (11), 1228-1240 993 1991**

## **Introduction to mathematical systems theory: a behavioral approach**

**JW Polderman, JC Willems**

**Springer 966 1998**



**The analysis of feedback systems**

JC Willems

The MIT Press

538

1971

**From time series to linear system—Part I. Finite dimensional linear time invariant systems**

JC Willems

Automatica 22 (5), 561-580

521

\*

1986

**Dissipative dynamical systems Part II: Linear systems with quadratic supply rates**

JC Willems

Archive for Rational Mechanics and Analysis 45 (5), 352-393

508

\*

1972

**Models for dynamics**

JC Willems

Dynamics reported, 171-269

390

1989

**The Riccati Equation**

S Bittanti, AJ Laub, JC Willems

Springer-Verlag New York, Inc.

326

1991

# **Almost invariant subspaces: An approach to high gain feedback design--Part I:**

## **Almost controlled invariant subspaces**

**JC Willems**

**Automatic Control, IEEE Transactions on 26 (1), 235-252**

**291**

**1981**

## **On interconnections, control, and feedback**

**JC Willems**

**Automatic Control, IEEE Transactions on 42 (3), 326-339**

**262**

**1997**

## **On quadratic differential forms**

**JC Willems, HL Trentelman**

**SIAM Journal on Control and Optimization 36 (5), 1703-1749**

**236**

**1998**

## **Parametrizations of linear dynamical systems: canonical forms and identifiability**

**K Glover, JC Willems**

**Automatic Control, IEEE Transactions on 19 (6), 640-646**

**214**

**1974**

## **Global adaptive stabilization in the absence of information on the sign of the high frequency gain**

**JC Willems, CI Byrnes**

**Analysis and Optimization of Systems, 49-57**

**193**

**1984**

## **From time series to linear system—Part II. Exact modelling**

**JC Willems**

**Automatica 22 (6), 675-694**

**190**

**1986**



# Awards and honors

- **Fellow IEEE, SIAM, AMS, IFAC**
- **1988: Automatica Best Paper Award for series of 3 papers on behavioral framework**
- **1998: IEEE Control Systems Award**
- **IEEE Control Systems Magazine Outstanding Paper Award for '300 years of optimal control'**
- **2003-2004: Francqui Chair  
@ UC Louvain**
- **2010: Doctor HC U Liege**



# Jan the mentor

- For generations of PhD, masters and undergraduate students
- Icon for the Systems and Control community, in the Netherlands, Europe and overseas
- Advisor of 72 Master's Theses
- Mathematical genealogy
- <http://genealogy.math.ndsu.nodak.edu/id.php?id=49680>
- 23 PhD students: From Keith Glover (1973) to Bart Van Luyten (2003)
- <http://homes.esat.kuleuven.be/%7Ejwillems/Curriculum.html#>



1999

60th  
birthday

**Keith Glover, Madhu Belur, Siep Weiland, Arjan van der Schaft, Henk Nijmeijer, Harry Trentelman, Jan Willem Polderman; second row: Tommaso Cotroneo, Paolo Rapisarda, Paula Rocha, Fabio Fagnani, Berend Roorda, Christiaan Heij, Tonny ten Dam.**

# Jan the scholar

- One of the founding fathers of mathematical system theory; pursuer of system theoretic paradigms; helped shaping the field
- Huge contributions to the field of systems and control, as a scientist and an organizer
- Many people benefitted from his vision and personal perspective
- Critical but positive and constructive thinker
- Unique mix of creativity, associative power, ability for deep insights that he loved to share
- Responsibility and dedication, true scholar
- Argued with energy but also listened empathically
- Perfectionist care for rigor and details
- ‘Science should be left to scientists, not to administrators’

# Jan the friend

- ‘Un grand monsieur’
- Cheerful, enthusiastic, inspiring
- Wonderful, considerate and animated
- Unquenchable amount of scientific and intellectual energy
- Charisma (‘the ‘X’-factor)
- Natural charm and skills in diplomacy and persuasion
- Talented story teller
- Enjoyed company with good glass and meal







# Remembering Jan

**The 21st International Symposium on Mathematical Theory of Networks and Systems (MTNS 2014)**

**July 7-11, Groningen, The Netherlands**



**<https://fwn06.housing.rug.nl/mtns2014/>**



# Tribute to a scholar and a friend

- 15.30 Opening (Harry Trentelman)
- 15.40 Roger Brockett: "Jan Willems: Clear thinking and its consequences"
- 16.10 Rodolphe Sepulchre: Dissipativity theory
- 16.40 Carsten Scherer: Algebraic Riccati equation and LQ control
- 17.10 - 17.50 Extended break
- 17.50 Malo Hautus: Geometric control
- 18.20 Jan Willem Polderman: Behavioral theory
- 18.50 Bart de Moor: Identification theory
- 19.20 Yutaka Yamamoto: Jan's international role
- 19.35 Paul van den Hof: Jan's role within The Netherlands
- 19.50 Closing

# Remembering Jan



*It is hard to imagine a world without Jan Willems.  
But he is not far away.*

*When you read him, you hear him speak.  
When you understand him, you feel the mentor.  
When you cite him, you will remember him.*

*The products of his scientific activity,  
the way he shaped our field of systems and control,  
his influence on the scientific taste and thinking,  
of generations of students,*

*will remain for ever.*





**Bedankt, Jan**

**Thank you, Jan**

<http://janwillems-memorial.net>

<http://homes.esat.kuleuven.be/~jwillems/>