Sine Chaotification Model for Enhancing Chaos and Its Hardware Implementation

By: Hua, ZY (Hua, Zhongyun)[1]; Zhou, BH (Zhou, Binghang)[2]; Zhou, YC (Zhou, Yicong)[3]

IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS
Volume: 66 Issue: 2 Pages: 1273-1284
DOI: 10.1109/TIE.2018.2833049
Published: FEB 2019
Document Type: Article

Abstract
When chaotic systems are used in different practical applications, such as nonlinear control and cryptography, their complex chaos dynamics are strongly required. However, many existing chaotic systems have simple complexity, and this brings negative effects to chaos-based applications. To address this issue, this paper introduces a sine chaotification model (SCM) as a general framework to enhance the chaos complexity of existing one-dimensional (1-D) chaotic maps. The SCM uses a sine function as a nonlinear chaotification transform and applies it to the output of a 1-D chaotic map. The resulting enhanced chaotic map of the SCM has better chaos complexity and a much larger chaotic range than the seed map. Theoretical analysis verifies the efficiency of the SCM. To show the performance of the SCM, we apply SCM to three existing chaotic maps and analyze the dynamics properties of the obtained enhanced chaotic maps. Performance evaluations prove that the three enhanced chaotic maps have more complicated dynamics behaviors than their seed chaotic maps. To show the implementation simplicity of the SCM, we implement the three enhanced chaotic maps using the field-programmable gate array. To investigate the SCM in practical application, we design pseudorandom number generators using the enhanced chaotic maps.

Keywords
Author Keywords: Chaotic system; chaotification; chaos-based application; cryptography; field-programmable gate array (FPGA) implementation; nonlinear control

Author Information
Reprint Address: Harbin Institute of Technology University Town of Shenzhen Harbin Inst Technol, Sch Comp Sci & Technol, Shenzhen Grad Sch, Shenzhen 518055, Peoples R China.
Corresponding Address: Hua, ZY (corresponding author)

Addresses:
[1] Harbin Inst Technol, Sch Comp Sci & Technol, Shenzhen Grad Sch, Shenzhen 518055, Peoples R China
[3] Univ Macau, Dept Comp & Informat Sci, Macau 999078, Peoples R China
University of Macau

E-mail Addresses: huazhongyun@hit.edu.cn; hn_zhaobh@qq.com; yicongzhou@umac.mo

Funding

<table>
<thead>
<tr>
<th>Funding Agency</th>
<th>Grant Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Natural Science Foundation of China (NSFC)</td>
<td>61701137</td>
</tr>
<tr>
<td>Shenzhen Science and Technology Program</td>
<td>JCYJ201701160212033</td>
</tr>
<tr>
<td></td>
<td>JCYJ201701570704051</td>
</tr>
<tr>
<td>Macau Science and Technology Development Fund</td>
<td>FDCT/18/9/2017/A3</td>
</tr>
</tbody>
</table>

Corresponding Address: Shenzhen
Reprint Address: Author Information

Abstract

When chaotic systems are used in different practical applications, such as nonlinear control and cryptography, their complex chaos dynamics are strongly required. However, many existing chaotic systems have simple complexity, and this brings negative effects to chaos-based applications. To address this issue, this paper introduces a sine chaotification model (SCM) as a general framework to enhance the chaos complexity of existing one-dimensional (1-D) chaotic maps. The SCM uses a sine function as a nonlinear chaotification transform and applies it to the output of a 1-D chaotic map. The resulting enhanced chaotic map of the SCM has better chaos complexity and a much larger chaotic range than the seed map. Theoretical analysis verifies the efficiency of the SCM. To show the performance of the SCM, we apply SCM to three existing chaotic maps and analyze the dynamics properties of the obtained enhanced chaotic maps. Performance evaluations prove that the three enhanced chaotic maps have more complicated dynamics behaviors than their seed chaotic maps. To show the implementation simplicity of the SCM, we implement the three enhanced chaotic maps using the field-programmable gate array. To investigate the SCM in practical application, we design pseudorandom number generators using the enhanced chaotic maps.

Keywords

Author Keywords: Chaotic system; chaotification; chaos-based application; cryptography; field-programmable gate array (FPGA) implementation; nonlinear control

Author Information

Reprint Address: Harbin Institute of Technology University Town of Shenzhen Harbin Inst Technol, Sch Comp Sci & Technol, Shenzhen Grad Sch, Shenzhen 518055, Peoples R China.
Corresponding Address: Hua, ZY (corresponding author)

Addresses:
[1] Harbin Inst Technol, Sch Comp Sci & Technol, Shenzhen Grad Sch, Shenzhen 518055, Peoples R China
[3] Univ Macau, Dept Comp & Informat Sci, Macau 999078, Peoples R China
University of Macau

E-mail Addresses: huazhongyun@hit.edu.cn; hn_zhaobh@qq.com; yicongzhou@umac.mo

Funding

<table>
<thead>
<tr>
<th>Funding Agency</th>
<th>Grant Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Natural Science Foundation of China (NSFC)</td>
<td>61701137</td>
</tr>
<tr>
<td>Shenzhen Science and Technology Program</td>
<td>JCYJ201701160212033</td>
</tr>
<tr>
<td></td>
<td>JCYJ201701570704051</td>
</tr>
<tr>
<td>Macau Science and Technology Development Fund</td>
<td>FDCT/18/9/2017/A3</td>
</tr>
</tbody>
</table>

Corresponding Address: Shenzhen
Reprint Address: Author Information

Abstract

When chaotic systems are used in different practical applications, such as nonlinear control and cryptography, their complex chaos dynamics are strongly required. However, many existing chaotic systems have simple complexity, and this brings negative effects to chaos-based applications. To address this issue, this paper introduces a sine chaotification model (SCM) as a general framework to enhance the chaos complexity of existing one-dimensional (1-D) chaotic maps. The SCM uses a sine function as a nonlinear chaotification transform and applies it to the output of a 1-D chaotic map. The resulting enhanced chaotic map of the SCM has better chaos complexity and a much larger chaotic range than the seed map. Theoretical analysis verifies the efficiency of the SCM. To show the performance of the SCM, we apply SCM to three existing chaotic maps and analyze the dynamics properties of the obtained enhanced chaotic maps. Performance evaluations prove that the three enhanced chaotic maps have more complicated dynamics behaviors than their seed chaotic maps. To show the implementation simplicity of the SCM, we implement the three enhanced chaotic maps using the field-programmable gate array. To investigate the SCM in practical application, we design pseudorandom number generators using the enhanced chaotic maps.

Keywords

Author Keywords: Chaotic system; chaotification; chaos-based application; cryptography; field-programmable gate array (FPGA) implementation; nonlinear control

Author Information

Reprint Address: Harbin Institute of Technology University Town of Shenzhen Harbin Inst Technol, Sch Comp Sci & Technol, Shenzhen Grad Sch, Shenzhen 518055, Peoples R China.
Corresponding Address: Hua, ZY (corresponding author)

Addresses:
[1] Harbin Inst Technol, Sch Comp Sci & Technol, Shenzhen Grad Sch, Shenzhen 518055, Peoples R China
[3] Univ Macau, Dept Comp & Informat Sci, Macau 999078, Peoples R China
University of Macau

E-mail Addresses: huazhongyun@hit.edu.cn; hn_zhaobh@qq.com; yicongzhou@umac.mo

Funding

<table>
<thead>
<tr>
<th>Funding Agency</th>
<th>Grant Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Natural Science Foundation of China (NSFC)</td>
<td>61701137</td>
</tr>
<tr>
<td>Shenzhen Science and Technology Program</td>
<td>JCYJ201701160212033</td>
</tr>
<tr>
<td></td>
<td>JCYJ201701570704051</td>
</tr>
<tr>
<td>Macau Science and Technology Development Fund</td>
<td>FDCT/18/9/2017/A3</td>
</tr>
</tbody>
</table>

Corresponding Address: Shenzhen
Reprint Address: Author Information

Abstract

When chaotic systems are used in different practical applications, such as nonlinear control and cryptography, their complex chaos dynamics are strongly required. However, many existing chaotic systems have simple complexity, and this brings negative effects to chaos-based applications. To address this issue, this paper introduces a sine chaotification model (SCM) as a general framework to enhance the chaos complexity of existing one-dimensional (1-D) chaotic maps. The SCM uses a sine function as a nonlinear chaotification transform and applies it to the output of a 1-D chaotic map. The resulting enhanced chaotic map of the SCM has better chaos complexity and a much larger chaotic range than the seed map. Theoretical analysis verifies the efficiency of the SCM. To show the performance of the SCM, we apply SCM to three existing chaotic maps and analyze the dynamics properties of the obtained enhanced chaotic maps. Performance evaluations prove that the three enhanced chaotic maps have more complicated dynamics behaviors than their seed chaotic maps. To show the implementation simplicity of the SCM, we implement the three enhanced chaotic maps using the field-programmable gate array. To investigate the SCM in practical application, we design pseudorandom number generators using the enhanced chaotic maps.

Keywords

Author Keywords: Chaotic system; chaotification; chaos-based application; cryptography; field-programmable gate array (FPGA) implementation; nonlinear control

Author Information

Reprint Address: Harbin Institute of Technology University Town of Shenzhen Harbin Inst Technol, Sch Comp Sci & Technol, Shenzhen Grad Sch, Shenzhen 518055, Peoples R China.
Corresponding Address: Hua, ZY (corresponding author)

Addresses:
[1] Harbin Inst Technol, Sch Comp Sci & Technol, Shenzhen Grad Sch, Shenzhen 518055, Peoples R China
[3] Univ Macau, Dept Comp & Informat Sci, Macau 999078, Peoples R China
University of Macau

E-mail Addresses: huazhongyun@hit.edu.cn; hn_zhaobh@qq.com; yicongzhou@umac.mo

Funding

<table>
<thead>
<tr>
<th>Funding Agency</th>
<th>Grant Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Natural Science Foundation of China (NSFC)</td>
<td>61701137</td>
</tr>
<tr>
<td>Shenzhen Science and Technology Program</td>
<td>JCYJ201701160212033</td>
</tr>
<tr>
<td></td>
<td>JCYJ201701570704051</td>
</tr>
<tr>
<td>Macau Science and Technology Development Fund</td>
<td>FDCT/18/9/2017/A3</td>
</tr>
</tbody>
</table>